SCOTTISH CROP RESEARCH INSTITUTE

ANNUAL REPORT 1989

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

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

£7.00 (post paid)

SCOTTISH CROP RESEARCH INSTITUTE

Post	:	Invergowrie, Dundee, Scotland, DD2 5DA
Telephone	:	+44 382 562731
Fax	:	+44 382 562426
Telex	:	9312133325 SC G
Telecom / CGNET	:	10087:NQQ003
Electronic Mail	:	
JANET (UK)	:	SCRI @ uk.ac.edinburgh
World (Non UK)	:	SCRI @ edinburgh.ac.uk
INTERNET	:	SCRI%edinburgh.ac.uk @ nss.cs.ucl.ac.uk
or INTERNET	:	SCRI%edinburgh.ac.uk @ cunyvm.cuny.edu
BITNET / EARN	:	SCRI%edinburgh.ac.uk @ ukacrl

ISSN 0263-7200

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

Published 1990

CONTENTS

GOVERNING BODY

(AS AT 31st DECEMBER 1989)

Chairman J. A. Inverarity, O.B.E.

H. R. G. Aykroyd, Esq.

Professor D. Boulter, M.A., D.Phil.(Oxon.)

J. B. Forrest, Esq., F.R.Ag.S.

Professor J. D. Hayes, B.Sc., M.S., Ph.D., C.Biol., F.I.Biol.

Professor D. L. Lee, B.Sc., Ph.D., C.Biol., F.I.Biol.

A. Logan, Esq.

Professor T. A. Mansfield, B.Sc., Ph.D., F.I.Biol., F.R.S.

J. L. Millar, C.B.E., C.A.

P. G. Mitchell, Esq.

Professor J. W. Parsons, B.Sc., Ph.D., C.Biol., F.I.Biol.

J. G. Porter, Esq.

Professor J. A. Raven, M.A., Ph.D., F.R.S.E., F.R.S.

G. Rennie, Esq.

R. O. Sykes, Esq.

L. M. Thomson, Esq.

STAFF LIST

(AS AT 31 DECEMBER, 1989)

Director Professor J. R. Hillman‡×§, B.Sc., Ph.D., F.I.S., C.Biol., F.I.Biol., F.R.S.E.

Deputy Director Professor N. L. Innes○×, B.Sc., Ph.D., D.Sc., C.Biol., F.I.Biol., F.R.S.E., F.I.Hort.

Secretary R. J. Killick, B.Sc., Ph.D., C.Biol., M.I.Biol.

Acting Assistant to Director T. J. W. Alphey, B.Sc., Ph.D., C.Biol., M.I.Biol.

CROP GENETICS DEPARTMENT

Head G. R. Mackay†, B.Sc., M.Sc., C.Biol., M.I.Biol.

J. E. Bradshaw, M.A., M.Sc., Ph.D.
R. Ellis, B.Sc., Ph.D.
W. H. MacFarlane Smith, B.Sc., Ph.D., C.Biol., M.I.Biol.
R. L. Wastie, M.A., Ph.D., F.I.S.P.
I. Chapman, B.Sc.
M. F. B. Dale, B.Sc., Ph.D.
M. J. De, Maine, B.Sc., M.Phil.
G. Ramsay, B.Sc., Ph.D.
J. S. Swanston, B.Sc., C.Biol., M.I.Biol.
W. T. B. Thomas, B.Sc., Ph.D.
Mrs Ruth M. Solomon-Blackburn, B.A., M.Sc.
Mary Coleman, B.Sc., Ph.D.
Helen E. Stewart, C.Biol, M.I.Biol
M. J. Wilkinson, B.Sc., Ph.D.
A. Young
J. N. Dick
Mrs Jill Middlefell-Williams, H.N.C.
G. E. L. Swan
R. N. Wilson
G. R. Young

Assistants Mrs Eva Bennett
A. Booth
Wendy Craig
P. Davie
G. M. Dobbie
Mrs Norma Dow
Michelle L. M. H. Fleming
Frances Gourlay
R. P. Keith
A. Lorimer
Mrs Karen McIlravey
Mrs Jane M. McNicol
Ann Todd
D. Todd
A. Wilson

P & GS, E M. P. L. Campbell

Experimental Workers Mrs Alice R. M. Bertie
Joyce I. Cairns
J. D. Fuller
Mrs Patricia Lawrence
Mrs A. Margaret McInroy
Moira Myles

SOFT FRUIT GENETICS DEPARTMENT

Acting Head R. J. McNicol, B.Sc.
R. Brennan, B.Sc., Ph.D.

Assistants Amanda Wilshin, H.N.D.
Mrs Karen H. M. Young

CELL AND MOLECULAR GENETICS DEPARTMENT

Head W. Powell[+], B.Sc., M.Sc., Ph.D.
B. P. Forster, B.Sc., Ph.D.
A. Kumar, B.Sc., Ph.D.
S. Millam, B.Sc., Ph.D.
R. Waugh, B.Sc., Ph.D.
Deborah Cawston, B.Sc.

Assistants Eileen Baird, H.N.C.
Mrs Nicola Duncan
M. Macaulay
Mrs Ashley March

Experimental Worker Diane Davidson

DIRECTOR'S GROUP

I. M. Morrison, B.Sc., Ph.D., C.Chem., F.R.S.C. (Seconded from HRI).
B. A. Goodman, B.Sc., Ph.D., C.Chem., F.R.S.C.
G. McDougall, B.Sc., Ph.D.
D. Stewart, B.Sc.
Mrs Susan Burrows, B.Sc. [+]

CELLULAR AND ENVIRONMENTAL PHYSIOLOGY DEPARTMENT

Acting Head H. M. Lawson, B.Sc., M.Agr.Sc., Dip.Agric., F.I.Hort.
H. V. Davies, B.Sc., Ph.D.
D. J. Linehan, B.Sc., Ph.D.
D. K. L. MacKerron, B.Sc., Ph.D.
B. Marshall, B.Sc., A.R.C.S., Ph.D.
K. J. Oparka[*], B.Sc., Ph.D.
M. R. Cormack, N.D.H.
J. W. Crawford, B.Sc., Ph.D.
B. S. Griffiths, B.Sc., Ph.D.
D. T. Mason, B.Sc., Ph.D.
K. Ritz, B.Sc., Ph.D.
D. Robinson[*], B.Sc., Ph.D.
H. Taylor, N.D.H.
R. E. Wheatley, B.Sc.
A. G. Bengough, B.Sc., Ph.D.
D. C. Gordon, H.N.C.
R. A. Jefferies, B.Sc., Ph.D.
D. L. Richardson, B.Sc., Ph.D.
Heather A. Ross, H.N.C., C.Biol., M.I.Biol.
T. Shepherd, B.Sc., Ph.D.
M. Taylor, B.Sc., Ph.D.
J. S. Wiseman, S.D.H.
Mrs Kathryn Wright, B.A., Ph.D.
I. Young, B.Sc., Ph.D.
Mrs Sandra Caul, H.N.C.
A. Gardner
D. A. M. Prior, H.N.C.
Mrs Susan R. Verrall, H.N.C.
Mrs Gladys McN. Wright, H.N.C.

Assistants B. Alexander
D. Crabb
G. Dunlop
Mrs Margaret Garland
Mrs Sandra L. Gordon, H.N.C.
C. J. McKenzie
Diane McRae
Lesley A. M. Scobie
Angela M. Smith
Fiona E. C. Stewart
Kara D. Webster, H.N.C.

CHEMISTRY DEPARTMENT

Head M. J. Allison, B.Sc., Ph.D.
I. A. Cowe, H.N.C.
D. W. Griffiths, M.A., Ph.D.
G. W. Robertson, B.Sc.
H. Bain, H.N.C., L.R.S.C.
W. Matheson, B.Sc.
Winifred M. Stein, H.N.C.
D. C. Cuthbertson, H.N.C.
K. Taylor, H.N.C.
Mrs Judith Taylor, H.N.C.

Assistants P. Cromwell
Mrs Fiona Falconer
Anne Morrice

Experimental Worker Mrs Jean Wilkie

DATA PROCESSING

Head R. J. Clark, B.A., M.B.C.S.
R. Kidger, B.Sc.
P. Smith, B.Sc.
I. Black, H.N.C.

Assistants S. Clark, H.N.C.
Jennifer Gorrod

MYCOLOGY AND BACTERIOLOGY DEPARTMENT

Acting Head D. A. Perry, B.Sc., Ph.D.
J. M. Duncan, B.Sc., Ph.D.
G. D. Lyon, B.Sc., M.Sc., Ph.D., D.I.C.
M. C. M. Perombelon, B.Sc., M.Sc., Ph.D.
B. Williamson, B.Sc., M.Sc., Ph.D.
J. G. Harrison, B.Sc., Ph.D., C.Biol., M.I.Biol.
A. C. Newton, B.Sc., Ph.D.
Cynthia J. Williamson, B.Sc., Ph.D.
E. Patricia Dashwood, B.Sc., M.Sc.
Mrs Lisabeth J. Hyman, B.A.
Diana M. Kennedy, B.Sc.
R. Lowe
Mrs E. Marion Burnett, H.N.C.
Ms Alison M. Campbell
Mrs Jacqueline Heilbronn, H.N.C.
D. Johnston, B.Sc.
Mrs Elaine Rees, B.Sc.
Mrs Naomi Williams, H.N.C.

Assistants Lynne McGurk
Sandra E. Millar

Experimental Worker Mrs Evelyn Warden

ZOOLOGY DEPARTMENT

Head
D. L. Trudgill*†, B.Sc., Ph.D.
T. J. W. Alphey, B.Sc., Ph.D., C.Biol., M.I.Biol.
B. Boag, B.Sc., Ph.D.
J. M. S. Forrest, B.Sc., Ph.D.
M. S. Phillips, B.Sc.
W. M. Robertson, H.N.C., F.I.S.
J. A. T. Woodford*, M.A., Ph.D.
D. J. F. Brown, B.A., Ph.D., C.Biol., M.I.Biol.
S. C. Gordon, H.N.C.
A. N. E. Birch, B.Sc., Ph.D., C.Biol., M.I.Biol.
Merryn Catley, B.Sc., Ph.D.
B. Harrower, O.N.C., H.N.D.
R. Neilson, H.N.C.

Assistants
Elizabeth Bowman, B.Sc.
Mrs Sheena Lamond
Mrs Gaynor Malloch
Anne Marshall
Susan P. Rawlings, H.N.D.

VIROLOGY DEPARTMENT

Head
B. D. Harrison*†, C.B.E., B.Sc., Ph.D., C.Biol., F.I.Biol., F.R.S.E., F.R.S.
A. F. Murant*, B.Sc., Ph.D., A.R.C.S., C.Biol., F.I.Biol., F.R.S.E.
H. Barker, B.Sc., Ph.D.
A. T. Jones, B.Sc., Ph.D.
M. A. Mayo, B.Sc., Ph.D., C.Biol., M.I.Biol.
W. P. Mowat, B.Sc., Dip.Agr.Sci.
I. M. Roberts, H.N.C., Dip. R.M.S.
D. J. Robinson, M.A., Ph.D.
Lesley Torrance, B.Sc., Ph.D.
G. H. Duncan, H.N.C.
B. Reavy, B.Sc., D.Phil.
J. H. Raschke, H.N.C.
Mrs Sheila M. S. Dawson, H.C.
Anne C. Jolly, H.N.C.
Wendy J. McGavin, B.Sc.
E. W. Milne, O.N.C.

Assistants
G. H. Cowan
Mrs Gillian L. Fraser
Mrs Ann Grant

Experimental Worker
Mrs Rena Reid

INFORMATION SERVICES

Information Officer
R. J. A. Exley, Dip. Hort.

Photography
T. G. Geoghegan, A.B.I.P.P., A.M.P.A.
S. F. Malecki
G. Menzies

Graphics
Mrs Geraldine Martin, C & G (Adv)

Library
Ursula McKean, M.A., Dip.Lib.
Lorna McLaren, O.N.C.

ADMINISTRATION

Secretary	R. J. Killick, B.Sc., Ph.D., C.Biol., M.I.Biol.
Assistant Secretary	D. L. Hood, B.Admin., L.T.I., A.I.I.M.
Personnel Officer	I. Paxton, H.N.C.
Accounts	Mrs Freida Soutar Mrs Margaret Barnes Mrs Dianne Beharrie Catherine McDougall Lesley Pollock Catherine Skelly Mrs Lorna Doig Mrs Linda Monks
Director's Secretary	Mrs Loraine Galloway
Typists	Mrs Linda Butler Jane Davidson Mrs Joyce Davidson Mrs Jean Findlay Mrs Sheena Forsyth Mrs Elizabeth Fyffe Mrs Maureen Murray Elizabeth L. Nicoll Mrs Myra Purves
Stores	Mrs Anne L. Bertie J. Heeney J. Flight

ENGINEERING AND MAINTENANCE

Institute Engineer:	T. Hopton, C.Eng., M.I.Mech.E. R. MacDonald S. Petrie, B.Sc. D. Gray J. Anderson D. Byrne J. R. Caithness A. R. Davidson D. Diduca D. Hutcheson A. Low K. Low R. White T. Purves J. Rowe R. Pugh
Garage Workshop	G. W. Pollock N. Anderson S. C. Bowick

ESTATE

Manager W. I. A. Jack

Experiments Officer G. Wood, B.Sc., Ph.D., F.E.T.C.

Glasshouse Manager P. A. Gill, H.N.D.

Supervisors D. S. Petrie
R. W. Reid
C. C. Carrie
A. D. Lindsay
A. W. Mills
R. Ogg
D. G. Pugh
B. D. Robertson
C. R. Dalrymple
E. A. M. Gardiner
J. P. T. Grant
W. D. J. Jack, B.Sc.
W. W. Killoh
N. McInroy
J. Mason
A. Nicoll
D. R. Simpson
J. R. K. Bennett
Ms Sybil Knight, B.Sc.
L. A. McNicol
J. T. Bennett
G. Dow
D. L. K. Robertson
P. W. Yeaman
B. Fleming
I. Fleming
A. Fuller
G. G. Pollock
Gillian Pugh
Angela Smith
M. Smith
Mrs Evelyn Watt

SCOTTISH AGRICULTURAL STATISTICS SERVICE

King's Buildings, University of Edinburgh

Director R. A. Kempton, M.A., B.Phil.
Mrs Helen K. Brown, B.A., M.Sc.
Isobel R. Craigie, H.N.D.
Mrs Janet M. Dickson, B.Sc.
D. A. Elston, B.Sc., M.Sc.
C. A. Glasbey, M.A., Dip.Math.Stats., Ph.D.
G. W. Horgan, B.A., M.Sc.
E. A. Hunter, B.Sc., M.Phil.
A. D. Mann, B.Sc.
Jacqueline Muscott, B.A.
Anne J. Soutar, B.Sc.
M. Talbot, F.I.S., M.Phil.
F. G. Wright, B.Sc., M.Sc., Ph.D.

Aberdeen Unit

Head	M. F. Franklin, B.Sc., M.Sc., Ph.D.
	S. T. Buckland, B.Sc., M.Sc., Ph.D.
	Jean M. Cooper, B.Sc., Dip.Stats.
	Elizabeth I. Duff, B.Sc.
	I. M. Nevison, M.A.
	Karen A. Robertson, B.Sc.

Dundee Unit

Head	J. W. McNicol, B.Sc., M.Sc.
	Christine A. Hackett, B.A., Dip.Math.Stats.
	Joanne E. Hall, B.Sc.

Ayr Unit

	I. Bradbury, B.Sc., Ph.D.
	Patricia Phillips, B.Sc., Dip. Stats.
Assistants	Muriel A. M. Kirkwood, D.A.
	Mrs I. M. S. Terris
Executive Officer	Elizabeth M. Heyburn, M.A.
	Mrs Ann G. Bruce
	Mrs Hazel J. Duff
	Mrs Diane Glancy
Director's Secretary	Mrs Christine M. Evans
Typist	Mrs Jan Fairbairn

INCREASED FLEXIBILITY SCHEMES

Crop Genetics	Mrs Margaret Ramsay, B.Sc.
Soft Fruit Genetics	Julie Graham, B.Sc.
	Mrs Diane Adamson
Cell and Molecular Genetics	Mrs Stephanie Cooper-Bland, B.Sc., Ph.D.
	J. F. Guerineau, B.Sc., Ph.D.
	P. Whitty, B.Sc.
	Mrs Jackie Lyon
Cellular and Environmental Physiology	J. Smart, B.Sc.
Mycology and Bacteriology	P. Lanham, B.Sc.
	Anne Wallace, B.Sc., Ph.D.
	R. Forrest, B.Sc.
	Lisa Fyffe
	Hazel Thomson
Virology	Vivian Blok, B.Sc., M.Sc., Ph.D.
	P. M. Derrick, B.Sc., Ph.D.
	Mary-Jo Farmer, B.Sc., Ph.D.
	A. D. Turnbull-Ross, B.Sc.
Zoology	Jenifer Robb, B.Sc.

OTHER SHORT-TERM CONTRACTS

Agricultural Genetics Company

Virology	Elizabeth A. Murant, B.Sc.
Virology	D. Liu, B.Sc., M.Sc.

ECSA

Cellular and Environmental Physiology	L. R. Burch, B.Sc., M.Sc., Ph.D.
Cellular and Environmental Physiology	Edna Cuthbert, S.N.C., H.N.D.
Cell and Molecular Genetics	G. Machray, B.Sc., Ph.D.
Cell and Molecular Genetics	P. Hedley, B.Sc.

DAFS

Virology	C. Watkins, B.Sc.

EEC

Cellular and Environmental Physiology	R. Viola, Dott. Agr. Sci.
Virology	Y. Hong, B.Sc., M.Sc.

Home Grown Cereals Authority

Crop Genetics	J. P. Camm, B.Sc., Ph.D.
Mycology and Bacteriology	A. Reglinski, B.Sc., Ph.D.
Cellular and Environmental Physiology	Shona McIntosh

Horticultural Development Council

Soft Fruit Genetics	S. Williams, B.Sc.
Mycology and Bacteriology	Pamela H. Scott, B.Sc.

Overseas Development Administration

Virology	Maud Aiton, B.Sc.
Virology	P. McGrath, B.Sc., Ph.D.

Potato Marketing Board

Mycology and Bacteriology	D. Hedley, B.Sc.
Mycology and Bacteriology	Miss Anne McLeod, H.N.D.
Mycology and Bacteriology	G. McMillan

United Biscuits

Cell and Molecular Genetics	I. M. Morrison

* 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.
× Visiting Professor in the University of Dundee.
§ Visiting Professor in the University of Edinburgh.

REPORT OF THE DIRECTOR

J. R. HILLMAN

Agriculture and its contribution to the advancement of mankind largely retained a low profile in the western world during a year noted for dramatic political changes in Eastern Europe. Economic cooperation between and within the regional blocks was counterbalanced as in the past by the tendency of certain nations to engage in neomercantilist protection or predatory policies in trade and investment. International trade practices in agricultural and horticultural commodities continued to cause dissatisfaction where interventions by governments or their agencies distorted the market. An unwitting consequence of these support, protection and restriction policies for producers was that the perceptions and funding of research and development priorities were directly and sometimes adversely affected in most countries.

Analysis of the general situation with regard to agriculture and food supplies in 1989 reveals a complex picture. According to the Quarterly Bulletin of Statistics issued by the Food and Agricultural Organisation of the United Nations, preliminary indices of total world agricultural and food production rose in 1989 after four years of barely perceptible growth. There was also evidence of a slight rise in per capita food production, stemming a worrying decline during the three previous years. Data from the United States Department of Agriculture, Foreign Agricultural Service, indicated that the 'ending stocks' of the world's cereal and sugar supplies would continue to decline during 1989-1990 to the lowest levels, as a percentage of consumption, since the mid-1970s. These statistics must be considered together with the disquieting fact that demographic trends for the foreseeable future will pose enormous pressures on food supplies and the natural environment.

A billion extra people are projected to be added to the present population of 5.3 billion over the next ten years, with inordinate strains placed mainly on the governments of countries of the third world for food, water, shelter, fuel, education and welfare. Access to the media will ensure that expectations for the quality of life will rise for all mankind regardless of local economic situations. Low-grade grazing systems coupled to poor, unsustainable agricultural systems will inexorably lead to the acceleration of deforestation, soil erosion, desertification and the rapid loss of natural and managed ecosystems, destroying genetic and environmental diversity. Social instability, emigration and trade disruption seem inevitable for

much of the third world. Biologists and agriculturalists fear that regional food surpluses and the capacity to respond to extra demand will be short-lived, not only because of a simple increase in human population but because of the possible effects of climate change arising from global warming. Agricultural and industrial activities have unequivocally modified the atmosphere. Although it is not clear how Earth will adjust to the increase in levels of the "greenhouse gases", there is the likelihood that significant changes in weather will occur within an average life span.

Largely as a result of major if unsung technological successes in the recent past, especially in plant breeding and pathology, agriculture and the related life sciences are widely assumed to be able to adapt without major investment to meet the challenges of population growth. Yet agriculture must not adversely affect the natural flora and fauna and exacerbate undesirable effects of climate change. Given that the area of land under cultivation is in reality limited and difficult to increase without massive migrations of people and devastation of rainforests, that pests and diseases have an incredible ability to overcome control measures, and that research and development require long-term commitments, current trends may not appear to offer bright prospects.

Fortunately, the life sciences have been revolutionised with huge advances in molecular and cell genetics, providing a common denominator for the application of all the other relevant sciences. Never before has there been such a sustained period of acquiring understanding of the major biological processes. With this understanding comes the ability to control and exploit development and performance of living organisms. Undoubtedly, population growth will eventually be reigned in to match world resources — nonetheless modern agriculture has the capacity to improve the quantity and quality of those resources if given the opportunity to do so.

SCRI is unique in the UK in having a wide range of scientific disciplines in agriculture and horticulture, linked by molecular, cell and population genetics. Modern laboratory and glasshouse facilities and biologically invaluable germplasm collections complement scientific departments of international standing. The research programme is designed to address at the strategic level major issues of temperate and tropical crop biology, linking with coordinated projects and research centres throughout the world.

Most important of the domestic issues for SCRI was the 1989 Visiting Group exercise organised by the Agricultural and Food Research Council (AFRC). This peer review system ensures that all institutes financed by the public purse are rigorously scrutinised and commented on by eminent scientists once every four years, with all research leaders interviewed and their records of achievement assessed. The Group, comprising Professor E. C. D. Cocking FRS (Chairman), Dr J. T. Braunholtz, Professor F. Brown FRS, Professor E. Griffiths, Dr M. A. Kirkman, Professor C. J. Leaver FRS, Professor T. A. Mansfield FRS, Mr H. H. Rogers, and

Professor J. K. Syers visited SCRI from 24 to 28 April 1989. The Group was accompanied by Professor W. D. P. Stewart FRS (Secretary of the AFRC), Dr J. V. Lake, Dr G. M. Price, Dr P. Mapleston and Mrs P. Cooper of the Council's Secretariat, and Dr A. M. Raven, Dr R. J. Dowdell and Mr E. J. Weeple from the Department of Agriculture and Fisheries for Scotland (DAFS).

The final report of the Group was sent to me in July 1989 for comment and I submitted a formal written response together with an industrial review paper which were considered by the AFRC Council in October 1989. In summary, the report was outstanding and a fitting tribute to the staff of SCRI. The Group was greatly impressed and stimulated by many of the scientists, noting the many high-calibre young scientists and climate of enthusiasm and keenness of the Institute. Excellent and exciting work was identified. In addition, the Group was very impressed with the overall appearance of the Institute and with the management of the Institute's field and glasshouse research programme. A number of constructive recommendations were made which were discussed with DAFS and AFRC in December 1989. Those recommendations which did not have major financial consequences were implemented immediately; the remaining recommendations related to new appointments which will be activated when finances permit.

Changes in the management structure of the Institute resulting from the Group recommendations are as follows:

1. Professor N. L. Innes becomes full-time Deputy Director but retains special interest in nurturing the three genetics departments.
2. The divisional and departmental structure is replaced by a single-tier departmental structure.
3. The Cereal & Legume Genetics Department and the Potato & Brassica Genetics Department fuse to form the Crop Genetics Department (Head: G. R. Mackay, UG6).
4. The Tissue Culture & Cytology Department and two staff from the Zoology Department combine to form the Cell & Molecular Genetics Department (Head: W. Powell, UG7).
5. The Soft Fruit Genetics Department is joined by two staff from the Physiology & Crop Production Department (Head: R. J. McNicol, UG7).
6. The Virology Division is retitled the Virology Department (Head: B. D. Harrison, UG5).
7. The Physiology & Crop Production Department is replaced by the Cellular & Environmental Physiology Department (Acting Head: H. M. Lawson, UG6(t)), with transfer into it of the Soil Microbiology Group from the Mycology & Bacteriology and Zoology Departments.
8. The Chemistry Department (Head: M. J. Allison, UG7) becomes free-standing.
9. The Data Processing Unit (Head: R. J. Clark, SSO) becomes a free-standing unit reporting to the Deputy Director.

10. The Crop Protection Division is replaced by two free-standing departments: Mycology & Bacteriology (Acting Head: D. A. Perry, UG6(t)) and Zoology (Head: D. L. Trudgill, UG6).

In addition to the Visiting Group, the work of the Institute was reviewed during visits of the Scottish Agricultural Research and Development Advisory Committee in February, the Fruit and Hops Research Consultative Committee in April, and various farming organisations throughout the year. There were also frequent visits by fellow scientists and politicians.

More stringent and bureaucratic commissioning procedures based on the ROAME principle (Rationale, Objective, Assessment, Monitoring and Evaluation) were announced by DAFS. Introduction of the procedures were expected to be phased in from April 1990 and would require full operation of the unified administrative computing system currently being installed throughout the Scottish Agricultural Research Institutes and Scottish Agricultural Colleges (SAC). As noted in the DAFS document 'Strategy for Agricultural Research and Development' released at the end of the year, commodity-based research is to be replaced by a thematic approach *viz:* land use, soil science, soil-plant-animal interactions, plant science, animal science, animal health and welfare, and animal and human nutrition. Revision took place of many of the SCRI research projects in any case to accommodate withdrawal of governmental support of near-market research and development, including plant breeding. As expected, the SCRI budget for the financial year 1989-1990 was slightly less than that for 1988-1989 so harsh restrictions were placed on spending and appointments. Greater emphasis was placed in obtaining external funding. Certain staff were able to take advantage of the limited voluntary redundancy scheme available through DAFS. Wage and overhead cost increases nevertheless posed difficult problems for senior management and staff alike.

Professor Noel F. Robertson CBE retired in March as Chairman of the Governing Body. A distinguished academic and past Principal of the East of Scotland School of Agriculture, he had long associations with the Scottish Horticultural Research Institute and Scottish Plant Breeding Station, the progenitors of SCRI. Sagacity, rigour, fairness and commitment to the development of the Institute were hallmarks of his chairmanship. Other members of the Governing Body retiring in March were Mr A. G. M. Forbes, Mr G. Gammie, Mr A. D. Kay, Mr G. D. Morrison, Mr A. Pattullo, Professor M. B. Wilkins and Professor M. M. Yeoman. All provided outstanding contributions to the success of the Institute. Seven new members were appointed in early summer by the Secretary of State for Scotland — Professor T. A. Mansfield FRS, Mr J. L. Millar CBE, Mr J. G. Porter, Professor J. A. Raven FRS, Mr G. Rennie, Mr R. O. Sykes and Mr L. M. Thomson. Mr J. A. Inverarity replaced Professor Robertson as Chairman.

Special mention must be made of honours and awards during 1989. Mr Inverarity was awarded an OBE, Professor Innes was elected Fellow of the Royal Society of Edinburgh, and Dr M. C. M. Perombelon was appointed Honorary Research Fellow in the Department of Medical Microbiology, Dundee University. In the New Year Honours List for 1990, Professor B. D. Harrison FRS was awarded the CBE.

Dr Derek L. Jennings, Head of Soft Fruit Genetics, retired in April. After making major contributions in East Africa to the breeding of cassava, he joined the staff at Mylnefield in 1957 to specialise in *Rubus* genetics and breeding. He is highly regarded by both the scientific community and soft fruit industry, and noted in the public eye for breeding new superior red raspberry and hybrid berry cultivars.

Closure of the Pentlandfield station and the Murrays Farm east of Edinburgh was accomplished efficiently if somewhat sadly at the end of March, marking the end of a long period of achievement in plant breeding in Edinburgh. Although the Edinburgh Centre for Rural Economy was in the process of being wound up, SCRI will intend to keep its links with related organisations and the higher education sector in Edinburgh.

On 14 September 1989, an agreement was signed by senior executives of Nickerson Seeds Limited and Dalgety Agriculture plc and the Chairman of the Governing Body on the commercial exploitation of products arising from the germplasm enhancement programmes. The agreement includes potatoes, barley, brassicas and legumes but does not cover soft fruit cultivars.

Mylnefield Research Services Ltd was incorporated on 16 November 1989. Devised primarily to protect the charitable status of SCRI as the Institute engages in commercial activities, the new commercial arm will not begin trading until a qualified accountant is recruited.

Following a review of horticultural research and development in England, Wales and Scotland, the Ministry of Agriculture, Fisheries and Food (MAFF) announced its intention to establish a single organisation, the British Society for Horticultural Research (BSHR), for horticultural research and development in England and Wales. There would be a single chief executive and management team encompassing the programmes and facilities of the AFRC Institute of Horticultural Research (IHR) and MAFF Agricultural Development and Advisory Service Experimental Horticulture Stations. The BSHR would be centred on the Wellesbourne site of IHR. Strategic research involving horticultural species is important to SCRI and thus the linking arrangements with the new organisation will need to be clarified in 1990 as a matter of urgency.

A Committee of Enquiry chaired by Sir Alwyn Williams published their report "A Collegiate System for Agriculture in Scotland" on 31 October 1989. The Committee was appointed by the Secretary of State for Scotland and the Chairman of Scottish Agricultural Colleges (SAC) Ltd to consider the future of the colleges. Of the report's conclusions and recommendations,

Government accepted the Central recommendation that the three individual Scottish Agricultural Colleges and SAC Ltd should be merged into a single national college, which would retain the functions of education, research and development, and advisory services under the management of a single Board of Directors and an executive Director. All three existing college centres at Aberdeen, Auchincruive and Edinburgh will be retained, as will the Schools of Agriculture at Aberdeen and Edinburgh. In view of the fact that SAC and the Scottish Agricultural Research Institutes are funded by DAFS, and that SCRI works closely with the Colleges, the evolution of the new integrated SAC will promote an already productive relationship.

My concluding comments relate to a scientifically rewarding calendar year. Independently assessed measures of performance, including bibliometric analyses and research reviews, point to a record of achievement by the staff. This is made possible by the assistance of individuals and organisations, and takes the form of DAFS core funding and the helpfulness of the DAFS staff, grants from governmental agencies, grower levy boards, local authorities and commercial companies, contracts, donations, farmers who generously make their land available for experiments, scientists with other organisations in the UK and abroad working on collaborative ventures, and the Scottish Society for Crop Research. SCRI is most grateful to all these collaborators and very appreciative of their invaluable assistance.

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

(a) Genetic architecture of potatoes and production of enhanced germplasm.
(b) Genetic architecture of traits of strategic importance to the UK seed potato industry.
(c) Genetics, exploration and exploitation of emergent techniques and conventional breeding/selection of potatoes.
(d) Develop new breeding material from primitive and novel germplasms.
(e) Develop and use methods for testing segregating potato populations for resistance to disease.
(f) Develop and use screening tests for biochemical compounds in potatoes.
(g) IFS The biochemical characteristics of good crisping quality in *Solanum tuberosum*.
(h) Maintain and evaluate the Commonwealth Potato Collection.
(i) The biochemical characteristics of good crisping quality in *Solanum tuberosum*.

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

(a) Produce improved germplasm of raspberry and study relevant characters.
(b) Provide improved germplasm of black currant and study relevant characters.
(c) Provide improved germplasm of blackberries and other Rubus fruits.
(d) Identify and select strawberry genotypes adapted to the Scottish environment and study genetics of factors involved.
(e) To evaluate genotypes and extend the genetic base available in novel fruit genera.
(f) IFS Develop methods of using *Agrobacterium* spp. as vectors for introducing DNA into soft fruit germplasm.
(g) Morphological and genotypic factors in relation to mechanical harvesting of soft fruits.
(h) Evaluate genotypes of and design production methods for raspberry and other Rubus.
(i) To evaluate genotypes and extend the genetic base available in novel fruit genera.
(j) Evaluate genotypes of and design production methods for raspberry and other Rubus.

PU 04 Develop more effective means of germplasm manipulation and produce enhanced germplasm of Brassica crops

(f) Multiply and stabilise breeder's selections; trial selections in collaboration with other organisations.
(m) Improve brassica root crop germplasms.
(n) Improve leafy forage brassica germplasms.
(o) Genetics and nature of resistance and susceptibility to root flies in brassicas.
(p) Inheritance and gene expression in brassicas.
(q) Study quantitative genetics in brassicas.
(r) Reproductive biology of Brassica spp.
(s) Content, variability and role of sulphur containing metabolites, oil and protein in plants and seeds of Brassica spp.
(t) IFS *In vitro* selection for herbicide resistance in Brassica spp.
(u) Factors influencing the growth rate and carcase gains of ruminants grazing forage brassicas.
(v) IFS Role of glucosinolates in affecting voluntary intake of forage brassicas by sheep.
(w) Multiply and stabilise breeders' selections; trial selections in collaboration with other organisations.

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

(a) Epidemiology and pathogenesis of fungal pathogens of soft fruit.
(b) Prediction and assessment of damage caused by pests of cane and bush fruits.
(c) Role of nematodes in planting disorders of raspberry.
(d) Properties, relationships and resistance mechanisms to Rubus viruses.
(e) Produce virus-free stocks, assess virus resistance and index British and imported Rubus genotypes.
(f) Devise diagnostic tests for reversion and other Ribes viruses and produce virus-free stocks.
(g) Determine the cause of, and devise diagnostic methods for, strawberry June yellows.
(h) Study the nature and properties of reversion and other Ribes viruses.
(i) Epidemiology and pathogenesis of fungal pathogens of soft fruit.
(j) Epidemiology and pathogenesis of fungal pathogens of soft fruit.

PU 11 Characterisation, effects and control of viruses of ornamentals

(a) Determine properties, relationships and detection of previously undescribed viruses from narcissus.
(b) Maintain virus-tested clones of narcissus and determine their health.
(c) Determine basis of effects of viruses on flower pigmentation.

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

(a) Characterise whitefly-transmitted viruses from cassava and other tropical crops.
(b) Epidemiology and assay methods for groundnut rosette and groundnut rosette assistor viruses.
(c) Detection and properties of West African whitefly-transmitted geminiviruses.

PU 19 The cellular and molecular basis of crop improvement

(a) Development of stable, single cell isolation and regeneration systems.
(b) Exploitation of protoplasts and microspore systems in crop improvements.
(d) Introduction of foreign genes into plants (genetic transformation).
(e) Develop strategies for cybrid production and study the segregation of organelles.
(f) Study the inheritance, stability and copy number of gene inserts in transgenic plants.
(g) Genome organisation and structure at the nucleic acid level.
(h) Construction of detailed genetic linkage maps using molecular (RFLPs) and isoenzyme markers.
(j) Develop and utilize suitable aneuploid stocks for use in genetic linkage studies.
(l) Gene isolation by insertional mutagenesis.
(m) Identify nematode resistance and susceptibility factors.
(n) IFS Isolation, proliferation, and regeneration of plants from potato protoplasts.
(o) IFS Transposon mutagenesis — a strategy for the isolation and cloning of important genes in potato.
(p) IFS UsnRNA-based transformation vectors for the delivery of antisense RNAs to plant cell nuclei.

PU 20 Statistical and mathematical support for agricultural, environmental and food R&D

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

PU 21 Plant fibres

(a) Physical and chemical characteristics of fibre-producing herbs, shrubs and trees.
(b) Control of differentiation and development of fibre cells.
(c) Factors influencing the ease of isolation of fibres.
(d) Determination of the composition and structure of plant fibre and fibre products.

PU 22 Control of root development, growth and function

(e) Physiological and environmental factors influencing root growth.
(f) Determine physiological and environmental factors influencing the induction and proliferation of roots.
(g) Mechanisms of drought tolerance and interactions between water and nutrient supply in potato.
(h) Nutritional effects on grain quality of barley.
(i) Nutrient availability and inflow.
(j) Identification and quantification of root exudates.
(k) Nutritional effects on grain quality of barley.

PU 23 Agriculture and the environment

(a) Production, utilisation and rotational value of nitrogen-fixing trees and shrubs.
(b) The role of the soil microbial biomass in plant nutrition, pesticide degradation and its interaction with root exudates.
(c) Prediction and monitoring of weed populations and weed management strategies in crops, uncropped areas and in rotations.
(d) Biology and population dynamics of plant-parasitic nematodes.
(e) Determine the factors influencing the activity of fungi and bacteria which attack nematodes.
(f) Determine the interactions between saprophytic and pathogenic microbial populations in the soil and on plants.
(g) The biology and ecology of entomophilic nematodes.
(h) Biology and ecology of pest and beneficial arthropods associated with cane and bush fruit plantations.
(i) Methods of risk assessment and control of risks of the release into the environment of plants with alien genes.
(j) Risk assessment: transgenic plants containing virus satellite nucleic acid.
(k) Research into the performance of disease resistant genotypes in pesticide free farming systems.
(l) Prediction and monitoring of weed populations and weed management strategies in crops, uncropped areas and in rotations.

PU 24 Strategic studies on pests and pathogens

(a) Mechanisms of host recognition, resistance and susceptibility to insects, mites and nematodes.
(b) Effects of vector and host on feeding behaviour in relation to virus acquisition and transmission by aphids.
(c) Role of neuroactive and other compounds in the development of nematodes.
(d) Investigate the control of pests by naturally occurring compounds.
(g) IFS Nature and function of nematode and plant pathogenesis related proteins.
(h) Genetic control of pathogenesis and changes in physiological races of fungal and bacterial pathogens of plants.
(i) Identify and elucidate the effects of pre- and post-formed host and pathogen compounds on disease resistance.
(j) Host and pathogen interactions: factors determining latency and host resistance.
(k) Electrophoretic and molecular techniques to determine groupings within invertebrate pests.
(l) Biochemical processes in parasite development.
(m) Ecology of the wild rabbit and development of novel strategies for population management.
(n) IFS Molecular genetical analysis of pectic enzyme production of *Erwinia carotovora* as affected by temperature.
(o) IFS Potato cell wall components as elicitors of plant resistance mechanisms.
(p) IFS Nature and function of nematode salivary secretions.
(q) Investigate the control of pests by naturally occurring compounds.
(r) Identify and elucidate the effects of pre- and post-formed host and pathogen compounds on disease resistance.

PU 25 Basic and strategic studies on viruses

(a) Mechanisms of virus transmission by aphids.
(b) Genome organization of viruses and molecular aspects of their biological behaviour.
(c) Enhance virus resistance by transforming plants with virus-related nucleic acid.
(d) Structure and function of the genome RNA of potato leafroll luteovirus.
(e) Genome organization and properties of gene products of plant picornaviruses.
(f) Mechanism of virus transport and intercellular movement in plant tissue.
(g) Monoclonal antibodies to identify and analyse important epitopes on virus proteins.

(h) Methods for electron microscopy of viruses and virus vectors.
(i) Methods for detection and study of virus-related proteins and nucleic acids.
(j) Structure and function of the genome of raspberry ringspot nepovirus.
(k) Molecular biology of potato mop-top virus.
(l) Mechanisms determining specificity and efficiency of nepovirus transmission by nematodes.
(m) Transmissibility of tobraviruses by nematodes: specificity and inhibition.
(n) IFS Structure and function of genome RNA of raspberry ringspot nepovirus.
(o) IFS Genome organisation of plant picornaviruses.
(p) IFS Mechanism of virus transport and intercellular movement in plant tissue.
(q) IFS Monoclonal antibodies to study epitopes on potato virus V protein.
(r) Structural analysis of viral proteins.
(s) Transmissibility of tobraviruses by nematodes: specificity and inhibition.

PU 26 Plant and crop physiology

(a) Mathematical analysis of plant and crop processes.
(b) IFS The use of Artificial Intelligence to model crop production systems.
(c) Physiological and biochemical regulation of carbohydrate transport and metabolism.
(d) IFS Sucrose transport in source versus sink potato tubers.
(e) Mechanisms regulating the initiation and differentiation of plant storage tissues.
(f) Mechanisms of salt tolerance in crop plants.
(g) IFS The biochemical basis for genotypic variation in susceptibility of potato tubers to calcium-related disorders.
(h) Effects of agrochemical contamination and misuse on the growth, yield and quality of seed potatoes.
(i) Mechanisms of uptake, transport and modes of action of Xenobiotics.
(j) Quantify the effects of environment on growth and development in crop plants.
(k) Physiological and biochemical processes limiting growth, development and quality of grain legumes.
(l) Environmental and nutritional factors affecting growth, cropping and propagation of soft fruits.
(m) *In vivo* characterisation of metabolic processes in plants by NMR spectroscopy.
(n) Mathematical analysis of plant and crop processes.
(o) Physiological and biochemical regulation of carbohydrate transport and metabolism.
(p) Quantify the effects of environment on growth and development in crop plants.

PU 27 Diseases and pests of arable crops

(a) Biology and pathogenesis of bacterial pathogens of potatoes.
(b) Survival and distribution of *Phytophthora infestans*.
(c) Immunodiagnostics for fungal plant pathogens.
(d) Interactions between tolerance, resistance and potato cyst nematodes.
(e) Genetic basis of virulence in potato cyst nematode and effects of selection.
(f) Epidemiology of potato leafroll virus.
(g) Mechanisms, effectiveness and inheritance of virus resistance in potato.
(h) Determine properties, transmission by vectors and identification of potato viruses.
(i) Expression and durability of partial resistance to mildew.
(j) Resistance of brassicas to *Plasmodiophora brassicae*.
(k) Biology and pathogenesis of bacterial pathogens of potatoes.
(l) Interactions between tolerance, resistance and potato cyst nematodes.
(m) Mechanisms, effectiveness and inheritance of virus resistance in potato.
(n) Expression and durability of partial resistance to mildew.

PU 28 The control, expression and manipulation of genes and gene complexes in cereals and legumes

(a) Biometrical genetics of barley and faba beans.
(b) Physiological genetics of barley.
(c) Genetics of biochemical components of cereals and beans.
(d) Utilize biochemical markers in genetic studies.
(e) Analysis of resistance conferred by novel genetic components of cereals to fungal diseases.
(f) Develop and utilize rapid screening tests for quality assessment in cereals.
(g) Trial extension crops.
(h) Tissue culture and transformation techniques.
(i) Trial extension crops.

PU 29 The control, expression and manipulation of genes and gene complexes in cereals and legumes

(a) Characterisation of barley composition in relation to malting quality.

PU 30 Effect of wounding and storage conditions on potato tuber contamination by soft rot erwinias

(a) Effect of wounding and storage conditions on potato tuber contamination by soft rot erwinias.

POTATO AND BRASSICA GENETICS

G. R. MACKAY

For the potato geneticists 1989 was inevitably dominated by the closure of the Pentlandfield site in March and the relocation to Mylnefield in April. The transfer has had an adverse effect on some research programmes. Most effort was of necessity devoted to conservation of valuable germplasm and maintenance of the integrity of existing programmes. Nevertheless it was possible to initiate new experiments and progress was made towards the achievement of several important objectives. A vigorous start has been made to revitalising the Commonwealth Potato Collection and new studies on a range of novel tissue culture-based techniques have already begun to produce interesting results.

For the first time all routine field experiments and trials were planted at Gourdie. The hot dry summer affected crop growth but access to irrigation ameliorated the affects of the summer drought and yields were good. An above average incidence of common scab and secondary growth in tubers, associated with the hot dry conditions, provided an opportunity to apply substantial selection pressure and reject clones prone to these disorders from the programmes.

Glasshouse activities were restricted as only the seedling houses were available.

Brassica genetics suffered from staff resignations and retirals, but nevertheless significant progress was made. Our Consortium partners have now assumed responsibility for the funding of the pre-NL trialling of potential cultivars. Whereas with potatoes the Consortium organised and ran the off-station ware trials in 1989, they contracted SCRI for brassica trials. Collaboration between the technical representatives of the Consortium and SCRI staff was excellent. In consultation with the Consortium another advanced potato clone was identified as a potential cultivar and submitted to National List Trials whilst four SCRI clones submitted in 1988 were resubmitted for their second and final year in 1990. A swede line satisfactorily completed NL1 trials and another rape line was submitted. Rape line SR8 was withdrawn after an indifferent performance in the drought conditions of 1989.

The Potato and Brassica Genetics Department was formed during a difficult season in more ways than one, not least the relocation from Pentlandfield into temporary quarters for the Potato group but also internal relocation of the Brassica staff to make more effective use of

facilities and to accommodate colleagues from the Cereal and Legume group Genetics Department. Consequent upon the recommendations of the AFRC Visiting Group in April the decision to merge this latter department with Potato and Brassica Genetics into a department of Crop Genetics was taken and is being implemented.

Some disruption of the Potato Genetics R & D programmes was inevitable as a consequence of the relocation to Mylnefield, and closure of Pentlandfield. In so far as many of the research objectives were met and a clone submitted to National List Trials as a potential cultivar, credit is due to all staff including those who chose not to transfer.

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

Sugar analyses on the tubers of the 1243 clones from a half diallel between cultivars and phenotypically low temperature sugar stable clones (*Ann. Rep. 1987*, 72 and 1988, 75) were completed. Preliminary analyses have confirmed the variation found amongst these progenies during the seedling glasshouse phase. The progeny means for fry colour and sugar levels of field-grown clones accord with those observed on the same progenies grown as seedlings in the glasshouse and the development of a glasshouse progeny method to investigate the genetic architecture of this phenomenon is under consideration. However, whilst the rankings of progeny means in the glasshouse and field are sufficiently consistent to permit identification of superior progenies it may not be possible to select particular clones with sufficient confidence on the basis of glasshouse data alone. Data from the glasshouse progeny phase indicate that for fry colour and sugar levels both general and specific combining ability effects are involved and whilst in some cases the mean performance of a progeny might be deduced from the phenotypes of the parent clones, in other cases this is not so. Of the thirty progenies planted at Blythbank, six of the most interesting progenies (in terms of sugar stability) have been retained in their entirety. Tuber samples of these were taken from the field at harvest and stored at 4°C. Chemical analyses should permit selection from within these progenies of clones with superior low temperature sugar characteristics and also provide definitive data against which the 1987 and 1988 experimental data can be checked. A single tuber of every clone was also retained to provide tuber progenies of the half diallel for further research. Approximately forty agronomically superior clones were selected for replicated trial in the routine third year (M_3) trials in 1990.

An extensive hybridisation programme, which includes several additional clones recently identified with this low temperature sugar stable phenotype is planned to supplement seed secured from crosses made in 1989.

(G. R. Mackay, Fiona Ritchie, H. Bain[1], D. W. Griffiths[1])

[1]Chemistry Department

Potato Regional trials [PU 1(a)]

Fifty-four advanced pre-National List clones were identified and together with 6 controls were provided to the Consortium of Dalgety/Nickersons for trialling in 1989 at four maincrop sites in England. SCRI undertook cooking quality tests on samples from these trials and also the subsequent analyses of data. Clone SCRI 13740(4), a white skinned maincrop with good table qualities, yield potential and disease resistance characteristics was identified for submission to National List Trials in 1990. It combines excellent levels of resistance to fungal diseases, particularly late blight in both tuber and foliage, with resistance to the common viruses.

(M. F. B. Dale)

Seed Multiplication and Maintenance [PU 1(a)(b)]

Although Pentlandfield has closed it has been necessary to retain the Institute's high grade seed potato facility at Blythbank Farm in Peeblesshire. Two staff have been relocated to Blythbank and arrangements made with the AFRC Institute of Animal Physiology and Genetics, who own the farm, to provide additional support during periods of peak activity.

At Blythbank the high organic soil's excellent moisture retention properties were a major advantage during the dry summer of 1989. Planting was completed in good conditions in early May, emergence was rapid and even and full cover rapidly achieved. The health of the crop was excellent and aphid control virtually complete. The dry conditions benefited seed tuber quality and although some common scab was noted on a few susceptible cultivars and clones but there was virtual freedom from powdery scab which can be a problem in more wet conditions.

The crop grew well, bulked rapidly and defoliation was carried out in early August. Harvest started early as a consequence but was not completed until early October.

Fourteen Approved Stocks were grown and all passed inspection. The excess seed produced from the Approved Stocks of the NL clones have been made available to the Consortium and the Approved Stock of an old SPBS-bred cultivar made available to the private company who contracted it. In addition 926 three-plant plots of somaclonal variants of a number of cultivars were also grown and seed produced on a contractual basis for AGC Ltd.

The Consortium have agreed to fund trials of approximately 20 advanced clones in Spain, Cyprus and Israel in 1990 thus partially reinstating the breeding of export cultivars. Seed of these clones was inspected and despatched from Blythbank direct. All samples passed inspection satisfactorily showing that the high standard of Blythbank seed tubers continues to be maintained.

(G. R. Mackay, I. M. Chapman, M. C. P. Campbell)

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

Virus diseases

Loss of the PBI site following privatisation led to the field exposure trial for resistance to potato leafroll virus (PLRV) and potato virus Y (PVY) being transferred to NIAB. Thirty clones were included to provide information for selection for National List submission. Six of these clones showed better PLRV resistance than the resistant control cv. Pentland Crown, in combination with a high degree of resistance to PVY. Most of the trial entrants were clones derived from crosses made in strategic studies into the genetics of resistance to both viruses.

(R. M. Solomon-Blackburn, J. S. Muir)

Fungal and bacterial diseases

Resistance screening was carried out against late blight, blackleg, common and powdery scab, skinspot and gangrene.

Desprouted seed tubers of 39 genotypes were vacuum-infiltrated or jet-injected with *Erwinia carotovora* subsp. *atroseptica* a few days before planting at Gourdie and Mylnefield, in late April. The mean yield depression from vacuum-infiltration was 13% and from jet injection 35%. This seems due to considerably reduced emergence in soft rot-susceptible cultivars. The yield of cv. Pentland Crown was least affected by inoculation, and the cultivars Estima, Pentland Javelin, Klondyke and Stormont Enterprise were most affected. The position of the last cultivar was unexpected in view of its previous record for resistance to soft rot. Five clones were as susceptible as the most susceptible control (Klondyke), and eleven, including cv. Brodick, were at least as resistant as Pentland Crown. Clone G8743ac15 was more intolerant than in 1988, with a mean yield loss of 59%.

The same clone, G8743ac15, which showed high resistance to powdery scab (*Spongospora subterranea*) in 1988, was also free of infection at the new joint SCRI/NSCA site near Oldmeldrum, Aberdeen. However, the dry summer resulted in very little infection overall, and among the controls only Estima was heavily infected.

Analysis of the 1988 powdery scab soil bed seedling experiment (*Ann. Rep. 1988*, 78) showed significant differences between the mean resistance of the progenies and a significant correlation between the mean scores of the parental cultivars (derived from their behaviour in field tests) and the mean number of infected tubers in each progeny. The most resistant progeny was derived from a cross between cultivars Desiree and Ulster Lancer and indications are that the resistance of a progeny can be predicted from the phenotypic resistance of its parents.

Late blight

Progenies from a hybridisation schedule designed to investigate the relationship between resistance to late blight in tubers and foliage were

assessed for a second year (*Ann. Rep. 1988*, 79). Blight assessments made on the foliage in the field trial at Yonderton Farm, Ayrshire, and in the laboratory on tubers grown at Mylnefield showed good agreement with the previous year's results (r=0.72 and r=0.71 respectively). The foliage blight resistance of the progenies was again correlated with the mean resistance of the parents (r=0.75), but tuber resistance was not. Whereas the correlation between foliage and tuber resistance was low but significant in 1988 it was not significant in 1989.

In a glasshouse study five cultivars, representing a range of resistance/susceptibility, were grown to determine the effect of soil moisture prior to harvest on the susceptibility of tubers to blight. Contrary to expectations, tubers from dry soil were more susceptible than those from damp or saturated soil.

An assessment of the value of foliage blight resistance to potatoes grown on organic farms was again (*Ann. Rep. 1988*, 80) undertaken. Four resistant cultivars (Shelagh, Teena, Torridon, Brodick), three resistant clones and three susceptible controls (Maris Piper, Wilja, Desiree) were planted in 20-tuber plots adjacent to farm crops. Two of the four replicates were simultaneously defoliated as soon as blight was observed in the crop in accordance with current practice, and the other two were left to normal harvest time. Blight was absent from one site, and at a second it was not possible to interpret the results but at the third the seven resistant genotypes gave a mean yield increase of 27% between the earlier and later defoliations, whereas the controls produced a 6% increase. Clone 13121ab2 gave the highest yield.

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

The resistance of microtubers to tuber blight was investigated for use as a potential rapid screening method. Micropropagated plants of nine cultivars covering a range of resistance/susceptibility to tuber blight were raised on agar medium, and single nodes transferred at weekly intervals to Petri plates containing a tuber-inducing medium. Microtubers aged between 2 and 6 weeks were then inoculated with a suspension of *P. infestans* zoospores. The cultivars exhibited differences in resistance but this did not consistently reflect their field performance. The age of the microtubers had no effect on their susceptibility.

(H. E. Stewart, M. C. Coleman, R. L. Wastie, W. J. J. Soppe)

Commonwealth Potato Collection [PU 1(h)]

Expansion of a potato gene bank

The Commonwealth Potato Collection (CPC) is a potato germplasm resource of international importance. It currently contains 1087 accessions which have been maintained as true seed since the early 1960s. All have

been positively screened and declared free of Potato Spindle Tuber Viroid (PSTV). The seed collection is being divided into a long-term collection, which is stored dry at −20°C, and a rapid access collection, where sealed packets of 25 seeds are stored at 6°C under controlled humidity. During 1989, 200 accessions were divided and stored. Additional collections have been created to reduce demand on seed stocks and to increase the range of requests which can be dealt with. These collections include: pollen stored dry at −20°C (80 accessions); herbarium specimens taken from 80 accessions; frozen plants from 50 accessions and tubers from 150 accessions. A limited supply of fresh material was also made available during the growing season (c. 200 accessions).

The CPC will be more than doubled in size over the next 4 years by the incorporation of the Birmingham (Hawkes) collection, which is at present being screened for PSTV by DAFS at East Craigs.

(M. J. Wilkinson)

Potato dihaploids [PU 1(c)(d)]

Potato dihaploids produced at SCRI have usually been male sterile. Some clones have been found which occasionally and unpredictably set seed as pollen parents but over the last year three dihaploids which are pollen fertile in repeated crosses have been identified. When PDH638 is used in interdihaploid crosses it gives rise to 2x and 4x offspring. This suggests it produces a mixture of reduced (1x) and unreduced (2x) pollen grains. The occurrence of unreduced diploid female gametes has been demonstrated previously in SCRI dihaploids. The tetraploid hybrids probably arise from the combination of unreduced male and female gametes. Unreduced male gametes may be produced by first meiotic division restitution whereby most of a diploid parent's genotype is transferred unaltered to its offspring. As PDH638 has high resistance to foliage blight and PCN, unreduced male gametes from this clone could be of potential value for cultivar breeding. Furthermore, a male fertile dihaploid resistant to pests and diseases allows the additional improvement of diploid material by intercrossing it with other dihaploids possessing complementary characters, prior to the resynthesis of tetraploids as potential cultivars. Test crosses with some of the diploid and tetraploid offspring of PDH638 showed that some of these were also male fertile.

Scoring of tetraploid field-grown progenies of highly homozygous, chromosome-doubled dihaploids crossed with cultivars showed that there was no significant reduction in within-progeny variance compared with control progenies derived from the intercrossing of heterozygous tetraploids. This differed from the seedling year glasshouse-grown material where there was reduced variance in tuber yield, and in yield components and overall appearance score, compared to the controls. Of the three doubled dihaploids used in the crosses, PDH40X2 (derived from cv. Pentland Crown) had the highest general combining ability for overall impression

score of field-grown tubers. The other two doubled dihaploids however, which were selected primarily for their foliage blight resistance, had negative general combining abilities for overall impression score. Analysis of the segregation of tuber flesh colour in crosses of two white-fleshed doubled dihaploids with the yellow-fleshed cv. Desiree indicated that this character was under the control of a single major gene with white dominant to yellow ($\underline{X}^2$=0.2098, P>0.975). This is in contrast to other potato species where yellow flesh colour has been found to be dominant.

(M. J. De, Maine)

The use of emergent techniques in genetical analysis of potato [PU 1(c)]

Potato anther culture

The production of monoploids (true haploids) in large numbers will enable the construction of homozygous pure lines, after diploidization. It takes many generations of selfing by conventional methods to obtain pure lines, while anther culture can reduce the time to one generation. Homozygous lines provide excellent material for genetical analysis which at present is extremely difficult in the cultivated potato due to its complex tetraploid nature. The anther culture response is genotype dependent and a large population of dihaploids, diploids and tetraploids were investigated for culturability. A number of responsive genotypes have been identified and will be used in crossing experiments with non-responsive genotypes.

(M. Coleman)

Genetic diversity in protoplast and explant derived plants [PU 1(d)]

Protoplast culture

A regeneration procedure from protoplasts of a range of tetraploids, dihaploids and wild species has been optimized. This procedure is a prerequisite to somatic hybridization and the exploration of methods of gene transfer in the development of new breeding material. It allows the more rapid introduction of genes from wild species into both diploid and tetraploid populations of *Solanum tuberosum* than is attainable using conventional breeding methods, as it bypasses sexual incompatibility and sterility barriers.

(M. Coleman)

Adventitious regeneration from tuber discs

During the last 15 years there have been many accounts of somaclonal variation in plants of numerous species regenerated from tissue culture. Several studies report breakdown in tuber colour as a result of tissue culture, possibly due to the release of hidden genetic variation already in existence in a cultivar. Such variation may be useful in new cultivar production. A study into the frequency and type of breakdown in skin

colour from twelve partly coloured cultivars has been undertaken. Genotypic differences in tuber disc regeneration response has already resulted in very large numbers of regenerants from some genotypes.

(M. Coleman)

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

The selection WMXcacc (SS8) successfully completed its first year in National List Trials in 1989 (*Ann. Rep. 1988*, 63). Selection GDLaaa, a high dry-matter (DM) line from a cross cv. Bangholm Dima x cv. Melfort, was included in SCRI's trials of advanced selections for a second year. Although it is resistant to turnip mosaic virus, its yield and mildew resistance are not sufficient improvements on cv. Melfort to warrant its entry into National List Trials.

FBC x rbab was the highest yielding F_6 line from a cross cv. Magres x cv. Criffel. All lines from this cross had good mildew resistance and suffered little yield loss despite the very dry summer. Their mean DM yield was 8.59 t/ha compared with 6.41 t/ha for the mean of the six control cultivars, Angela, Angus, Magres, Marian, Melfort and Ruta Øtofte. As FBC x rbab has white flesh it will be suitable for processing as well as for stock feeding.

Three F_5 lines HAM x bbc (from cv. Acme x cv. Marian), HAR x bdf and HAR x laj (from cv. Acme x cv. Ruta Øtofte), were identified as potential shopping swedes to replace cv. Acme. The lines had the deep purple skin and yellow flesh of Acme, but were higher yielding.

Two F_5 lines, JZRfiab and JZR fjbd, were identified which combined clubroot resistance with high DM yield and very good mildew resistance. The clubroot resistance was derived from the experimental Dutch Stubble Turnip population ECD04 through a synthetic *B.napus* produced in 1976.

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

Inheritance of resistance to turnip mosaic virus in swede [PU 4(q)]

The inheritance of resistance to turnip mosaic virus was studied in a cross between a very resistant line from cv. Bangholm Wilby (BWc4hca) and a susceptible line from cv. Criffel (CRdagaa). One plant in the F_1 showed symptoms and virus was also detected by ELISA in two symptomless plants. The segregation ratios in the F_2 and Bx(CR) generations were a reasonable fit to those expected for a single dominant gene. Additional inheritance studies are required to confirm whether 12 other symptomless lines in the SCRI collection contain the same gene.

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

[1]Mycology and Bacteriology Department

Heterosis in swede [PU 4(q)]

Genetic analyses of heterosis for DM yield in swede have concentrated on two heterotic crosses identified from earlier work (*Ann. Rep. 1987*, 60) and from part of a joint project with Birmingham University. The first triple test cross (inbred line from cv. Marian x inbred from cv. Criffel) was assessed in 1988. Significant additive genetic variation was found for DM yield and its components fresh-weight (FW) yield and DM content, and also for powdery mildew, neck length and splits/rots. Dominance variation was found for FW yield, DM yield and mildew. The dominance ratios were 0.64, 0.53 and 0.35, respectively. It should therefore be possible to produce inbred lines from this cross that outperform the F_1 and inbred lines are being produced by single seed descent and *in vitro* androgenesis for this purpose.

The second triple test cross (inbred from cv. Bangholm Wilby x inbred from cv. Criffel) was also assessed and data are being analysed.

(J. E. Bradshaw, M. J. Kearsey[1], L. D. Ramsay[2])

Stock multiplication [PU 4(f)]

F_1 hybrid swedes

High yielding inbred lines of swede with S-alleles giving high levels of self-incompatibility were produced to facilitate the production of large quantities of F_1 seed by insect pollination. The first such line, SIRE641b with S-allele E in inbred line BRdfc from cv. Ruta Øtofte, was used to produce eight F_1 hybrids in 1989 for assessment in 1990. A second line, SICF646a with S-allele F in inbred line CRdagaa from cv. Criffel, was also used to produce hybrids for assessment in 1990.

(J. E. Bradshaw, J. N. Dick)

Improvement of leafy brassicas [PU 4(n)]

Kale population improvement and cultivar production

In 1981 the foundation population (generation 0) for a new kale improvement programme was produced from 16 marrow-stem kale cultivars with some resistance to clubroot. A sub-population with improved clubroot resistance was rapidly produced (*Ann. Rep. 1987*, 63) and is undergoing further evaluation. Generation 3 of the main population was assessed in 1989 as 88 half-sib families. There were no statistically significant differences between families for digestible organic-matter (DOM) yield, but their mean yield (9.05 t/ha) was considerably higher than that of the four control cultivars, Bittern, Condor, Kestrel and Merlin (7.62 t/ha). There were, however, differences for dry-matter (DM) content (heritability $h^2 = 0.47$), DOM content ($h^2 = 0.29$) and thiocyanate ion

[1]Birmingham University
[2]Research Student

(SCN^-, a goitrogen) content ($h^2 = 0.45$). Smith's optimum index was used to select 12 families for the next generation which combined high DM and DOM contents with low levels of SCN^-. There were also height differences ($h^2 = 0.60$), but taller plants are undesirable because they are prone to lodging.

As in the second generation, there were no differences in levels of S-methyl cysteine sulphoxide (SMCO, the haemolytic factor) so prospects are not good for reducing SMCO in kales. Research into the role of SMCO in the sulphur metabolism of cruciferous plants is therefore desirable.

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

Anther culture of inbred swede lines [PU 4(p)]

Analysis of results from the 1988/89 anther culture programme showed that there was variation in response between the three inbred swede lines: BMCR, ML and BC. These lines were derived from crosses between the cultivars Marian and Criffel (MC), Bangholm Magres and Criffel (BMCR) and Bangholm Wilby and Criffel (BC), this last cross being least responsive.

Yields of haploids overall were very poor when compared to oilseed rape cultivars of *B.napus*. For most cultivars growth conditions did not significantly influence androgenesis for which the greatest effect was genetic. However, with the highly responsive cv. Ariana media type was significant, the anther culture response being greatest on a half solid, half liquid medium.

Over 400 haploid plants were raised from 200 unique embryos. Overall losses during the culture phase were very low and culture medium changes were relatively few. Assessment of ploidy levels is in progress and haploid plants are being treated with colchicine to restore chromosome number and fertility prior to seed production and field assessment.

(J. Middlefell Williams)

Improvement of leafy brassicas [PU 4(n)]

Rape improvement programme

The programme combining improvements in yield, disease resistance and reduced levels of sulphur-containing anti-metabolites continued. Together with the back-crossing programme to introgress low levels of seed glucosinolates and erucic acid from oilseed to forage rape, 40 new crosses were made. Existing genotypes were assessed in F_2-F_5 generations under very adverse conditions with both drought and high levels of mildew attack reducing yields by an average of 34% compared with the 1988 values. The conditions adversely affected the performance of SR8 in the first year of National List trials and the decision was taken to withdraw it and replace it

[1]Chemistry Department

by SR11 which had performed well in both SCRI and VARTEST trials. Three selections from F_5 trials, five from F_4, five from F_3 and 15 from F_2 were retained for seed production and further trials.

(W. H. Macfarlane Smith)

Early-generation cross-prediction [PU 4(q)]

A further stage of the cross-prediction studies in forage rape was completed, with assessments made for yield parameters, height, flowering, breaking and mildew resistance. In addition a 'Breeders Preference' score was assigned. This correlated well with yield and with total ranking figures for all characters assessed ($r = 0.86$). Initial analyses suggest that performance prediction at the F_2 generation is a valid method for selecting the best potential cultivars.

(W. M. Macfarlane Smith, P. D. S. Caligari[1])

Levels of anti-metabolites in seed and vegetative tissue of Brassica napus [PU 4(s)]

An improved paper chromatographic method was developed for assessing levels of erucic acid in 'half-seeds' of *Brassica napus* produced in the 'double-low' transfer programme. The method is sufficiently accurate to discriminate high and low erucic acid lines. Selections from the latter have been grown on to produce seed for further trials and inheritance studies.

(W. H. Macfarlane Smith)

Anti-nutritional factors in rape [PU 4(u)]

Changes to individual and total glucosinolate contents of aerial tissue of two forage rapes (cultivars Hobson and Bonar) and two oilseed rapes (cultivars Bienvenn and Ariana) following over-winter feeding damage by rabbits were found. Grazed plots had almost double the total glucosinolate concentration of ungrazed plots over the period October to January but differences diminished thereafter. The percentage of aliphatic glucosinolates in the total fell in grazed plots while the aromatic glucosinolates, particularly the indole glucosinolates, increased. Response to rabbit damage was rapid, with significant changes in glucosinolates occurring in as little as 10 days.

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

Production of new brassica material through tissue culture [PU4(h)]

In vitro *selection for herbicide resistance*

The *in vitro* culture of haploid microspores is being examined as a means of producing herbicide resistant *Brassica napus*. Investigations are being

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

made to determine the effects of the herbicide glyphosate on viability of late uninucleate/early binucleate microspores, the stage thought to be most suitable for microsporogenesis. Studies on three *Brassica napus* genotypes showed that viability of mature pollen and trinucleate microspores was rapidly reduced by high concentrations of glyphosate (50-100mM). This response was not shown by uninucleate/binucleate microspores which maintained higher levels of viability at 50mM glyphosate than were achieved after incubation in either glyphosate-free media or a lower glyphosate concentration (5mM). The preliminary results indicate the response of *Brassica napus* microspores to glyphosate alters during development. This could be a reflection of enzymatic differences between developmental stages influencing herbicide action.

(M. Ramsay, T. Hodgkin)

Trials of advanced selections [PU 4(f)]

Six trials funded by Nickersons were successfully carried out at Aberdeen, Ayr, Berwickshire and Dundee. All trials suffered drought conditions in early summer but recovered when normal rainfall returned in late July. Yields were down 20% overall on last year. Mildew (*Erysiphe cruciferarum*) was present at most sites making the selection process easier as certain forage rapes and swedes showed marked resistance. The swede SS8 completed its first year in National List successfully and was declared distinct, uniform and stable (DUS) with good resistance to powdery mildew.

The forage rape SR11 performed well in the Scottish trials with a 15% increase in dry yield above the mean of control cultivars. SR11 also has good mildew resistance and does not lodge.

(R. N. Wilson)

Stock multiplication project

Advanced selections of 46 forage rape, 12 swede, 3 turnip and 2 kale breeding lines were multiplied in polythene tunnels. In addition, multiplications were made for conservation purposes of a further 15 obsolete swede cultivars and 1 obsolete turnip cultivar in the SCRI collection. Breeding lines were rigorously screened to the official standards for DUS and no significant disease problems were encountered. However, aphid (*Myzus persicae*) infestations in a number of crops proved difficult to control and resulted in a modest reduction in yield and quality.

(R. N. Wilson)

The success of cv. Tyne as a replacement for Golden Promise reflects the success of breeding disease-resistant spring barley of high malting quality for Northern Britain at SCRI.

However, as a consequence of the Barnes Review on 'near-market' research, cultivar breeding and the commercial development of new cultivars bred at SCRI has now to be supported financially by non-Government funds. The signing of an agreement with a Consortium of Dalgety Agriculture plc and Nickerson Seeds Ltd. will reduce, but not eliminate, cultivar breeding work, with a switch in emphasis to fundamental and strategic research. Inevitably such a change is accompanied by an increase in collaboration with other Departments at SCRI and with Universities and private organisations, as is reflected by the authorship of much of this report.

New spring barley cultivars [PU 28(a)]

The hot dry summer favoured genotypes with the *erectoides* dwarfing gene in the selection process.

Cv. Tyne, an *erectoides* type, yielded well and continues to be recommended by SAC in Scotland. It may replace cv. Golden Promise; some 1200 hectares were entered into the UK seed certification scheme.

Cv. Annan (PEG 141/4/1/6) yielded more than the control mean in NLT1 and BSPB trials but was only just in the top half of the entries and has therefore been withdrawn. Following consultation with the Dalgety/ Nickerson Consortium, two new submissions have been made by SCRI to NLT1; SCRI 895 is a high yielding, malting selection from a cross between cultivars Sherpa and Blenheim with the *denso* dwarfing gene, conferring a semi-prostrate juvenile growth habit, and good resistance to powdery mildew. 22708Co24/4 is a selection from a cross between cultivars Casino and Corniche made at WPBS and transferred to SCRI as a random F_2 population. It also has the *denso* dwarfing gene and is high yielding, late maturing and has good disease resistance.

Seven, 18 and 200 selections have been entered into NLT-1, NLT-2 and NLT-3 trials respectively by Nickerson Seeds Ltd, who will be responsible for pure stock production and maintenance, and by Dalgety Agriculture plc. (W. T. B. Thomas, A. Young, G. R. Young, P. T. Gymer[1], M. R. Jeffes[2])

[1]Nickerson Seeds Ltd
[2]Dalgety Agriculture plc

Early generation yield trials of spring barley [PU 28(a)]

The system of growing two single replicate trial series for evaluating the yields of F_5 selections (*Ann. Rep. 1988*, 58) was repeated. Powdery mildew developed up to GS39 but was halted by the hot dry summer. However plots treated with fungicide and 77, 38.5 and 38.5 kg/ha of N, P and K respectively yielded 10.3% more than did the series without disease control and half the rate of fertiliser. The agreement between the two trial series was better than in 1988, with an overall correlation of 0.55 ($P<0.001$) between the yields of the entries adjusted for local variation detected by the control grid, probably reflecting the limited mildew development in 1989.

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

Cross prediction in spring barley [PU 28(a)]

Crosses grown in cross prediction experiments were ranked according to their predicted probabilities of producing inbred lines that were of shorter height, lower milling energy and higher yield than the mean of two controls. The parameters used to make the predictions were the cross mean and genetic standard deviation and the control mean for each character and the additive genetic correlations between the characters. Multiple regression analysis revealed that the cross and control means were the most important parameters in determining the predicted probabilities, suggesting that mean performance relative to the control mean may provide a simple method of ranking crosses. However, the correlation between this ranking and the ranking based on the predicted probabilities was only 0.49 in the 1987 and 0.62 in the 1988 crosses and, in 1987, one cross which was in the bottom 10 ranks based on means was in the top half of the ranks based on predicted probabilities.

(W. T. B. Thomas)

Localisation of characters of agronomic importance in barley [PU 28(a)]

Doubled haploid, produced by the *Hordeum bulbosum* technique, and single seed descent lines from TS311, which segregated for the *erectoides* dwarfing gene found in cv. Golden Promise (GP*ert*), and TS332, which segregated for the *denso* dwarfing gene found in cv. Maris Mink, were grown in field trials in 1987 (*Ann. Rep. 1987*, 56). The GP*ert* gene was significantly associated with high milling energy and screenings and low hot water extract and thousand grain weight. As the gene has been located on chromosome 7, some of the genes controlling malting quality characters may be located on the same chromosome. Among the inbred lines from TS332, the *denso* gene was also associated with low thousand grain weight, late maturity, high screenings and high grain ß-glucan content. The chromosomal location of the *denso* gene is unknown but some of the genes controlling these characters may be located close to it.

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

[1]Tissue Culture Department

The effects of major genes on quantitatively varying characters in barley [PU 28(a)]

Inbred lines were extracted from the cross Dissa x Sabarlis, which have six-row and two-row ear types respectively, by single seed descent and by the *Hordeum bulbosum* doubled haploid technique. Estimates of additive genetic variation from the single seed descent and doubled haploid lines revealed an association between the *V-v* locus on chromosome 2, which conditions ear type, and characters influencing plant height and biomass production. This effect of a major gene locus on quantitative traits helps to explain historic difficulties in obtaining useful recombinant lines in two-row by six-row crosses.

(R. P. Ellis, W. T. B. Thomas, W. Powell[1])

Genetical control of environmental tolerance [PU 28(b)]

The mild weather prevented selection for frost tolerance in the field but increased disease pressure, in particular from barley yellow dwarf virus and mildew allowing good selections to be made. The winter barley line WB1256 has been entered into commercial yield trials by Nickerson Seeds Ltd.

An experiment in a polythene tunnel showed that different levels of nitrogen, applied in nutrient solutions, significantly affected grain size, nitrogen content and length of post harvest dormancy.

(R. P. Ellis, B. Marshall[2])

Biochemical properties of starch [PU 28(c)]

Samples of starch were obtained between anthesis and harvest from barley genotypes with normal (Glacier and Oderbrucker), high (Glacier selection) and low amylose (Waxy Oderbrucker) grown in the field. Large starch granules were separated from small granules and genotypically determined differences demonstrated in their amylose and lipid contents. These results support the model of a granule core with low amylose and lipid surrounded by a shell of higher amylose and lipid. The composition of small granules differed from the large indicating a sophisticated regulation of starch synthesis. The concept of compartmentalised starch synthesis was strengthened by the evidence that inhibition of amylose synthesis was progressively weakened in large, but not in small, granules in Waxy Oderbrucker.

Studies on starches of barley grown in constant environments of 10, 15 and 20°C showed that stress at the higher growing temperatures resulted in lower starch accumulation with smaller and fewer granules. Temperature influenced the lipid content and relationship with amylose in the waxy and normal genotypes.

[1]Tissue Culture Department
[2]Physiology and Crop Production Department

Gelatinisation temperature of the starches increased at higher temperatures reflecting an increase in crystallinity, and because the crystalline fractions are resistant during early stages of malting, temperature effects may explain differences in the malting potential of field crops.

(R. P. Ellis, W. R. Morrison[1], J. B. South[1], R. F. Tester[1], J. R. Stark[2], A. M. L. McDonald[2])

Effects on malting quality associated with variation in the properties of barley starch [PU 28(c)]

Waxy barleys, which have a high amylopectin content, had higher milling energies but faster water uptake during steeping than barleys with a normal amylose : amylopectin ratio. In contrast, a mutant genotype, in which microscopic examination revealed a fractured appearance of the large starch granules, had a lower milling energy than its parent. A crossing programme has been initiated to produce genotypes with varying combinations of starch composition and enable development of random inbred lines to study the genetical control of starch composition.

(J. S. Swanston)

Environmental constraints on selection for malting quality [PU 28(c)]

The results of trials of several barley genotypes grown over a range of sites in several seasons showed that hot water extracts, relative to those of a control cultivar present in all trials, gave a good prediction of the malting potential of genotypes over seasons, providing trials in which poor germination occurred during malting were discounted. Genotypes which had useful quality attributes, but did not perform well under the standard micro-malting procedure, could be selected by tests such as milling energy performed on unmalted grain.

(R. P. Ellis, J. S. Swanston, K. Taylor[3])

Anti-nutritional factors in faba beans [PU 28(c,d)]

The levels of toxic glycosides vicine and convicine in mature faba bean seeds varied between accessions. Intra-accession variation was found to be low in an inbred cultivar and higher in a partial inbred and a synthetic line. Genetic studies are being undertaken on lines with very low levels of convicine.

(G. Ramsay, D. W. Griffiths[3])

[1]Department of Bioscience and Biotechnology, Strathclyde University
[2]Department of Biological Sciences, Heriot-Watt University
[3]Chemistry Department

Biochemical genetics of milling energy [PU 28(d)]

The genetical control of milling energy (ME) was explored. Genes influencing ME in aneuploid stocks of Chinese spring wheat were found on all seven homoeologous chromosome groups. The addition of some complete wheat chromosomes increased ME, while chromosome 3B conditioned low ME.

Alien chromosome additions from barley and rye conferred high ME while others from *Hordeum chilense*, *Aegilops umbellulata*, *Secale cereale* and *S. montanum* conferred a low ME. Although the genetical control of ME is polygenic there is a general and major effect of genes located on the short arms of homoeologous group 5 chromosomes.

(R. P. Ellis, B. Forster[1])

Isozymes as biochemical markers in faba beans [PU 28(d)]

Several isozyme profiles were obtained from a small portion of dry individual seeds of a number of genotypes using iso-electric focusing while leaving sufficient tissue to provide a vigorous seedling. Different loci were expressed for many isozymes in mature seed cotyledons, seedling leaf tissue and pollen. One third of isozyme/tissue combinations were polymorphic.

(G. Ramsay, B. P. Forster[1])

Applications of grain and malt milling energy tests [PU 28(f)]

Gibberellic acid treatment did not increase water uptake or the initial rate of germination of several cultivars with a range of malting quality but a reduction in milling energy (ME), relative to untreated samples, was observed after 24 h germination. Therefore ME detected uptake of gibberellic acid at an early stage in the malting cycle, although differences between cultivars did not become apparent until the completion of malting, and could be used to predict increase in extract.

ME of malt can be used to assess comparative degrees of endosperm modification between cultivars with similar grain ME prior to malting. Cultivars with high grain ME may retain high ME after malting since, despite considerable endosperm modification, the ME of the residual unmodified structure will be related to that of the unmalted grain. The ME of many cultivars bred in western Europe over the last 30 years declines rapidly during malting due possibly to the replacement of visual selection of barleys with a mealy endosperm by micro-malting techniques which favour genotypes with rapid modification.

(J. S. Swanston, K. Taylor[2])

[1]Tissue Culture Department
[2]Chemistry Department

Field performance of lines derived from barley anther culture [PU 28(h)]

Some 280 lines derived by anther culture from crosses between cv. Blenheim and breeding lines E224/3 and TS264/22 and their reciprocals were grown in replicated field trials with disease control, together with lines produced by single seed descent from the same crosses. The lines derived by anther culture comprised one group in which the chromosome complement had doubled spontaneously and another in which colchicine had been used. There were significant differences between the two groups for heading date, height, yield, thousand grain weight and grain diameter. In general, the spontaneously doubled group was later maturing, shorter, higher yielding, had a lower thousand grain weight and smaller grain than the colchicine treated group and frequently differed from the mid-parental value.

(D. Cawston[1], W. T. B. Thomas, W. Powell[1])

Faba bean tissue culture and transformation studies [PU 28(h)]

Cotyledon-based regeneration systems

Transformation of *Vicia faba* has not yet been achieved, largely due to the lack of a suitable regeneration system. When cotyledons were excised from seedlings, leaving the axillary buds on the seedling axis, and placed on a shoot-inducing medium, the quantity of callus produced varied between genotypes. Altering the type and amount of exogenous cytokinin did not improve shoot regeneration. However, excised cotyledonary buds of a range of genotypes grew and branched on the same medium.

A survey of five accessions of species related to *V. faba* demonstrated some shoot regeneration, with one accession (*V. narbonensis* 7) outstanding in the proportion of explants producing *de novo* buds and the number of shoot buds per explant.

Silver nitrate is an ethylene inhibitor which promotes regeneration in some species, and its effect on regeneration in *V. narbonensis* 7 and *V. faba* ETS 56/7/1 and cv. Troy was explored. Silver nitrate inhibited shoot bud formation and further growth in *V. narbonensis* and did not stimulate regeneration in *V. faba*.

(G. Ramsay, F. Walls[2], A. Kumar[1])

Cytology of Agrobacterium rhizogenes *transformed tissues*

Cotyledons and stems of *in vitro* grown seedlings of *V. faba* genotypes infected with *Agrobacterium rhizogenes* produced transformed roots. Chromosome counts revealed diploid, tetraploid and higher ploidy roots. Deletions of parts of chromosome arms were found in some root clones showing that tissues transformed with *Agrobacterium rhizogenes* should be screened for cytogenetic abnormalities.

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

[1]Tissue Culture Department
[2]Short-term appointment

Trial cereal and legume crops in collaboration with other organisations [PU 28(i)]

Spring and winter oat trials were grown on behalf of IGAP (Welsh Plant Breeding Station). Spring barley, oats and navy beans were also trialled on a commercial contract basis.

(A. Young)

Barley composition and malting quality [PU 29(a)]

In a field trial of 22 cultivars of spring and winter barley the effect of nitrogen top dressing on ME was much smaller than on hot water extract (HWE) while other environmental factors had similar effects. The contribution of the husk, aleurone and endosperm to ME was determined by physically removing the two outer tissues by hand dissection and then abrading the endosperm. There were differences in the proportion of milling energy attributable to the husk and the removal of the aleurone, which caused larger changes in the ME of cultivers Doublet and Natasha than in Klaxon and Tyne, indicating that the husk and aleurone layer mask the softness of the endosperm. While at least 50% of grain hardness resides in the physical properties of the endosperm, the contribution from other components e.g. cell walls, protein and starch, is to be determined.

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

[1]Department of Bioscience and Biotechnology, University of Strathclyde

SOFT FRUIT GENETICS

R. J. McNICOL

We report the release of three new cultivars, a strawberry (cv. Melody), and two blackcurrants (SCRI seedling P10/18/116 and P10/18/121). Melody was also added to the National Fruit Trials (NFT) list of Approved New Fruit Varieties under the Approved for Special Purposes Category and the SCRI-bred strawberry cv. Rhapsody, released in 1987, was given Full Approval under the same scheme.

Significant improvements in soft fruit germplasm, using traditional hybridisation, have been attained while the development of techniques for single gene transfer and screening offer enhanced efficiency in soft fruit breeding.

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

Twenty-nine raspberry selections with various combinations of high fruit quality, earliness of cropping and desirable vegetative characteristics were made. Three were regarded as having many of the main requirements for successful machine harvesting. All the selections were propagated for further evaluation and some were identified as future parental material.

The advanced raspberry selections 8032A3, 8042E6, 8216B6, 7815A12 and 7815B8 continued to perform well with 8216B6 producing high yield and an excellent product in commercial canning tests. However, the performance of the very early maturing selection 8242E6 was disappointing.

(R. J. McNicol)

Resistance to root rot

The lack of effective field resistance to *Phytophthora megasperma*, the causal organism of raspberry root rot, and the seriousness of root rot outbreaks prompted a major diversion of resources towards the incorporation of resistance into raspberry germplasm with acceptable agronomic traits.

Seedlings derived from crosses of parents which had been reported to possess resistance with parents of superior fruit quality were planted directly on to a diseased farm site for assessment of survival and ultimately fruiting potential.

(R. J. McNicol)

Polyploid production in Rubus

Protocols were developed which reliably resulted in the *in vitro* production and identification of polyploids of clonal blackberry and red raspberry germplasm. Polyploidy was induced with colchicine and detected by measuring stomatal size of leaves grown in *in vitro* culture.

(R. J. McNicol, S. C. K. Williams[1])

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

SCRI seedlings P10/18/116 and P10/18/121 were recommended by the NFT Panel for commercial release for the non-juicing, pick-your-own and amateur markets. Due to the impending closure of the NFT site at Brogdale EHS the remaining SCRI lines in trial were returned to the institute. Provision for the further trialling of the most promising lines, including C1/9/10, C2/2/1, F4/1/67 (cv. Ben Alder x cv. Golubka believed to be reversion resistant) and the new seedlings described last year (*Ann. Rep. 1988*, 84) has been made at a grower site at Bradenham Hall, Norfolk.

(R. M. Brennan)

Imported germplasm

The SCRI *Ribes* germplasm collection was increased considerably during the year. Over 50 new accessions of Swedish breeding material and Russian cultivars were received from the Institute of Fruit Breeding, Balsgard, Sweden, for incorporation into the SCRI programme, and crosses using the most advanced of these accessions were made. Various *Ribes* spp. were received from the Institute of Horticulture, Piikkio, Finland and the Institute of Pomology, Poland and the *Ribes* species collection held at Institute of Horticultural Research (East Malling) was transferred to SCRI.

(R. M. Brennan)

Fruit quality

Over 350 fruit samples from selected genotypes were analysed. The quality of fruit samples in terms of anthocyanin and ascorbic acid content was high due to the warm, dry summer conditions. Seedlings with the most suitable colour characteristics for processing were identified using a Hunter Gardiner Colour Difference Meter. The most outstanding genotypes were hybrids of P10/9/13 x 243/7, and hybrids of the seedling C2/4/51. 243/7 is the established standard for fruit quality in the SCRI programme and is a parental component of P10/9/13 and C2/4/51.

(R. M. Brennan)

[1]Short-term appointment

Resistance to gall mite

Metabolic profiling studies of resistance to *Cedidophyopsis ribis* continued using a wide range of interrelated resistant and susceptible genotypes. Gas chromatographic/mass spectrometric evidence from bud samples indicated that although most of the major peaks found in both the resistant and the susceptible samples were similar, there were differences in the composition of the minor peaks. Principal Components Analyses did not separate susceptible and resistant genotypes with complete accuracy, but further data analyses appear to be promising for the accurate identification of resistant genotypes.

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

Frost hardiness studies

The technique of chlorophyll fluorescence has potential for the identification of stress-resistant genotypes, and it was applied in the examination of the effect of freezing stress in blackcurrant genotypes at flowering time. Genotypes varied in their response as shown previously (*Ann. Rep. 1987*, 90-91), and it was found that the time taken for the variable induced fluorescence to decay to half its maximum value corresponded to decreases in frost hardiness. Further examination of the chlorophyll fluorescence parameters is in progress, as this technique provides a rapid assessment of the spring frost hardiness of genotypes. The relationship between winter and spring frost hardiness requires further investigation.

(R. M. Brennan, R. A. Jefferies[2])

Provide improved germplasm of blackberry and other Rubus fruit [PU 3(c)]

A tetraploid plant of a spine-free mutant of the red raspberry cv. Williamette was crossed with a tetraploid and spine-free blackberry (SCRI 82417A12). All seedlings were spine-free. The bulk of the resulting seedlings were planted in a field for fruit evaluation in 1992. Ten seedlings, selected at random, were grown in the glasshouse, hardened-off and then chilled in a controlled environment chamber to artificially hasten the breaking of dormancy. Most of these plants flowered within 8 months of seed sowing and the best have been used in crosses with cultivars Ashton Cross, Bedford Giant and Silvan.

The large progeny of open-pollinated tetraploid purple raspberries reported previously (*Ann. Rep. 1987*, 94), although predominantly purple fruited, showed considerable variation in fruit colour from red through to black. Several selections, notable for their dark fruit colour, large drupelet and fruit size, high fertility and spineless canes were propagated by leaf bud cuttings. Propagation from root cuttings was not possible due to the non-transfer of the gene sk_1 for suckering from the red raspberry.

(R. J. McNicol)

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

Agrobacterium spp. as vectors of DNA [PU 3(f)]

The development of procedures for the regeneration of leaf discs and internodal segments of *Ribes* made possible the transfer of exogenous DNA into *Ribes* germplasm. This is the first resport of the transfer of exogenous DNA into *Ribes* germplasm. The same binary vector system of *A. tumefaciens* that had been used previously to successfully inoculate *Rubus* with the beta-glucuronidase (GUS) marker gene (*Ann. Rep. 1988*, 84-85) was highly effective with *Ribes* and 10 transformed plants were obtained.

A technique for the regeneration of *Vaccinium* from leaf segments has also been developed but attempts to incorporate exogenous DNA have not yet been successful.

(R. J. McNicol, J. Graham)

NEW STRAWBERRY CULTIVAR

MELODY

The Institute and DAFS have applied for Plant Breeders' Rights for a new strawberry cultivar, Melody, bred at SCRI. A stock is being propagated by the Nuclear Stock Association for release in 1992/93.

Breeder's Number	71WC64
Parentage	Derived from 66M1, a highly red core resistant selection which is a third generation derivative of *Fragaria virginina,* crossed with cv. Senga Sengana.
Yield	Consistently yielded at the same or slightly above the level of cv. Cambridge Favourite. Defoliation has not favourably influenced yield in the year following treatment.
Cropping season	Mid season
Fruit	Small to medium size with exceptionally easy calyx removal even when unripe. Firm textured and of good internal and external colour.
Disease and pest resistance	High degree of field resistance to red core and moderately resistant to *Verticillium* in laboratory tests.
Use	Highly suited to processing (canning, yoghurt and gateau manufacture). Fruit cans well without added artificial dye and the firm textured fruit are ideal where a whole fruit product is required after processing.
Propagation	Runners well

NEW BLACKCURRANT CULTIVARS

The Institute has released two new blackcurrant cultivars, P10/18/116 and P10/18/121. Plant Breeders' Rights have been applied for and stocks are being propagated for commercial sale in 1993/94.

P10/18/116

Parentage	cv. Ben Sarek x cv. Ben Lomond.
Flowering	c. 7 days later than cv. Baldwin at first flower.
Productivity	Usually outyields all other cultivars in trials, including Ben Lomond.
Cropping season	c. 7 days earlier in ripening than Ben Lomond.
Mechanical harvesting	Has been successfully harvested by machine in ADAS trials.
Growth habit	Small bush hybrid with compact habit. Branches often weighed down with fruit, but return to upright position after harvest.
Fruit size	Very large berries borne on medium length strigs.
Use	Not suitable for juice production, but useful for other purposes including jamming.
Disease and pest resistance	Resistant to mildew, leaf spot and highly resistant to leaf-curling midge.

P10/18/121

Parentage	cv. Ben Sarek x cv. Ben Lomond.
Flowering	c. 5-6 days later than cv. Baldwin and slightly earlier than P10/18/116.
Productivity	Very high yielding, usually only slightly outyielded by P10/18/116.
Cropping season	Ripens c.2 days before cv. Ben Lomond, and c. 4 days after P10/18/116.
Mechanical harvesting	Has been successfully harvested by machine in ADAS trials.
Growth habit	Compact bush size in most regions with branch strength similar to P10/18/116.
Fruit size	Very large berries borne on short strigs.
Use	Suitable for a range of uses but not for juice processing.
Disease and pest resistance	Resistant to mildew, leaf spot and leaf-curling midge.

TISSUE CULTURE

W. POWELL

Plant science is now benefiting from basic studies in cell and molecular biology. New research findings are being used to improve our understanding of scientific principles and may also be used in applied agricultural research. These developments are evident in this year's report. During the course of the year the name of the department has been changed from 'Tissue Culture' to 'Cell and Molecular Genetics'. This reflects the Institute's increasing commitment to these new research areas which are also of great interest to local institutes and universities. Research staff are very active in presenting lectures and seminars of their work both nationally and internationally. Links with UK universities have also been strengthened by our post-graduate students. Much of the research reported is multi-disciplinary and both short and long term objectives are being pursued. The continuance of these projects is dependent on adequate levels of funding and the department has been particularly successful in attracting external funding to support the wide research programme.

Several lines of research emphasise the importance of tissue culture in providing a link between whole plant and cellular and molecular approaches to crop improvement. Totipotent protoplast culture systems have been developed for tetraploid, dihaploid and wild potato species. Both intra- and inter-somatic hybrid plants have been generated and characterised by isozyme analysis. Efficient and reliable genetic transformation methods based on *Agrobacterium* Ti and Ri plasmid procedures have been used to transform potato, *Brassica*, tobacco and *Vicia faba* genotypes. These transformation systems are vital for studies on gene expression. The Ac (autonomous) and Ds (non-autonomous) transposable elements have been introduced into potato dihaploids and rapid cycling populations of *Brassica oleracea*. Both excision and re-integration of the maize transposable element has been demonstrated by Southern blot analysis and polymerase chain reaction analysis.

Genetic marker based selection strategies offer great potential in improving the speed and precision of cultivar production and considerable effort has been devoted to the development and exploitation of biochemical and molecular markers. This report includes the first example of the use of protein markers in conjunction with doubled haploids to identify quantitative trait loci (QTL) associated with specified regions of the barley genome.

A major new initiative on the fundamental aspects of gene structure and expression is also reported. Genes coding for components of the machinery responsible for processing pre-mRNAs have been cloned and sequenced. The U1, U2 and U5snRNA multigene families have been isolated from potato and maize genomic libraries. To compare splicing in monocotyledonous and dicotyledonous plants a number of hybrid intron constructs have been inserted both singly and doubly into the zein gene from maize. Transgenic tobacco plants have been obtained and the efficiency of splicing will provide vital information for future crop improvement strategies based on transformation technology.

Cell and tissue culture studies [PU 19(a)(n)]

To combine agronomically useful genetic traits in potato both intra and interspecific somatic hybrid plants have been produced. At the intraspecific level, several dihaploid lines possessing traits such as good tuber yield and shape and disease resistance have been used. Following electrofusion of PDH 40 protoplasts (good tuber shape and yield) with PDH 417 [Potato Cyst Nematode (PCN) resistance] protoplasts; PDH 40 with PDH 724 (foliage blight and PCN resistance) regenerated plants are being screened for hybridity on the basis of isozyme and molecular analyses. At the interspecific level, somatic hybrid plants between a dihaploid line PDH 40 and the wild species *Solanum brevidens* (potato leaf roll virus resistance and cold tolerance) have been produced successfully. Isozyme analysis has demonstrated the expression of both parental esterase isozyme profiles. Both intra and interspecific somatic hybrids are being propagated to facilitate further characterisation at the cytological, biochemical and molecular levels and also to assess field performance.

The availability of homozygous, recombinant doubled haploid families offers many advantages for gene mapping studies. Considerable effort has been devoted to the characterisation of microspore-derived lines of barley. Isozymes and cDNA clones of known function have been used to monitor the stability of regenerants. The level of gametoclonal variability has been shown to be low with only a small proportion (<1%) of the renenerants exhibiting novel biochemical or molecular profiles.

Over 50 microspore-derived lines have been regenerated from F_1 hybrids of the cross cv. Blenheim x TS264 and Blenheim x E224. The parental lines used to generate these populations have been characterised for polymorphism in isozyme and protein banding patterns and restriction fragment length polymorphisms (RFLP). Polymorphism has been detected for six isozyme and protein loci, three RFLP loci and one morphological marker. These markers are located on four of the seven barley chromosomes. The inheritance of alleles at six of these loci did not deviate significantly from the expected 1:1 ratio. Significant deviations from the expected Mendelian ratios were observed for loci located on chromosomes 4H and 6H.

An excess of Blenheim phenotypes was observed where significant deviations from the expected 1:1 ratio were detected. Blenheim is known to be more responsive to anther culture than the other parents tested and the distorted segregation ratios may reflect the preferential survival of gametes containing genes conferring improved response to anther culture.

Green plantlet regeneration from barley microspores was enhanced primarily due to the replacement of sucrose by maltose in the culture medium. This significant finding has promoted further studies on the role of carbohydrate source on flax *in vitro* culture response. Maltose and cellobiose have been found to induce a higher frequency of shoot regeneration from cultured explants than sucrose. The establishment of a well defined and controllable *in vitro* culture system for flax will allow the biochemical and molecular basis of fibre differentiation to be studied.

(D. M. Cawston[1], S. Cooper-Bland, S. J. Finnie[2], S. Millam)

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

Efficient and reliable genetic transformation procedures based on *Agrobacterium* mediated transformation have been developed for a range of species, including potato, flax, Brassica, *Nicotiana* and various leguminous plants. Three potato cultivars: Desiree, Maris Piper and Pentland Squire, together with a dihaploid genotype PDH 505, have been successfully transformed using *Agrobacterium* mediated transformation. In addition, two wild potato species *Solanum stoloniferum* and *S. vernei* have been transformed and the transgenic lines characterised at the molecular level.

Agrobacterium rhizogenes mediated transformation has been used to produce transgenic 'hairy roots' of the potato cultivar Desiree. These transformed roots were inoculated with J2 of *Globodera rostochiensis* pathotype Ro1. Adult males emerged after 3-4 weeks and mating with females occurred. After 8 weeks viable J2 were released by gentle pressure from the eggs of maturing females. This technique enables the production of vigorously growing roots with numerous laterals and it may therefore be suitable for rearing large quantities of sterile nematodes, and for *in vitro* screening of large numbers of susceptible and resistant mutant lines in a programme of transposon mutagenesis designed to locate resistance genes in potato.

Three leguminous plant species: faba bean (*Vicia faba*), lentil (*Lens culinaris*) and chickpeas (*Cicer aeritinum*) have been transformed using *A. rhizogenes*. The LBA 9402 strain of rhizogenes, carrying the Ri plasmid and a binary vector pBin 19 has been used to transform cotyledon and stem tissues. The transgenic nature of the hairy roots has been confirmed by demonstrating their ability to grow on hormone free media and by the expression of the NPT II gene in their roots.

(A. Kumar, P. Whitty, M. C. Coleman[3], G. Ramsay[4], J. M. S. Forrest[5])

[1]Short-term Appointment
[2]Research Student
[3]Potato and Brassica Genetics Department
[4]Cereal and Legume Genetics Department
[5]Zoology Department

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

Genes with unknown products can be cloned by 'transposon tagging'. This is the process of producing insertion mutants using transposable elements in order to identify a gene. We have initiated a research programme of cloning genes from potato, flax and *Brassica* using this method.

A dihaploid potato line PDH 505 in which the H_1 gene conferring resistance to potato cyst nematode (*Globodera rostochiensis* Ro1) is present in the heterozygous condition, has been used to receive the Ac (autonomous) and DS (non-autonomous) elements of maize using *Agrobacterium* mediated transformation. The development of efficient systems for transformation, selection and regeneration of the PDH 505 line has led to generation of a large population of plants carrying the Ac or DS elements. The presence of the Ac or DS elements has been demonstrated in *in vitro* grown transgenic plants by the polymerase chain reaction (PCR). Furthermore, using the PCR it has been demonstrated that the Ac element of maize can excise and in some cases re-integrate in the genomes of these transgenic plants. The DS element of maize has not been seen to excise in the potato genome.

The introduction of the Ac element into the genome of flax with relatively high excision frequency (>25%) has been successfully demonstrated. However, no re-intergration events have been detected amongst the 25 independent transgenic calli analysed. Attempts are being made to regenerate plants from these calli to ascertain whether the flax genome is unique in this respect or whether the re-integration is such a rare event in flax that more transgenic calli/plants need to be analysed.

Transgenic *Brassica oleracea* plants exhibiting Ac excision and re-integration have been obtained. Southern blot analysis is generally used to characterise the presence and integrity of introduced DNA in transgenic plants. This procedure although reliable is labour intensive when large numbers of samples need to be analysed. An alternative method based on the simultaneous amplification of different segments of foreign DNA in transgenic plants using the PCR has been developed and used. Compared to Southern analysis, PCR technology is quicker and does not involve the use of radioisotopes.

(A. Kumar, S. Millam, P. Whitty, L. Wen[1], M. Roberts[2], R. Scott[2], J. Draper[2])

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

The high resolution of the isoelectric focusing (IEF) technique enables the detection of polymorphism between genotypes and this is exploited in pure and applied genetic studies. IEF has been used to characterise spring and winter barley cultivars obtained from standard seed stocks of the National

[1]Visiting worker
[2]University of Leicester

Institute of Agricultural Botany, UK. Seven protein and isozyme systems can be used to uniquely distinguish 23 of the 29 cultivars. The small amount of tissue used, the standardisation achieved between gels and the large number of samples processed in a working day are advantages which can be exploited in commercial varietal identification.

IEF analysis has also been applied to doubled haploid (DHs) families extracted from the F_1 hybrid of the spring barley cross cv. Dissa x cv. Sabarlis. Six isozyme and protein loci examined segregated with an expected 1:1 ratio and two esterase loci on chromosome 3H were mapped intra-chromasomally. The relationship between quantitative gene loci (QTL) and protein markers was also examined: increased yields of DHs were found to be associated with the ∝-amylase-1 phenotype of Sabarlis. The ∝-*Amy-1* gene located on the long arm of chromosome 6H is therefore a potential marker gene for yield in barley.

Superoxide dismutase (SOD) isozymes of potato have been studied both for cultivar identification purposes and in conjunction with a calcium-related physiological disorder project. SOD extracted from potato tubers exhibits a high degree of polymorphism and is therefore of value in genotype identification. SOD, esterases and total water soluble proteins of microtubers show the same characteristic banding pattern asa conventional tubers and can be used to verify genotype identity, this is of particular importance in potato as microtubers usually do not reproduce the diagnostic skin phenotypes of conventionally produced tubers. A positive correlation between the number of SOD isozyme bands as detected by IEF and genotype resistance to internal rust spot was also found. SOD may be involved in protection against internal rust spot which is linked to calcium deficiency.

Restriction fragment length polymorphisms are being used to analyse the genome structure and organisation of barley, potato and *Vicia faba*. Genomic and cDNA libraries have been generated and are being used to assess the level of polymorphism at the nucleic acid level in these organisms.

To establish the degree of polymorphism within *Vicia faba* a survey of 16 *Vicia faba* genotypes and four wild species (from the SCRI collection) has been made. From this study three parents, cv. Optica, 172 and AxBxC have been chosen for the generation of a linkage map based on RFLPs. Over 30 polymorphic markers have so far been identified between AxBxC and 172 and 10-15 between 172 and Optica. Segregating populations from crosses between both pairs of parents are now being screened with these polymorphic probes and other polymorphic markers are being assembled.

(B. P. Forster, D. M. Cawston[1], M. C. Coleman[2], L. S. Talbot[3], R. Waugh, W. T. G. van de Ven[4], E. Baird, G. Ramsay[5])

[1]Short-term appointment
[2]Potato and Brassica Genetics Department
[3]Physiology and Crop Production Department
[4]Research student
[5]Cereal and Legume Genetics Department

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

Research has focused on the wheat/barley disomic chromosome addition lines. These lines carry the complete complement of 21 pairs of wheat chromosomes plus an additional chromosome pair from barley, thus the effect of each isolated barley chromosome can be studied independently. Wheat/*Hordeum vulgare* and wheat/*H. chilense* addition lines have been tested for tolerance to salt (NaCl) and for vigour. Genes with positive effects for salt tolerance were located on chromosomes 4H and 5H of *H. vulgare* and $1H^{ch}$, $4H^{ch}$ $5H^{ch}$ of *H. chilense*. Genes influencing plant vigour were located to homoeologous group 6 and 7 chromosomes of barley.

Waterlogging is another abiotic stress researched in the department. The tolerance of wheat and barley to waterlogging has been correlated with pH changes in the cytoplasm of root cells. Nuclear magnetic resonance (NMR) provides a new non-destructive approach to study initial plant responses to this stress. P31-NMR work has shown that increase in cytoplasmic acidity is more rapid in susceptible crops such as barley than in wheat which can maintain a neutral cytoplasmic pH under waterlogged conditions and the genetic control of acidiosis will be studied using the wheat/barley chromosome addition lines.

The aneuploid stocks maintained in the department have also been used to locate genes influencing milling energy requirement. These genes are located on all 7 chromosome groups of the Triticeae, but with major effects on group 5 chromosomes.

(B. P. Forster, A. Cassidy[1], J. A. Chudek[2], R. P. Ellis[3], B. A. Goodman[4])

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

Cloning small nuclear ribonucleic acid genes

The majority of protein coding genes contain intervening sequences which must be removed from their pre-mRNAs before they are exported from the nucleus into the cytoplasm where translation into proteins can occur. The cellular machinery responsible for these processing events contains both RNA and protein moieties assembled into a range of discreet complexes called small nuclear ribonucleoprotein particles or 'snRNPs'. Three of the four major snRNPs contain a single uridylic acid rich small RNA molecule (U1, U2 and U5snRNAs) while the other contains two (U4 and U6snRNAs). We have cloned and sequenced genes from potato and maize genomic libraries coding for representatives from the U1, U2 and U5snRNA multigene families. The majority of the genes have sequence motifs in their 5′ and 3′ regions which have been shown from studies on

[1]Short-term appointment.
[2]Department of Chemistry, University of Dundee
[3]Cereal and Legume Genetics Department
[4]Director's Group

Arabidopsis and tomato to be essential for expression in plants. At least one of the potato U1 genes appears to be a pseudogene which has arisen by RNA mediated events. RNAse protection assays have shown that some of the cloned U2 genes are expressed in plants. These studies are currently being extended to examine the expression of U1 and U5 genes.

(R. Waugh, P. Vaux[1], D. Leader[1], J. W. S. Brown[1])

Homology between yeast and plant splicing proteins

In addition to the major snRNPs, several other poorly characterised nuclear proteins are essential for the splicing of pre-mRNAs. In yeast, where *in vitro* splicing systems and mutants defective in pre-mRNA processing both exist, two proteins, PRP2 and PRP8, have been cloned and shown to be involved in the splicing reaction. Antibodies raised against the latter protein, PRP8, which is over 200 KD in size, have been shown to detect homologous proteins of a similar size in both humans and *Drosophila*. Currently plant nuclear extracts are being examined to determine whether an immunologically cross-reactive protein of similar size exists in plants.

(G. Simpson[1], R. Waugh, J. W. S. Brown[1], J. Beggs[2])

UsnRNA-based transformation vectors for the delivery of antisense RNAs to plant cell nuclei [PU 19(p)]

Modification of UsnRNAs into vectors for plant transformation

U-type small nuclear RNAs are a class of highly expressed metabolically stable RNAs present in high concentrations in the nucleus of all higher eukaryotic cells. Potato and maize U2snRNA coding sequences have been modified by inserting synthetic oligonucleotides into a unique SauIIIA site located in the region of the RNA thought to interact with the pre-mRNA during the splicing reaction. The synthetic oligonucleotides contain restriction sites to facilitate the rapid insertion of specific DNA fragments which, after transcription, will not be translated into proteins but will accumulate as stable hybrid RNA molecules in the nucleus. The vectors will be assessed for their ability to deliver RNAs to the nucleus either effectively interfering with the expression of a reporter gene (ß-glucuronidase) or with the splicing of an intron containing marker gene previously inserted into the plant (tobacco) genome.

(J. F. Guerineau[3], R. Waugh, J. W. S. Brown[1])

[1]University of Dundee
[2]University of Edinburgh
[3]Short-term appointment

MYCOLOGY AND BACTERIOLOGY

D. A. PERRY

The work of the Department continues to examine the relationships of fungal and bacterial pathogens with their host plants and the nature of host resistance to disease development. A long term objective is to lessen reliance on the use of agrochemicals to control diseases by exploiting intrinsic host resistance mechanisms, improving methods of detecting pathogens in planting stock, understanding the genetic basis of adaptation to new host genotypes, and developing methods of biological control. Basic research into several aspects of pathogenesis is required to achieve this aim and the programme of the Department shows progress in all of these areas.

Blackleg epidemiology and etiology [PU 27(a)]

An antibiotic resistant marker stain of *Erwinia carotovora* ssp. *atroseptica* (Eca) was inoculated to potato plants in the field and two months later it was detected on leaves up to 10 m away both along and across the prevailing wind direction. Progeny tubers of plants within 3 m of the source were also contaminated.

When seed tubers cv. Maris Bard were inoculated with Eca by four different methods, the highest incidence of blackleg was observed following vacuum infiltration of lenticels after blocking the stolon end with vaseline. The other methods in order of effectiveness were stabbing the stolon end with a needle dipped in bacterial suspension, wounding in a concrete mixer and dipping in a mud slurry. Vacuum infiltration was the best method for rapidly inoculating bulks of seed tubers. The experiment confirmed the importance of internal compared with external contamination as inoculum for blackleg development.

Seed tubers were inoculated by vacuum infiltration with Eca strains and strains of *E. carotovora* ssp. *carotovora* (Ecc) alone or together in different combinations. In the field, blackleg incidence caused by Eca was reduced when Ecc was present, presumably because of competition effects in the rotting mother tubers.

(E. M. Burnett, M. C. M. Pérombelon)

Tuber resistance to erwinias [PU 24(i)(r)]

The resistance of several cultivars to tuber rotting by Eca was determined by injection into the cortex, vacuum infiltration of lenticels, and by

deposition on a bruised area of skin followed by incubation at 20°C in air, in N_2 at 100% r.h., and in a mist chamber. The results showed that relative resistance was affected more by inoculation method than by incubation conditions.

(E. M. Burnett, M. C. M. Pérombelon)

The inhibitor of pectate lyase (PL) in extracts from tubers of cv. Record was a 45-48 kDa protein, as determined by electrophoresis and gel filtration, stable for 2 min at 58°C and progressively denatured at temperatures from 60-70°C. It competitively inhibited PL but not polygalacturonase (PG) or alkaline phosphatase.

Filtered extracts from the cortical tuber tissue of two clones with low and high resistance to rotting derived from a protoplasmic fusion hybrid between *Solanum tuberosum* and *S. brevidens* inhibited PL from Eca to the same extent as that from cv. Record. The resistance of the high resistance hybrid clone was maintained when tubers were injected with cell-free PL from Eca but was lessened when a mixture of Eca PL, tomato pectin methylesterase (PME) and a preparation containing PG and pectin lyase (PNL) from *Aspergillus* were injected. A cell wall extract of the resistant hybrid contained 45% more methyl ester groups than that of cv. Record. These results indicated that the hybrid clone resistance was due to the failure of the enzymes produced by Eca to degrade cell wall pectic components because of the high degree of methyl esterification.

(D. Hedley, M. C. M. Pérombelon)

Serology of Erwinia carotovora [PU 27(a)]

The numbers of cells of Eca and Ecc strains detected in pure culture by indirect ELISA ranged from 10^4-10^6 cells/ml and was an order of magnitude less than that obtained with a double antibody sandwich ELISA (DAS) method. Sensitivity of both methods was decreased by the presence of tuber peel extract. Attempts to improve sensitivity by changing the test protocols were unsuccessful and it was concluded that determination of Eca population numbers in potato peel extract at or below a threshold level of 10^3 cells/ml for blackleg development could not be achieved by ELISA.

The specificity of antiserum raised against live Eca cells for Eca was better than that raised against dead cells in indirect ELISA. It was improved further when the antiserum was absorbed against live cells and supernatants from sonicated cells of strains of Ecc serogroups II and III. Adsorbing antiserum raised against the lipopolysaccharides (LPS) of Eca serogroup I with an Ecc serogroup III strain also increased the specificity for Eca but reduced the sensitivity to both Eca and Ecc.

(L. J. Hyman, A. McLeod, M. C. M. Pérombelon)

Molecular genetics of pathogenicity of E. carotovora [PU 24(h)(n)]

Cellulase was produced by Eca SCRI 1043 only in a medium containing carboxymethyl cellulose; it was cell-bound and unaffected by temperature. In contrast, production of polygalacturonase (PG) was shown to be 3-6 times greater at 27 than at 30.5°C in pectate minimal medium as demonstrated previously (*Ann. Rep. 1988*, 104) for pectate lyase (PL) production. Additional work showed that both synthesis and secretion of PL and PG were affected by temperature.

(P. Lanham, M. C. M. Pérombelon)

Molecular genetics of the regulation of pectic enzyme secretion in Erwinia carotovora [PU 24(n)]

Several mutants of Ecc SCRI 193 obtained by transposon mutagenesis were avirulent on potatoes due to their inability to secrete pectate lyase and cellulase while retaining the ability to secrete protease (pel^- cel^- prt^+). Complementation of the mutants, using a cosmid gene bank of SCRI 193, was achieved with a 14 Kb region of the genome and random transposon insertional mutagenesis with Tn*phoA* of the 14 Kb region was carried out to define the regulatory region of the *out* gene cluster. Initial screening of mutants expressing a marker enzyme to study the expression of individual *out* genes has indicated that a regulatory site is present.

(S. Wharam[1], G. P. C. Salmond[1], M. C. M. Pérombelon)

Exploitation of novel erwinia phages

In addition to phage Økp capable of generalised transduction in Ecc SCRI 193, two other phages were isolated from sewage which were able to perform generalised transduction in Eca SCRI 1043.

A phage resistant mutant of SCRI 1043 with a reduced virulence phenotype on potato stems had similar pectic enzyme production, growth rate *in vitro* and nutrient utilisation (including iron) to that of the wild type. SDS-PAGE analyses of the outer membrane proteins of the mutant showed that the banding pattern was similar to that of the wild type but some lipopolysaccharide bands were absent. Increased sensitivity of the mutant to 0.1% SDS and 0.1% EDTA was further evidence for an alteration in cell wall structure. When tested on tobacco leaves, the mutant, unlike the wild type, was unable to elicit a hypersensitive reaction.

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

Inhibition of erwinia protease [PU 24(i)]

A protocol for the purification of an extracellular metalloprotease from Ecc has been worked out using ion-exchange columns. Two isozymes were detected with pH optima of 8.0 and 9.2. Resistance of potato to rotting by

[1]University of Warwick

Ecc was not associated with a chymotrypsin inhibitor as it did not inhibit the proteases *in vitro*.

Experiments with *Phytophthora infestans* have failed to detect extracellular protease suggesting that factors involved in environmental control of gene expression have not been optimised.

(J. Heilbronn, G. D. Lyon)

Host pathogen recognition between potato and erwinias [PU 24(o)]

A rapid technique was developed for the preparative purification of unsaturated oligogalacturonides released from polygalacturonic acid by Ecc PL using a TSK DEAE-5PW column on an HPLC eluted with a linear gradient over 160 min from 0 to 0.25M NaCl with sodium acetate buffer. Baseline separation of oligogalacturonides containing between 2 and 26 uronic acid residues was achieved. For preparative work up to 160 mg oligogalacturonides could be separated.

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

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

Leaflets of three potato cultivars grown in controlled conditions were inoculated with *Phytophthora infestans* and incubated at 10 or 20°C. Fungal growth was determined by ELISA. At 10°C growth of *P. infestans* in leaflets of the quantitatively resistant cultivars Shelagh and Teena was slow, while those of Bintje were extensively colonised. At 20°C both Bintje and Teena were extensively colonised, while the resistance of Shelagh was similar to that exhibited at 10°C, demonstrating an interaction between the expression of horizontal resistance and temperature.

ELISA was also used to improve quantification of the reaction of R-gene differential genotypes to pathogenic populations of the fungus.

(J. G. Harrison, R. Lowe)

Immunological methods for detecting fungal pathogens [PU 27(c)]

Potato roots infected with plasmodia of *Spongospora subterranea* were used to raise an antiserum for use in ELISA to detect soil borne infection in roots of bait plants. Antibodies to the root tissue were removed by cross-absorption with an extract from healthy roots. Although plasmodia in heavily infected roots were detected by ELISA, the titre of the gamma-globulin was too low to detect low levels of infection.

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

[1]Short-term appointment

Antagonistic activity of fungi towards potato pathogens [PU 23(f)]

Roots of axenic potato plants, cv. Maris Piper in steam-sterilised compost became infected with *Colletotrichum coccodes*, *Rhizoctonia solani* and *Polyscytalum pustulans* but not with *Helminthosporium solani* following inoculation. Good control of infection by *P. pustulans* was achieved by simultaneous inoculation with *Trichoderma viride* or *Penicillium expansum*. When plants were grown in field soil, the incidence of infection was lower than in compost. *T. viride* was still effective against *P. pustulans* in field soil, whereas *P. expansum* was not. Some isolates of *Trichoderma* spp. and *Penicillium* spp. grew well on agar at 5°C and could be potential antagonists in cold storage conditions.

When cultures of *T. viride*, *Gliocladium viride* and *P. hirsutum* were applied to seed potato tubers which had been subjected to hot water treatment for 5 min at 55°C (HWT) and inoculated with *P. pustulans* and *H. solani*, *T. viride* and *G. viride* reduced the incidence of both pathogens in HWT tubers. In untreated tubers, the antagonists reduced the incidence of *P. pustulans* but not of *H. solani*.

HWT controlled *H. solani* when it was in a latent form but not when extensive symptoms were visible on the tubers. Sclerotia of *C. coccodes* and *R. solani* present on extensively injured tubers remained viable after treatment.

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

Polygalacturonases of Botrytis cinera associated with post-harvest grey mould of soft fruits [PU 24(j)]

B. cinerea was cultured in a pectin-containing liquid medium and extracellular filtrates subjected to preparative liquid-phase isoelectric focussing. Two isozymes of polygalacturonase (PG) were detected with pI values of 4.6 and 8.6 and designated PGI and PGII respectively. PGII was purified by FPLC and HPLC and a protein of *c* 38 kDa with endo-polygalacturonase activity and temperature and pH optima of 37°C and 4.7 respectively was obtained. A single band was revealed on SDS polyacrylamide gels by silver staining and a polyclonal antiserum raised to the protein was shown to be specific to PGII in a Western blot.

PGI isozyme was found to be a 41 kDa protein with exo-PG activity and temperature and pH optima of 49°C and 4.0 respectively.

(B. Williamson, D. J. Johnston)

Downy mildew (Peronospora rubi) of Rubus cane fruits [PU 9(i)]

The relative susceptibility of 18 Rubus fruits to downy mildew was examined on leaf disks in an *in vitro* study and in a polyethylene tunnel experiment. Leaf disks of Tummelberry, Boysenberry and Tayberry and red raspberry cv. Leo were most susceptible; raspberry cultivars Glen Prosen, Glen Moy,

Malling Delight and Glen Clova and blackberry cv. Aurora were intermediate; and blackberry cultivars Silvan, Loch Ness and raspberry cultivars Malling Jewel, Glen Lyon, Heritage and Autum Bliss were least susceptible. No sporulation was seen on blackberry cultivars Ashton Cross, Bedford Giant and Marion.

The ranking of cultivars following exposure to sporulating infected plants in a polytunnel was similar, except for blackberries which were more susceptible in the tunnel than in the *in vitro* study, with slight sporulation occurring on Bedford Giant, Marion and Ashton Cross.

Peronospora sparsa which causes downy mildew of roses, is morphologically identical to *P. rubi* and rose cv. Can Can exposed to *P. rubi* alongside the *Rubus* cane fruits in the polytunnel became infected. When authentic isolates of *P. rubi* and *P. sparsa* were inoculated to leaf disks of Tummelberry and rose, more infection occurred with *P. rubi* on Tummelberry and with *P. sparsa* on rose than on the alternative hosts, but sporulation occurred in all combinations. Inoculum of *P. sparsa* from roses therefore could infect cane fruits at the weaning stage following *in vitro* propagation (Ann. Rep. 1988, 113-114).

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

Screening for resistance to raspberry root rot [PU 3(a)]

Twenty selections from the *Rubus* genetics programme were inoculated with the pathogenic *P. megasperma* in pot tests. A number of selections from East Malling, including Autumn Bliss, were shown to have some resistance to root rot. Inoculation tests on 240 seedlings from resistant parents confirmed that cv. Latham was a good source of resistance.
(D. M. Kennedy, R. J. McNicol[2], V. Knight[3], P. H. Scott[4], J. M. Duncan)

Epidemiology and control of raspberry root rot [PU 9(a)(j)]

The number of new root rot outbreaks in Scotland increased in 1989 and the highly pathogenic *P. megasperma* type was isolated from most of them. A wet and cool summer was followed by a mild winter providing soil conditions conducive to infection for most of the year. Many of the new outbreaks could have been due to movement of the fungus in the ground water.

Isolates of the pathogenic *P. megasperma* from root rot outbreaks in the British Isles, continental Europe and N. America were compared morphologically and physiologically with other non-papillate *Phytophthora* spp. The isolates were most similar to *P. fragariae* in respect of sporangial and oospore size, cardinal temperatures, appearance and growth rates but were not pathogenic to strawberry except for a few rotted root tips with

[1]School of Biological Sciences, University College of North Wales
[2]Soft Fruit Genetics Department
[3]IHR (East Malling)
[4]Short-term appointment

with oospores in some pot tests. Whole protein electrophoretic patterns of the pathogenic *P. megasperma* from N. America and Europe supported the observations that it was a homogeneous group distinct from other *Phytophthora* spp. but most closely related to *P. fragariae*.

A polyclonal antiserum raised to *P. megasperma* detected the fungus in infected root material in 1/10000 dilutions. It reacted most strongly with *Phytophthora* spp. but did not distinguish between species within the genus. Antiserum raised to specific bands from whole protein extract separated on polyacrylamide gel and cross-absorbed with other *Phytophthora* spp. also failed to distinguish *P. megasperma* from the other species.

In a continuation of the field trial of fungicides to control root rot (*Ann. Rep.* 1988, 111), oxadixyl plus mancozeb gave significantly better control than metalaxyl plus copper oxychloride and four further trials have been established in co-operation with ESCA.

In pot tests, although mancozeb and oxadixyl applied singly reduced the level of disease compared to untreated plants, greatest control was achieved when they were applied in combination. Calcium peroxide had no effect on root rot, even when combined with a fungicide. The level of disease control obtained with fungicides was less in pots where the soil had been compacted before treatment compared with non-compacted soils.

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

Measurement of total mildew per leaf and colony biomass using ELISA techniques [PU 28(e)]

An antiserum raised against *Erysiphe graminis* was used in an ELISA to provide an objective method of selecting for partial resistance to mildew in field grown progeny.

Flag leaves and leaves immediately below the flag leaf of quantitatively resistant genotypes were inoculated with *E. graminis* in controlled conditions. Measurements of infection frequencies and fungal biomass by ELISA were used to identify genotypes for further testing. Flag leaves had consistently larger biomass per colony than the sub-tending leaf which was only partly accounted for by higher infection frequencies.

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

Stability of expression of partial resistance and mildew aggressiveness [PU 27(i)]

Isolates of mildew varied in aggressiveness towards partially resistant barley genotypes over time and single spore derivatives of an isolate showed similar variability after multiple generations of subculture. There was an overall trend towards increased aggressiveness when isolates were continuously grown on partially resistant genotypes.

[1]Short-term appointment
[2]Cereal and Legume Genetics Department

Variation in the expression of partial resistance was affected by both the pre- and post-inoculation environment of the host and by the isolates of mildew.

(A. C. Newton)

The effects of mixtures of partially resistant cultivars on yield of spring barley [PU 27(i)]

In field trials, mixtures of barley cultivars with major genes for resistance to mildew generally showed lower levels of infection and yield increases compared with the cultivars grown singly. However, most mixtures of cultivars containing partial resistance of WPBS origin plus either a defeated or an effective major gene had increased levels of mildew infection but yields still increased. Mixtures containing partial resistance of SCRI origin alone sometimes had reduced levels of mildew infection with increased yield. There was a relationship between high susceptibility and yield loss due to mildew with yield advantage in mixtures of partially resistant genotypes, in contrast to major gene mixtures. Many factors not attributable to resistance phenotype such as inter-plant competition and yield compensation contributed to mixtures effects.

(A. C. Newton, W. T. B. Thomas[1])

Induction of host resistance by yeast extracts [PU 24(n)]

Several yeast extracts protected detached barley leaves against infection by powdery mildew (*Erysiphe graminis* f.sp. *hordei*) in proportion to their ability to elicit phytoalexins in a biossay. The extracts modified papilla size (one aspect of the resistance mechanism to mildew) on detached leaves.

In the field, the yeast extracts reduced mildew infection on three spring barley cultivars and increased thousand grain weight although the magnitude of the effects varied between cultivars.

(T. Reglinski[2], A. C. Newton, G. D. Lyon)

Molecular genetics of Rhynchosporium secalis and Puccinia spp. [PU 24(h)]

A DNA library was prepared from a brown rust isolate and was screened for clones which showed polymorphisms. A further library was prepared from *R. secalis* and Southern blots made for probing. The karyotype of *R. secalis* is being characterised using orthogonal field agarose gel electrophoresis and three bands have been observed.

(A. C. Newton, J. M. Smith[3])

[1]Cereal and Legume Genetics Department
[2]Short-term appointment
[3]Research Student

Microbial activity in arable soil [PU 23(b)]

When potatoes, cv. Maris Piper, were grown in soil to which nitrogen, as NH_4NO_3 with or without a carbon source, had been added, very little mineral-N could be detected immediately after application. The concentration of mineral-N increased prior to haulm emergence, particularly in the absence of a carbon source. Most of the mineral-N was nitrate and vulnerable to loss by leaching or denitrification and the addition of carbon therefore had an environmentally desirable effect. Addition of carbon to the soil had no effects on plant dry matter yield or nitrogen content. Biomass carbon and respiration were stimulated by the addition of sucrose for 20 days after application but fertilisation had no effect on the microbiological parameters. Crop growth did not stimulate total microbial biomass or activity and there was no residual effect of any of the crop treatments on the biomass. The potential nitrification rate was high early in the season and declined as the plants developed. The potential denitrification rate showed a peak in activity coinciding with the development of new roots and a second during root senescence. Measurements suggested that the amount of carbon released by potato plants was only a quarter of that required for maximum microbial activity.

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

Quantitative isolations of bacteria made from the rhizosphere of potato plants in the field throughout the growing season showed that the numbers of colony forming units in rhizosphere soil were generally an order of magnitude greater than those in surrounding soil and that approximately one third of the bacteria in both situations could denitrify nitrate in *in vitro* studies.

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

ZOOLOGY

D. L. TRUDGILL

The value of applying the techniques of molecular biology to zoological problems has been demonstrated. Two races of aphid, previously indistinguishable except for the difference in their virulence on resistant raspberry cultivars, have been shown to differ at a molecular level. Also, progress has been made in detecting variation in the DNA complement of potato cyst nematode populations which differ in virulence and which might derive from separate introductions from South America. The long-term aim is to identify the genes and mechanisms associated with virulence and avirulence.

In entomology, the work on host recognition and resistance mechanisms has shown that raspberry volatiles are involved in host recognition by raspberry beetle and in resistance to the large raspberry aphid.

Development and application of RFLP analysis to a range of pest species [PU 24(k)]

Restriction fragment length polymorphism (RFLP) analysis is a useful means of studying variation in pathogen DNA. It is being used to identify the distinct introductions of PCN from South America into Europe as a basis for classifying populations. *G. rostochiensis* (pathotype Ro 1), *G. pallida* pathotype Pa 1 and *G. pallida* pathotype Pa 2/3 were distinguished readily on the basis of variations in abundant repetitive DNA sequences and, by using a range of endonucleases, differences were detected between populations within the Pa2/3 group in which a Scottish population able to overcome the resistance of cv. Morag was the most distinct. Variation in less abundant, non-repetitive sequences were examined by treating nematode DNA with endonucleases and hybridising it with a labelled DNA probe. Using a heterologous probe consisting of a region of the M13 bacteriophage genome, further differences were detected between pathotypes and between populations within the Pa 2/3 virulence group.

RFLP analysis has also been used to distinguish biotypes of the large raspberry aphid *Amphorophora idaei* which previously could only be identified by differences in their ability to colonise raspberry genotypes containing specific major resistance genes. Although no differences in repetitive DNA sequences were seen with the restriction endonucleases used, probing Southern blots of digests with the M13 probe revealed differences between populations belonging to different biotypes.

(M. A. Catley, B. E. Harrower, M. S. Phillips, A. N. E. Birch)

Production of antibodies to plant parasitic nematodes [PU 24(a)(g)(p)]

Antibodies raised to juveniles of potato cyst nematode (PCN) bind to the cuticle surface (*Ann. Rep.*, 1988, 123) but they are rapidly shed by live juveniles, suggesting that the surface antigens may also be shed as is known to occur with animal parasitic nematodes.

An immunologically based screen for resistance using stage-specific monoclonal antibodies to PCN has been developed. Within 14 days of invasion, numbers of J2 and later stages can be assayed, providing a rapid indication of whether the nematodes have developed and therefore whether the plant is susceptible or has major gene (H_1) resistance.

Saliva injected into plants by nematodes and which induces characteristic feeding syncytium/giant cells may contain RNA. Using a monoclonal antibody[1] specific for brominated uracil, RNA has been demonstrated within the oesophageal bulbs of *Xiphinema index* at light microscope level. However, not all bulbs were labelled and the pattern of labelling within the bulb varied according to which portion had been sectioned.

Narcissus pseudonarcissus agglutinin (NPA) has been stated to be specific for the sugar mannose and shown to bind to the amphidial exudate of PCN juveniles (*Ann. Rep.* 1988, 123). However, when NPA was isolated and purified, binding was blocked by the disaccharide melibiose. In collaborative tests, NPA, which is highly specific for (α-1,3) linked mannosyl residues, prevented HIV-infection of cells *in vitro* by binding to viral envelope glycoprotein[2].

(J. M. S. Forrest, H. J. Atkinson[3], K. Backett, J. Robb, D. Stewart)

Studies on resistance breaking populations of Meloidogyne [PU 24(k)]

Observations on six populations of *Meloidogyne* morphologically indistinguishable from *M. incognita*, but able to overcome resistance to *M. incognita* in several crops, showed that the arrangement of chromosomes during prophase, some isozyme patterns and general morphometrics were indistinguishable from those of *M. incognita*. However, the phenotype of other isozymes differed from those of *M. incognita* and some monoclonal antibodies prepared to *M. incognita* bound to the populations but others did not. Tests with a series of specific strains of a bacterial parasite, *Pasteuria penetrans*, also revealed differences even within the resistance breaking group. The esterase phenotype of the virulent populations was indistinguishable from *M. myagyensis*, and it is tentatively suggested that these populations, and *M. myagyensis*, should be regarded as belonging to an *M. incognita* group of related species.

(M. Fargette, K. Davies[4], M. Robinson[4], D. L. Trudgill)

[1]From G. Harms, Department of Pathology, University of Groningen
[2]W. E. G. Müller, Department of Molecular Biology, University of Mainz
[3]Department of Pure and Applied Zoology, University of Leeds
[4]Institute of Arable Crops Research, Rothamsted Experimental Station

Epidemiological aspects of potato-cyst nematodes (Globodera spp.) in the Canary Islands [PU 24(k)]

South American varieties of potato grown in the north of Tenerife and the Canary Islands may have been a first stepping stone in the spread of potato cyst nematode (PCN) into Europe. A survey in Tenerife has shown that *G. pallida* was found mainly in the south of the island where H1 resistant cultivars (Cara and Red Cara) were commonly grown. Both *G. pallida* and *G. rostochiensis* occurred, sometimes as mixed populations in the north.

A morphological study of 36 populations revealed substantial and consistent differences in the mean values and in the variances associated with some characters, especially in *G. pallida*. However, discriminant analysis based on population means produced two main groups representing the two species that was confirmed by electrophoresis of soluble proteins, isoelectricfocussing and by female colour. Applying stepwise discriminant analysis to the data for single cysts showed that most could be identified to species with a high probability. Granek's distance "A" (distance between anus and nearest ridge to fenestra) was of little value for discriminating species.

(J. Gonzales-Peres, M. S. Phillips)

Integrated control of potato cyst nematodes (PCN) using nematicides and potatoes with quantitative resistance [PU 27(d)(l)]

The integrated control of *Globodera pallida* was investigated from 1987 to 1989 by treating plots of cv. Maris Piper (susceptible) and cv. Morag (quantitatively resistant) with the recommended rate or half rate of aldicarb or leaving untreated.

Although the initial infestation was high (c. 100 eggs per g soil) the aldicarb treatments had no effect on yield in the first year and the populations in the untreated plots of Maris Piper increased to 350 eggs/g at the end of 1987 and to 1100 eggs/g at the end of 1988. In 1989 the population of *G. pallida* on the untreated Maris Piper fell to c. 480 eggs/g of soil following heavy crop damage exacerbated by a dry growing season and yields were less than half that following the full rate of aldicarb. The half rate also increased yields but in 1989 it was less effective than the full rate. However, the full rate did not prevent the population from slightly increasing.

Populations of *G. pallida* in the untreated plots of cv. Morag were not increased in 1987 but increased three-fold in 1988, following a vigorous, high yielding crop. In 1989 the population was slightly decreased. Yields in the aldicarb treated plots yields were slightly increased (7-15%) in 1988 and 1989 and both rates of aldicarb reduced populations, with the full rate being most effective. Alternating Morag and Maris Piper with a half rate of aldicarb failed to prevent either the population increasing or yield losses.

Treating Morag with the full rate of aldicarb will reduce high populations of *G. pallida*, especially if combined with a rotational gap and the half rate will also prevent increase of lower populations, provided there is a 2 or 3 year gap between potato crops. However, any susceptible cultivars within a rotation would still require the full rate of aldicarb to prevent population increases.

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

Mechanisms of cultivar tolerance to potato cyst nematodes [PU 27(d)(l)]

An agronomic study was made of reasons for the tolerance of PCN damage of cv. Cara and the relative intolerance of cv. Pentland Dell at a field site with plots encompassing a range of population densities of *Globodera pallida*. Shoot growth of both cultivars in the first month was similarly decreased by increasing numbers of *G. pallida*. However, Cara produced 25% more leaf area than Pentland Dell per g dry matter invested in the top. Consequently, Cara grew more rapidly than Pentland Dell and still achieved 100% ground cover by mid July in the most heavily infested plots. In contrast, Pentland Dell never exceed 75% ground cover in the heavily infested plots.

Dry matter productivity was directly related to the effects of nematode damage on ground cover and was similarly decreased in both cultivars until early July. Thereafter, the productivity of Cara on heavily infested plots was similar to that on the lightly infested plots while that of Pentland Dell was always less on the heavily compared with the lightly infested plots. Consequently, the maximum decrease in tuber yield for Cara and Pentland Dell was 16% and 44% respectively.

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

The transmission of serological variants of tobraviruses by (Para)Trichodorus species [PU 25(m)(s)]

Last year it was reported that serologically distinguishable strains of tobacco rattle virus (TRV) are specifically transmitted by different (*Para*)*Trichodorus* species (*Ann. Rep. 1988*, 118). However, populations of trichodorids frequently occur in mixtures of several species and at some sites only one of the species, which may be only 5% of the total population, was capable of transmitting TRV. At others, two or more species each transmitted a serologically distinct strain of TRV. Generally, with nematodes from the field only 5 to 15% of the individual nematodes within each vector species transmitted virus but the efficiency was increased from c.15 to c. 70% if nematodes were given prior access to the appropriate strain of virus. However, approximately 60% of the individuals of a monospecific population of *P. teres* from the Netherlands transmitted virus. The results may explain the lack of correlation between sites with large populations of trichodorid nematodes and the incidence of diseases caused by TRV.

In a study with population of *P. pachydermus* from the Netherlands, Sweden and Scotland, all of which naturally transmitted virus which reacted with PRN antiserum, only isolates of tobraviruses of the PRN-serotype were transmitted. There were, however, differences in the efficiency of transmission and the type strain and one isolate from Denmark were not transmitted by any of the populations. Although studies such as this indicated a high degree of specificity between virus serotype and nematode species, recently it was shown that populations of *P. anemones* and *T. similis* could acquire and transmit a virus isolate previously transmitted by the other species. Similarly, *T. primitivus* from Scotland and *T. viruliferus* from the Netherlands both transmitted virus which reacted with an antiserum prepared from the RQ-strain of TRV.

(D. J. F. Brown, A. T. Ploeg, D. J. Robinson[1], C. Asjes[2], C. Vanderperre[3])

Migratory plant-parasitic nematodes associated with cereals in Scotland [PU 8(c)]

Soil samples from 98 cereal farms contained 26 species of plant-parasitic nematodes. *Longidorus elongatus* was recovered from 60% of the samples with an average of 29 nematodes/200 g soil. Populations were greatest in fields recently under grass. Extrapolation of field trial results indicated an average loss of 0.27 t/ha on fields where longidorid nematodes were present. Populations of other parasitic nematode species were usually small and individually unlikely to cause economic losses.

Analysis of the relationship between the different nematode species showed that there were no significant interactions and that interspecific competition, predation by other nematodes and the soil factors measured were not important factors limiting nematode distribution and population size.

(B. Boag, S. Bowen[4], A. M. Spaull[4], G. McN. Wright[5], B. F. L. Smith[6])

Behavioural studies on raspberry insects [PU 24(a)]

In experiments using a dual choice, T-shaped, "linear track" wind tunnel olfactometer adult raspberry beetles (*Byturus tomentosus*) clearly discriminated flowers of raspberry and several other *Rubus* species, with 5-10 times as many turning towards the source of raspberry flower odour. However, compared with humidified air they were equally attracted to odour from flowers of strawberry and lime but not from flowers of *R. phoenicolasius* and *R. tricolor* or oilseed rape. Beetles also moved towards the source of ether extracts from raspberry flowers.

---

[1]Virology Department
[2]Flowerbulb Research Institute, Lisse, The Netherlands
[3]Katholieke Universiteit, Leuven, Belgium
[4]Crop Protection Division, ESCA
[5]Physiology and Crop Production Department
[6]MLURI, Aberdeen

In contrast, alate *A. idaei* failed to discriminate between non-host (Chinese cabbage), host (raspberry cv. Malling Jewel) and humidified air. However, apterous adult *A. idaei* showed clear responses to host leaf volatiles in a four-chambered Petterson design (low flow rate) olfactometer and more aphids walked towards leaf volatiles from Malling Jewel than from Chinese cabbage. Also, apterous *A. idaei* preferentially walked towards host leaf volatiles from the susceptible Malling Jewel compared to the resistant Autumn Bliss in the same apparatus.

When aphids were placed on the upper leaf surface of Malling Jewel they walked rapidly to the lower leaf surface, settled and began to probe. On Autumn Bliss, however, they repeatedly moved from upper to lower leaf surface, settling was delayed and aphids spent a greater proportion of time walking and a smaller proportion stationary or probing, compared with those on Malling Jewel. The removal of their antennae did not alter aphid behaviour on Malling Jewel but on Autumn Bliss they spent less time walking and settled sooner.

(J. A. T. Woodford, A. N. E. Birch, S. C. Gordon, D. R. Jones[1], L. J. Wadhams[2])

Resistance to Macrosiphum euphorbiae infestation in raspberry genotypes differing in resistance to Amphorophora idaei [PU 24(d)]

Large populations of *Macrosiphum euphorbiae*, a vector of at least one *Rubus* virus, were observed in a field trial containing raspberry genotypes with different resistance genes to *A. idaei*. Differences in susceptibility to *M. euphorbiae* were observed with resistance in some genotypes containing major resistance to *A. idaei* genes. Cv. Glen Clova, which has moderate resistance to *A. idaei* due to minor genes, showed some resistance to *M. euphorbiae* suggesting that the minor genes in Glen Clova may be effective against both forms.

(A. N. E. Birch, M. R. Cormack[3], A. T. Jones[4])

Observations on the grazing of double low oilseed rape and other crops by roe deer [PU 4(u)]

Excessive intake of double low oilseed rape has been associated with the death of roe deer in Germany, probably caused by S-methyl cysteine sulphoxide (SMCO) poisoning. To determine if the introduction of double low cultivars might produce a similar problem in the UK, observations of

[1]Visiting research student, Wye College
[2]Institute of Arable Crops Research, Rothamsted Experimental Station
[3]Soft Fruit Genetics Department
[4]Virology Department

the feeding preferences of roe deer were made 2-3 hours after sunset at sites with a range of different crops. In January deer had a significant preference for oilseed rape and winter barley but in February and March they fed mainly on the winter barley. Chemical analyses of the double low cv. Cobra revealed significant increases in the concentrations of individual glucosinolates over the study period which may have made it progressively less palatable.

(B. Boag, W. H. Macfarlane Smith[1], D. W. Griffiths[2])

[1]Potato and Brassica Genetics Department
[2]Chemistry Department

VIROLOGY

B. D. HARRISON

Among the most important and interesting features of plant viruses are their mechanisms of transmission by vectors. A combination of biological, molecular and ultrastructural approaches has made substantial progress towards the elucidation of several of these mechanisms. The probable site of retention of particles of parsnip yellow fleck virus was identified in the foregut of vector aphids. In a system involving the attachment and detachment of particles of a tobravirus on the oesophagus wall of vector nematodes, the importance of the virus particle surface was implied by the observed specificity of transmission of different serotypes of tobacco rattle virus by different species of trichodorid nematode. In the circulative transmission of geminiviruses, the role of specific features of the particle surface was suggested by a study of the epitopes which are conserved in different viruses that have the same whitefly vector. In circulative transmission of potato leafroll luteovirus by aphids, circumstantial evidence was obtained that a newly discovered virus particle protein, produced by readthrough of the coat protein gene, may have a key function. However, perhaps the most remarkable finding was that the circulative transmission of groundnut rosette virus by aphids depends on the presence in source plants not only of groundnut rosette assistor luteovirus, but also of the satellite RNA of groundnut rosette virus.

Other progress includes the production and use of monoclonal antibodies to potato mop-top furovirus, establishment of the extent of antigenic relationships among the 'pinwheel' proteins of potyviruses, determination of the nucleotide sequence of RNA-3 of raspberry bushy dwarf virus, detection in plants and intracellular localisation of the 16K non-structural protein of tobacco rattle tobravirus, and recognition of several non-structural virus-coded proteins in protoplasts infected with tomato black ring nepovirus.

Expression of the P5 gene of potato leafroll luteovirus (PLRV) [PU 25(d)]

The P5 gene of PLRV is an open reading frame that is immediately 3′ of the coat protein gene. Circumstantial evidence suggests that the P5 gene is expressed by readthrough of the termination codon of the coat protein gene (*Ann. Rep. 1988*, 160). An antiserum (anti-P5), made to part of the P5 amino acid sequence, reacted with a polypeptide with an apparent Mr of 90000 (P90). P90 accumulated during PLRV multiplication in protoplasts

Inheritance and effect of ability to restrict potato leafroll luteovirus (PLRV) multiplication in potato [PU 13(j)]

The genetic control of the ability to restrict PLRV concentration in leaves was examined by testing the progeny of reciprocal crosses between the susceptible cv. Maris Piper and the resistant clone G7445(1) using a quantitative ELISA technique. Among 40 genotypes from the progeny, about half had a low PLRV concentration in plants with secondary infection and the other half had a high concentration, suggesting that resistance is controlled by a major gene in a simplex state.

(H. Barker)

Tubers of two cultivars and six SCRI clones, infected in the previous year with PLRV, were planted within a field crop of cv. Maris Piper (a cultivar which is susceptible to infection) to provide infectors with high, medium and low concentrations of PLRV. Large numbers of alate *Myzus persicae* colonised the crop shortly after emergence in late May. By 12 June, all plants were infested, and exceptionally high populations (exceeding 2000/plant) were recorded on 27 June. PLRV spread extensively (up to 94% infection) in plots which contained infectors with high concentrations of PLRV. In contrast, spread was 3- to 11-fold less in plots containing low-concentration infectors and 1.5- to 6-fold less in plots with intermediate-concentration infectors. The low level of infection (4%) in guard areas between plots suggests that most infections resulted from movement of vectors within the plots.

(H. Barker, J. A. T. Woodford[1])

Outbreaks of barley yellow dwarf luteovirus (BYDV) in cereals [PU 25(g)]

Symptoms resembling those of BYDV were unusually prevalent in the spring in cereal trials at SCRI. Eight virus isolates from winter barley were tested by ELISA using monoclonal antibodies which distinguish between three types of BYDV (MAV, PAV, RPV). Seven isolates were of the MAV type and one reacted weakly both with antibodies to MAV and with antibodies to PAV.

(A. T. Jones, L. Torrance)

Role of satellite RNA in luteovirus-dependent transmission of groundnut rosette virus by aphids [PU 25(a)]

Transmission of groundnut rosette virus (GRV) by *Aphis craccivora* depends on the presence in the source plants of a luteovirus, groundnut rosette assistor virus (GRAV). All plants naturally infected with GRV contain several species of dsRNA including a 0.9 kbp dsRNA which is the ds form of a satellite RNA. However, satellite-free isolates can be produced

[1]Zoology Department

experimentally. The satellite RNA of GRV is the main cause of rosette symptoms in groundnut and different variants of the satellite cause the green and chlorotic forms of rosette.

GRAV-dependent transmission of GRV by *A. craccivora* occurred in the glasshouse only from groundnut plants infected with satellite-containing isolates of GRV regardless of whether the GRV isolates came from Nigeria or Malawi, were from plants with the green or chlorotic forms of rosette, or contained homologous or heterologous satellites. Aphid transmission of GRV therefore depended not only on the presence of GRAV but also on that of the GRV satellite RNA. This probably explains why satellite-free isolates of GRV have not been found in nature.

(A. F. Murant)

Nucleotide sequence of raspberry bushy dwarf virus (RBDV) RNA

[PU 25(b)]

RNA-3 is the smallest RNA component of RBDV and encodes the virus coat protein (*Ann. Rep. 1984*, 182). The nucleotide sequencing of this RNA was completed. Terminal sequences were determined by reverse transcription using synthetic oligonucleotide primers and by partial enzyme hydrolysis of end-labelled RNA. The putative coat protein gene encodes a polypeptide of Mr 30509, which coincides with the coat protein Mr estimated by polyacrylamide gel electrophoresis. In gene content, RBDV RNA-3 thus resembles the coat protein-encoding RNA-4 species of ilarviruses, cucumoviruses and alfalfa mosaic virus. The lengths of its non-coding sequences are 26 nucleotides at the 5′ end and 73 nucleotides at the 3′ end; the 3′ non-coding sequence can be folded into a highly base-paired structure.

(M. A. Mayo, C. A. Jolly, A. F. Murant, J. H. Raschké)

Previous work (*Ann. Rep. 1984*, 182) showed that the 2.5 kb RNA-2 of RBDV was translated *in vitro* to yield a Mr 46 000 polypeptide which accounted for half the coding capacity of the RNA. Further analysis of RNA-2 indicated that its 3′ half comprises the same nucleotide sequence as RNA-3. In contrast, the 3′ ends of RNA-2 and RNA-3 share a sequence of only about 20 nucleotides with RNA-1. This explains the lack of reaction in Northern blots between RNA-1 and cDNA to sequences near the 3′ end of RNA-3.

(T. Natsuaki[1], M. A. Mayo, C. A. Jolly, A. F. Murant, J. H. Raschké)

Nucleotide sequencing of raspberry ringspot nepovirus (RRV) RNA

[PU 25(j)(n)]

Analysis of the sequences of cloned cDNA obtained by priming reverse transcription at the 3′ termini of RRV RNA showed that cDNA had been

[1]Visiting Worker

derived from both of the genome RNA species. Further cloning using synthetic oligonucleotides to prime reverse transcription has yielded cDNA clones representing at least 95% of the 4 kb RNA-2 molecule. The nucleotide sequence of the 3′ 70% of RNA-2 was found to contain one continuous open reading frame which ends 397 nucleotides from the start of the poly(A) tail. In RNA-1 (8 kb), the sequence of the 383 3′-terminal nucleotides (excluding the poly(A)) was identical to that of the 383 terminal nucleotides of 3′ non-coding sequence in RNA-2 but differed from other known nepovirus sequences. However, the amino acid sequence encoded by the 3′ terminal part of the open reading frame in RRV RNA-2 includes two short peptides which are conserved almost unchanged in four nepoviruses.

(V. Blok[1], M. A. Mayo, C. A. Jolly, D. J. Robinson)

Expression of tomato black ring nepovirus (TBRV) RNA in tobacco protoplasts [PU 25(b)]

The genome of TBRV consists of two RNA species which can each be translated *in vitro* to yield a single large polypeptide. Functional proteins probably arise from these polypeptides by proteolytic cleavage. Analysis of the amino acid sequences has suggested where these cleavages might occur and most of the presumed products have been detected *in vitro*. In tobacco protoplasts infected with TBRV, three products derived from the RNA-1 polyprotein were detected by immunoblotting: a Mr 90 000 putative polymerase, a Mr 24 000 putative protease and a polypeptide comprising both these proteins. Similarly, two products of cleavage of the RNA-2 polyprotein were detected, the Mr 57 000 coat protein and a Mr 46 000 putative transport protein. These proteins were also detected as TBRV infection-specific polypeptides by analysing ^{35}S-methionine-labelled polypeptides by one- and two-dimensional polyacrylamide gel electrophoresis. Mr 68 000 and 50 000 products, thought to be derived from the RNA-1 and RNA-2 polyproteins respectively, were also detected. The results confirmed that TBRV-specific proteins arise in infected cells by proteolysis of precursors and that the products predicted from *in vitro* translation studies are made *in vivo*.

(G. Demangeat[2], M. A. Mayo)

Isolates of cherry leaf roll nepovirus (CLRV) occurring in areas of forest decline [PU 25(b)]

Isolates of CLRV from diseased beech* and birch* trees in an area with forest decline near Bonn, West Germany, were found to be serologically closely related and distinct from ten other CLRV isolates from different

[1]Short-term Appointment
[2]Institut de Biologie Moleculaire des Plantes, Strasbourg
*Held under DAFS licence

natural hosts and from various countries. Serologically, the German beech isolate was closest to English isolates from walnut and birch, and the German birch isolate was closest to an English cherry isolate and a Finnish isolate from *Sambucus racemosa*.

(A. T. Jones, R. Koenig[1])

Detection of tobacco rattle tobravirus (TRV) non-structural protein in infected tissue [PU 25(b)]

The genome of TRV codes for several non-structural proteins, including one of Mr 29 K and another of Mr 16 K. Two synthetic peptides were prepared, corresponding to a 14 amino acid sequence at the C-terminus of the 29 K protein and a 20 amino acid sequence near the C-terminus of the 16 K protein. Antisera were raised which reacted specifically with their eliciting peptides in ELISA. The anti-29 K serum reacted in ELISA and in immunoblots with a bacterial fusion protein produced by coupling the 29 K protein gene to a truncated ß-galactosidase gene, and specifically precipitated a product of *in vitro* translation of RNA transcribed from the 29 K protein gene. However, it did not react with extracts from infected *Nicotiana clevelandii* leaves or protoplasts, nor was any reaction with ultrathin sections of infected leaves detected by immunogold labelling and electron microscopy.

In contrast, the anti-16 K serum detected a protein of the expected size in immunoblots of extracts from systemically infected *N. clevelandii* leaves that was tightly bound to a sub-cellular structural component. The amount of 16 K protein, found in systemically infected leaves at different times after inoculation, was proportional to the amount of TRV particle protein present. The anti-16 K antibody did not bind to purified TRV particles or to virus particles in ultrathin sections of infected leaves, but detected the 16K protein in the cytoplasm and, especially, the nucleus by immunogold labelling.

(D. Liu[2], G. H. Duncan, D. J. Robinson, B. D. Harrison)

Infection of leaf trichomes by microinjection with tobacco rattle tobravirus (TRV) [PU 25(p)]

A method was devised of injecting individual cells of leaf trichomes of *Nicotiana clevelandii*. The molecular weight exclusion limit for movement of injected fluorescein-labelled peptides through the plasmodesmata linking trichome cells was approximately 850 daltons. Following injection of TRV particles into single cells, approximately 70% of injected leaves became infected, showing the versatility of the method.

(P. M. Derrick[2])

[1]Institut für Viruskrankheiten der Pflanzen, Braunschweig, W. Germany
[2]Short-term Appointment

Serological variation among tobacco rattle tobravirus (TRV) isolates [PU 25(b)]

TRV isolates are serologically very diverse and although clusters of similar isolates can be recognized, the extent of cross-reactions between them depends on the kind of test used. Six serotypes have been distinguished using $F(ab')_2$ ELISA, in which cross-reactions are minimal. 1) PRN serotype, including strain PRN, isolated from potato from Scotland, and isolates from six other countries; where known, their vector is the nematode *Paratrichodorus pachydermus*. 2) Oregon serotype, including *P. teres*-transmitted isolates from the USA and The Netherlands. 3) SYM serotype, represented by a single isolate from England. 4) RQ serotype, including *Trichodorus primitivus*-transmitted isolates from Scotland and England. 5) B2-8 serotype, represented by *T. cylindricus*-transmitted isolates from one site in Scotland. 6) Greek serotype, represented by an isolate from Greece. Isolates transmitted by *P. anemones* and *T. similis* did not react with any of the antisera, and may represent further serotypes. In addition, two serotypes have been recognized that are probably natural recombinant isolates which contain the coat protein gene of either of two serotypes of pea early-browning tobravirus. The range of serotypes of TRV is therefore greater than previously recognised, and different vector species are associated with the different virus serotypes.

(D. J. Robinson)

Monoclonal antibodies to potato mop-top furovirus (PMTV) [PU 25(g)]

Ten monoclonal antibodies (MAbs) specific for PMTV were produced. Four reacted well in indirect sandwich ELISA in which anti-PMTV polyclonal antibodies were used to trap PMTV from infective sap, and they each detected all nine isolates of PMTV from Britain, Northern Ireland, Sweden, Finland and Denmark. PMTV was detected in infected leaves of *Nicotiana benthamiana* and potato by coating microtitre plates with one MAb and using a biotin-labelled second MAb followed by streptavidin-alkaline phosphatase to detect trapped virus. When PMTV coat protein was analysed by electrophoresis, a major band of Mr *c.* 22 000 and several minor bands were detected. All ten MAbs reacted in electro-blot immunoassays of denatured purified PMTV coat protein and also with the minor bands.

(L. Torrance)

Cloning of genomic nucleic acid of potato mop-top furovirus (PMTV) [PU 25(k)]

RNA extracted from PMTV particles which were purified from infected *Nicotiana debneyi* or *N. benthamiana* plants contained three species with approximate sizes of 6.4 kb (RNA-1), 3.0 kb (RNA-2) and 2.5 kb (RNA-3).

In vitro translation experiments with the RNA produced a protein of Mr *c.* 22 000, similar to that of the virus coat protein. A cDNA library of unfractionated PMTV RNA was made in a lambda phage expression vector and screened with PMTV antibodies to detect clones expressing coat protein fusion proteins. A clone of 83 base pairs, which was isolated and sequenced, hybridized on Northern blots to PMTV RNA-2, indicating that RNA-2 contains the coat protein gene. Part of the amino-acid sequence encoded by this small clone resembles a sequence in the particle protein of beet necrotic yellow vein furovirus.

(K. P. Scott[1], B. Reavy)

Site of retention of parsnip yellow fleck virus (PYFV) in vector aphids [PU 25(a)]

PYFV depends on anthriscus yellows virus (AYV) for transmission in a semi-persistent manner by the aphid *Cavariella aegopodii*. *C. aegopodii* carrying both viruses were sectioned and the PYFV antigen located by its reaction with PYFV antibody and an immunogold probe (15 nm diam.). In aphids that were embedded immediately after leaving the source plant, numerous virus-like particles (VLP) were found throughout the lumen of the foregut; these were not labelled with PYFV antibody and were assumed to be particles of AYV. However smaller clumps of granular material were labelled specifically with the PYFV probe, indicating the presence of PYFV antigen; as in plants (*Ann. Rep. 1988*, 179), it seems that particles of PYFV did not survive the embedding and fixation procedures in recognisable form. In aphids which were allowed to feed for 2-3 h on 10% sucrose after leaving the source plant, the lumen of the foregut was almost empty and specific labelling for PYFV was confined to the pad of mucus-like material on the ventral wall of the foregut close to the tentorial bar where, as reported previously, the VLP were also found. This area appears to be the site of retention of particles of PYFV, as well as those of AYV.

(I. M. Roberts, A. F. Murant, E. W. Milne)

Monoclonal antibodies to parsnip yellow fleck virus (PYFV) [PU 25(g)]

Purified particles of isolate A421 of PYFV were used for the production of monoclonal antibodies. The cell culture supernatant fluids obtained from the hybridomas produced were screened against virus isolates A421 and P121 by ELISA and electro-blot immunoassay. Cell lines were identified that secreted antibodies which showed differences in reactivity with these virus isolates, and 15 cell lines were cloned.

(K. T. Natsuaki[2], L. Torrance, A. F. Murant)

[1]Research Student
[2]Visiting Worker

Occurrence of cucumber mosaic cucumovirus (CMV) satellite RNA in Spain [PU 25(c)]

The prevalence of CMV and the incidence of associated satellite RNA were surveyed in Spanish crops. Leaf samples were tested for CMV by ELISA using polyclonal and monoclonal antibodies, and satellite RNA was detected by spot hybridization tests using a cloned cDNA probe. CMV was detected in cucumber, melon, pepper, squash, tobacco and tomato crops in five provinces and some antigenic variation was found among the samples. About 25% of CMV-infected samples contained satellite RNA, including plants of cucumber, melon, tobacco and tomato. Most satellite-containing tomato plants were affected by a necrotic disease.

(E. A. Murant[2], J. Romero[1], B. D. Harrison)

Genetic engineering of resistance to cucumber mosaic cucumovirus (CMV) [PU 25(c)]

Satellite-free isolates of CMV from Spain caused prominent mosaic symptoms when transmitted to control tobacco plants but only transitory symptoms in satellite-transformed plants. Similar results were obtained with Price's yellow strain of CMV, originally obtained from the United States. Satellite-transformed plants have not developed obvious symptoms when infected with any satellite-free isolate in tests during the past 4 years. Satellite-mediated transgenic tolerance of CMV infection was expressed both at 28-30°C and at lower temperatures. It seems unlikely to be overcome readily in field conditions.

(E. A. Murant[2], B. D. Harrison)

Epitopes on the particle protein of potato V potyvirus (PVV) [PU 25(q)]

The epitopes of PVV detected by monoclonal antibodies (MAbs) were either conformation-sensitive and located on the virus particle surface, or sequence-specific and not on the particle surface. Putative sites of four epitopes of the second type were indicated by results of immunoblotting tests with fragments of PVV particle protein and by comparisons of reactions of potyvirus isolates that have particle proteins with known amino-acid sequences. The sites were predominantly in hydrophilic regions of the trypsin-resistant core polypeptide, suggesting they are on the surfaces of protein subunits but inside the virus particle. The putative site of one of the epitopes, which is shared by many potyviruses, was confirmed by the reaction of the corresponding MAb with a synthetic hexapeptide.

(M-J. Farmer[2], B. D. Harrison)

[1]Instituto Nacional de Investigaciones Agrarias, Madrid
[2]Short-term Appointment

Specificity and reactivity of antisera to the cytoplasmic inclusion and coat proteins of potyviruses [PU 25(i)]

An antiserum prepared to the cytoplasmic inclusion protein (CIP) of potato virus Y (PVY) detected five out of 11 other potyviruses in plate trapped antigen ELISA whereas eight were detected with an antiserum to PVY coat protein. Four viruses, alstroemeria mosaic, bean yellow mosaic, potato V and tulip chlorotic blotch, were detected by both antisera. These limited results suggest that, in the type of test used, antisera to CIP may be more discriminating than those to virus coat protein, and may have potential for clarifying the complex pattern of relationships among potyviruses.

(W. P. Mowat, S. Dawson, G. H. Duncan)

Addition of the surfactant Tween 20 to the extraction buffer was necessary to detect narcissus yellow stripe virus using homologous CIP antiserum in dot-blot ELISA (*Ann. Rep. 1988*, 181). Tween 20 also improved detection of PVY with CIP antiserum. When antisera to virus coat protein were used, Tween 20 was required for detection of narcissus latent and narcissus late season yellows viruses, was disadvantageous for detecting PVY, and prevented detection of tulip chlorotic blotch and turnip mosaic viruses.

Dot-blot ELISA was superior to $F(ab')_2$-ELISA for detecting narcissus late season yellows and narcissus latent viruses in narcissus leaves using antibodies to the virus coat proteins.

(W. P. Mowat, S. Dawson)

Field spread of aphid-borne narcissus viruses [PU 11(a)]

When virus-free narcissus plants were grown for 2 years within commercial plantings of infected stocks, the proportion that became infected by narcissus late season yellows virus (NLSYV) depended on the cultivar. Cultivars King Alfred (65% infection) and Golden Harvest (40%) were the most susceptible, Corinthian, Barrett Browning and Fortune were less susceptible, and Carlton and Red Goblet were not infected. However, Carlton was not immune because extracts from 15% of plants in two out of four commercial stocks reacted with NLSYV antiserum in ELISA and contained potyvirus-like particles which were detected by immunosorbent electron microscopy.

(W. P. Mowat, S. Dawson)

Immunogold labelling of virus particles in thin sections [PU 25(h)]

Purified virus particles of differing morphologies were pelleted by high speed ultracentrifugation and then fixed, either with glutaraldehyde alone, or with glutaraldehyde followed by a second fixation with osmium tetroxide. After embedding in Araldite resin, ultrathin sections of the virus-containing pellets were mounted on nickel grids and exposed to

homologous antiserum followed by immunogold labelling. In general, pellets fixed with glutaraldehyde alone gave a much greater density of label than those fixed with osmium. However, sections of particles of narcissus mosaic or tulip X potexviruses labelled well irrespective of the method of fixation. Rod-shaped or filamentous virus particles labelled best when they were aligned at a shallow angle to the surface of the section. Among viruses with isometric particles, areas of pellets containing degraded particles of tomato black ring nepovirus or parsnip yellow fleck virus labelled as well as did areas containing well preserved particles.

(I. M. Roberts)

Characterization of the genome of solanum apical leaf curling geminivirus (SALCV) [PU 25(b)]

SALCV* has particles resembling those of geminiviruses, except that most are trisegmented not bisegmented; its vector is unknown. Nucleic acid extracted from preparations of purified particles was shown by enzyme digestion experiments to be single-stranded DNA, with circular molecules having a contour length equivalent to 3.1 kb. Nucleic acid extracts stimulated incorporation by reverse transcriptase of dATP into polynucleotide without the addition of a primer, suggesting that the particles contained an oligonucleotide that acted as a primer, a characteristic of leafhopper-transmitted, but not of whitefly-transmitted geminiviruses. More efficient conversion of single-stranded to double-stranded DNA was achieved using an oligonucleotide complementary to a short sequence common to all sequenced geminiviruses. A molecule of about 3.15 kb pairs was produced and this was cleaved by endonuclease Bam HI to give two fragments of *c.* 1.42 and 1.68 kb pairs. This result suggests that the genome of SALCV consists of one species of DNA, as do those of the leafhopper-transmitted geminiviruses, whereas those of the whitefly-transmitted geminiviruses consist of two species of similar size.

(Y. Hong[1], D. J. Robinson)

Cloning and nucleotide sequencing of Indian cassava mosaic geminivirus DNA [PU 12(c)]

Virus-specific DNA was isolated from plants infected with Indian cassava mosaic virus (ICMV)* and three species, covalently closed circular double-stranded, open circular double-stranded, and single-stranded, were detected. However, as yields of the double-stranded species were low and attempts to clone them were unsuccessful, single-stranded DNA from ICMV particles was made double-stranded, using a synthetic oligonucleotide

[1]Short-term Appointment
*Held under DAFS licence

primer complementary to a short sequence conserved in all sequenced geminivirus genomes. The product was digested with endonuclease EcoRI and the fragments cloned. The sizes and restriction maps of the resulting clones suggest that they included all the sequences of the ICMV genome. Initial sequence information indicates that some parts of the ICMV genome are similar to those of other whitefly-transmitted geminiviruses, especially African cassava mosaic virus and mungbean yellow mosaic virus, but no homology was found in other parts, indicating that ICMV is a distinct geminivirus.

(Y. Hong[1], D. J. Robinson)

Antigenic constitution of whitefly-transmitted geminiviruses from India [PU 12(a)]

Tests with panels of monoclonal antibodies to African cassava mosaic virus (ACMV) and Indian cassava mosaic virus (ICMV), confirmed that most Indian geminivirus isolates† examined were more closely related antigenically to ICMV than to ACMV. Bhendi yellow vein mosaic virus was closely related to ICMV, and tobacco leaf curl and croton yellow vein mosaic viruses were antigenically indistinguishable from each other. Isolates of the croton virus from different places in India differed slightly in antigenic constitution. Indian tomato leaf curl virus, previously thought to be a strain of tobacco leaf curl virus, was found to be antigenically distinct, but isolates from different tomato crops in Karnataka State were very similar.

(M. M. Aiton[1], V. Muniyappa[2], B. D. Harrison)

Epitope profiles of whitefly-transmitted geminiviruses from different continents [PU 12(a)]

The epitope profiles were established of a range of whitefly-transmitted geminiviruses† from the Americas, the Mediterranean area and Thailand by testing their reactions with monoclonal antibodies (MAbs) to African cassava mosaic (ACMV) and Indian cassava mosaic (ICMV) viruses. Viruses obtained from bean, cotton, cucurbits, pepper or tomato from Brazil, Colombia, Dominican Republic, Guatemala, Mexico, Puerto Rico or the United States reacted with several MAbs to ACMV but with few to ICMV. Isolates† from tomato and watermelon from Israel, Sardinia or Yemen gave reactions resembling those of East African isolates of ACMV while a tomato geminivirus† from Thailand gave reactions which somewhat resembled those of Indian tomato leaf curl virus. It was concluded that

[1]Short-term Appointment
[2]University of Agricultural Sciences, Bangalore
†Imported under DAFS licence

virus isolates associated with similar diseases of tomato in Mexico, Mediterranean countries, India and Thailand have different epitope profiles whereas those occurring in other crops in the same geographical area mostly have similar profiles.

(M. M. Aiton[7], Y. Antignus[1], J. K. Brown[2], J. C. de Faria[3], G. P. Martelli[4], D. Rochester[5], B. D. Harrison)

Geminiviruses† were identified serologically in several naturally infected wild plants from Nigeria, but none of them closely resembled ACMV.

(M. M. Aiton[7], G. Thottappilly[6], B. D. Harrison)

Properties and transmission of okra leaf curl geminivirus (OLCV) [PU12 (a), PU 12(c)]

OLCV* was transmitted by whiteflies (*Bemisia tabaci*) to okra, *Althaea rosea*, *Malva crispa* and *M. sylvestris*, and with difficulty to *Nicotiana benthamiana* but not to *Gossypium hirsutum*. All hosts developed leaf curl and vein thickening symptoms. Okra cultivars differed in reaction to OLCV but symptom severity was not proportional to virus concentration. The geminate particles of OLCV were serologically related to those of several other whitefly-transmitted geminiviruses and were purified in small amounts. OLCV is closely serologically related to African cassava mosaic virus, sharing at least 13 of its 18 known epitopes.

(K. P. N'Guessan[8], P. F. McGrath[7], B. D. Harrison)

OLCV was detected by a specially adapted penicillinase-based ELISA in viruliferous *B. tabaci*. Females contained more virus than males although the virus content varied considerably between individuals. OLCV could be detected in some *B. tabaci* caged on infected plants for 24 h and, in insects allowed longer acquisition access periods, it remained detectable for at least 10 days after they were removed from the virus sources.

(P. F. McGrath[7], B. D. Harrison)

---

[1]Volcani Center, Israel
[2]University of Arizona, Tucson, USA
[3]University of Wisconsin, Madison, USA
[4]University of Bari, Italy
[5]Washington University, St Louis, USA
[6]International Institute of Tropical Agriculture, Ibadan, Nigeria
[7]Short-term Appointment
[8]Visiting Worker
†Imported under DAFS licence
*Held under DAFS licence

Properties of cassava Ivorian bacilliform virus (CIBV) [PU 12(a)]

Although CIBV particles are only weakly immunogenic, an antiserum was obtained that trapped particles effectively in immunosorbent electron microscopy and detected as little as 6 ng virus/ml in double antibody sandwich-ELISA. CIBV was found in several cassava samples from the Ivory Coast, frequently together with African cassava mosaic virus but, when transmitted to *Nicotiana benthamiana*, neither virus affected the concentration of the other. All five isolates tested, including one that caused only faint symptoms in systemically infected leaves of *Chenopodium quinoa*, were detected readily by ELISA. CIBV resembles alfalfa mosaic virus (ALMV) in particle morphology and may belong to the same taxonomic group but CIBV antiserum gave little or no reaction with ALMV.

(D. Fargette[1], B. D. Harrison)

Properties of wineberry latent virus (WLV), a possible cause of calico disease in blackberry [PU 9(d)]

The flexuous filamentous particles of WLV were found to measure 620 x 12 nm and not, as previously reported, 510 x 12 nm. In indirect ELISA, WLV particles in plant extracts or purified preparations failed to react with antisera to twelve potexviruses, nine carlaviruses, three capilloviruses or apple chlorotic leafspot closterovirus. Also, in immunosorbent electron microscopy, no reaction was detected between WLV and several of these antisera. When graft inoculated with a field culture of WLV mixed with raspberry bushy dwarf virus (RBDV), but not with RBDV alone, blackberry cultivars Marion and Olallie developed line-pattern symptoms typical of calico, a disease of unknown etiology reported from the USA.

(A. T. Jones, W. J. McGavin, I. M. Roberts)

New virus from Bedford Giant blackberry [PU 9(d)]

A virus was mechanically transmitted from an apparently symptomless plant of Bedford Giant blackberry to a range of herbaceous plants in the Chenopodiaceae. In *Chenopodium amaranticolor* and *C. quinoa*, it induced faint chlorotic local lesions followed a few days later by a faint mottle and epinasty in uninoculated leaves. Sap of infected *C. quinoa* lost infectivity after dilution to 10^{-3}, or storage at 22°C for 24 h or at 4°C for 2 days. Infectivity of *C. quinoa* sap was abolished following treatment with *n*-butanol or 10 mM EDTA but not with 50% diethyl ether or 50% chloroform. The virus infected *Rubus occidentalis* symptomlessly and has not been reported previously in *Rubus* in Britain.

(A. T. Jones, W. J. McGavin)

[1]Visiting Worker

Analysis of double-stranded RNA from Ribes [PU 9(h)]

In studies of reversion and other virus-like diseases of *Ribes*, apparently healthy plants were tested for the presence of dsRNA. Of more than 42 cultivars of black, white and red currant, and gooseberry, only eight, most of which were recently introduced cultivars of black currant, lacked dsRNA. The most prominent dsRNA species detected were in the Mr range $1.5 \times 10^6 - 5.5 \times 10^6$.

(A. T. Jones, K. Knoll[1])

Double-stranded RNA associated with spider mites infesting strawberry [PU 9(g)]

Some extracts of strawberry leaves gave anomalous dsRNA profiles, which were unlike those associated with June Yellows and contained 10-12 components of Mr $1.0 - 2.7 \times 10^6$. These dsRNA components came from two-spotted spider mites (*Tetranychus urticae*), which were infesting some of the plants. They may represent parts of the genome of a mite-infecting virus, possibly a reovirus. No evidence was obtained that the plants became infected with this agent. Large concentrations of about 10 dsRNA species were also found in extracts from a single unidentified leafhopper on a strawberry plant in the field.

(C. A. Watkins[2], A. T. Jones)

The effect of heat treatment and meristem-tip culture on June Yellows (JY) in strawberry [PU 9(g)]

Cambridge Favourite strawberry plants affected by JY were subjected to combinations of heat treatment and meristem-tip culture, known to eliminate some viruses from tissues. However, none of 397 propagants derived from treated plants was freed from JY. Indeed, all propagants showed more obvious JY symptoms than the parent plants, suggesting that the treatment may be useful for detecting incipient JY in symptomless strawberry stocks.

(C. A. Watkins[2], R. J. McNicol[3], K. Young[3], A. T. Jones)

[1]Visiting Worker
[2]Short-term Appointment
[3]Soft Fruit Genetics Department

PHYSIOLOGY AND CROP PRODUCTION

H. M. LAWSON

The work of the Department has continued to undergo considerable modification in response to changes in emphasis, staff retirals and staff realignment within the core-funded programme, to the gradual withdrawal of public funding for "near-market" research and to opportunities offered by alternative sources of funding. The Soil Microbiology Group was transferred from the Mycology and Bacteriology Department and integrated into the Roots, Soils and Simulation Group to form a new Soil-Plant Dynamics Group.

Following the recommendation by the Visiting Group, the Department was renamed the Cellular and Environmental Physiology Department and now consists of four groups — Cell Physiology, Environmental Physiology, Soil-Plant Dynamics and Weed Ecology.

Research progress has been maintained in many areas of plant, crop and environmental physiology and the continuing change in emphasis from applied areas of research towards more basic work is apparent in the following report. Nevertheless, the Department retains the ability and expertise to carry out research across the whole spectrum from basic to applied research on a wide range of topics.

POTATO

Agrometeorology of the potato crop [PU 26(a)]

A data base was compiled containing information on cropped areas, yields, husbandry practices, seasons for production, maturity classes and cultivars grown, soil types, timing of operations, and constraints on production in each of the countries of the European Economic Community from information provided by Ministries of Agriculture, crop advisers and specialists, and by scientific contacts. A bibliography of the physiology, agronomy and pathology of the potato was extended and used in a review of quantified relations between the crop and its environment. A small database of known mathematical models of the growth and development of the potato and of disease development was assembled.

(D. K. L. MacKerron)

The role of Artificial Intelligence in potato production [PU 26(b)]

Mathematical models of crop development and growth usually ignore uncertainty surrounding the empirical relations upon which they were built and qualitative information which cannot be represented mathematically.

Also, much information is inaccessible when a model is implemented in a standard programming language such as FORTRAN or PASCAL. A modular model of factors which affect size distribution of potato tubers, from pre-planting to pre-harvest, has been developed using Goldworks II on an IBM PC to overcome some of these problems. In this new approach, the system (or model) is defined first, without prior knowledge of the specific questions, although the solution depends on the problem lying within the knowledge domain.

(B. Marshall, J. Smart[1], J. W. McNicol[2])

Relation of photosynthesis to nitrogen supply in potato [PU 22(g)]

Potato yields in a field experiment increased as the amount of nitrogen fertiliser applied increased up to the equivalent of 360 kg N ha^{-1}. Measurements of the light saturated rate of photosynthesis made on leaves either at a fixed position on a first level branch or the youngest measurable leaf at the top of the canopy showed that few, if any, leaves were produced above the fixed position when no nitrogen was applied. In contrast, branching continued to second and third order at the higher rates of nitrogen so that leaves at the fixed leaf position became increasingly shaded. The relation between the light saturated rate of photosynthesis and nitrogen concentration in the leaf was linear and there was a critical nitrogen concentration at which photosynthesis ceased. The critical concentration increased systematically with rate of nitrogen application. At the fixed leaf position, leaf nitrogen declined most rapidly at the higher application rates, consistent with nitrogen being relocated to newly expanding leaves.

(B. Marshall, J. Vos[3])

Modelling the balance of advantage in characters for drought tolerance [PU 22(g)]

Potato genotypes differ in their sensitivity to drought. Some of the more sensitive e.g. cv. Cara and cv. Kingston have the largest root systems. A model has been devised to test the effect of modifying plant characters, such as epidermal conductance, lethal relative water content, root hydraulic conductivity and rooting extent within the ranges found experimentally in order to quantify the changes in the water and carbon economies of the plant that would follow from different combinations of characters.

(D. K. L. MacKerron, A. G. Bengough)

[1]Short-term Appointment
[2]SASS
[3]Department of Field Crops and Grassland Science, University of Wageningen

Drought tolerance is dependent on the balance between root and shoot characters [PU 26(j)]

Both root and shoot production were influenced by watering regime in 24 potato genotypes and generally root production was least under drought. Partitioning of dry matter between shoot and tuber was altered by treatment but root dry matter was a conservative fraction. Reductions in stomatal conductance, caused by water-stress, differed between genotypes. Epidermal conductance did not differ between genotypes but the effect of watering treatment and its interaction with genotype were statistically significant. Lethal values of relative water content (RWC) occurred at the same points of insertion in all genotypes but the associated levels of RWC differed between genotypes.

(D. K. L. MacKerron, Z. Y. Peng[1])

Genotypic variation in potato leaf growth in response to water-stress [PU 26(j)]

Drought reduced the final area of leaves in all of 24 cultivars examined but there was a significant interaction between treatment and genotype because drought reduced leaf area more in some cultivars than in others. The relation between leaf growth rate and soil moisture deficit (SMD) also showed significant differences between genotypes. The critical SMD at which leaf growth was affected by water-stress varied from 11 mm for cv. Desiree to 41 mm for cv. Kingston.

(R. A. Jefferies)

Effects of water-stress on the kinetics of chlorophyll fluorescence in potato [PU 26(j)]

The effects of water-stress on chlorophyll fluorescence were examined in seven potato genotypes which were either fully irrigated or droughted from the time of plant emergence. Fluorescence declined with increasing time from emergence more rapidly in droughted than in irrigated plants and the rate of decline was cultivar dependent. Fluorescence values were significantly correlated with leaf water potential but genotype had no significant effect. However, genotype did affect the rate of fluorescence decay and its relation to leaf water potential. These results suggested that drought affected photosynthetic activity by reducing photochemical quenching and by promoting the decline in the light harvesting complex and that genotypes varied in their ability to maintain photosynthetic activity when droughted.

(R. A. Jefferies)

[1]Research Student

Purification of potato tuber acid invertases [PU 26(c)]

Acid invertase is believed to regulate sucrose hydrolysis and modify hexose levels in stored potato tubers. Total enzyme activity was eluted in a preliminary preparative step from S-Sepharose (cation exchange), followed by a further preparative step on Phenyl-Sepharose (hydrophobic interaction). Active fractions were subjected to anion exchange on Q-Sepharose (pH 6.5) and two peaks of activity resolved. The first peak was purified further on a glycoprotein affinity column. The M_r was approximately 30kD. The second form of invertase had a pI of c. 5.6, almost identical to patatin, making further purification by ion exchange difficult. However, use of a metal chelating Sepharose column resulted in a major protein band on SDS-PAGE (M_r approximately 58kD).

(L. Burch[1], H. V. Davies, H. A. Ross)

Effect of sink removal on sugar uptake and starch synthesis by potato tuber storage parenchyma [PU 26(d)]

In discs isolated from rapidly-growing tubers attached to plants, 77% of supplied ^{14}C glucose was converted to starch within 3 h compared with 64% and 27% for ^{14}C fructose and sucrose, respectively. The values fell as tubers aged but a similar ranking was maintained, demonstrating the presence of a rate-limiting step following the import of sucrose. Tuber removal had little effect on the ability of the storage cells to take up exogenous sucrose across the plasmalemma for up to 7 days after sink removal. However, the ability of the same cells to convert sucrose to starch was inhibited within 24 h, as was the sensitivity of starch synthesis to turgor. Sink removal inhibited both the uptake of glucose and conversion to starch. A metabolic study of excised tubers showed that sucrose synthesis was an alternative carbon sink when starch synthesis was inhibited, sucrose synthase and ADPG-pyrophosphorylase activities decreased following sink removal, while other enzymes were unchanged. Acid invertase activity increased fivefold.

(K. J. Oparka, H. V. Davies, K. M. Wright[1], R. Viola[2], H. A. Ross, D. A. M. Prior)

Hexose partitioning in potato tubers [PU 26(d)]

A large proportion of D-glucose or D-fructose taken up by sink tuber discs was converted to starch but showed, in common with sucrose, a marked sensitivity to tissue turgor, suggesting that turgor sensitive steps were common to all three pathways of starch synthesis. In source tissue there was very little conversion of either D-glucose or D-fructose to starch. The uptake kinetics obtained for D-glucose and its non-metabolised analogue

[1]Short-term Appointment
[2]Research Student

3-oxymethyl-D-glucose, suggested that the uptake of D-glucose in both sink and source tissue was partly carrier mediated. In contrast, the uptake kinetics obtained for D-fructose suggested that either the transport of D-fructose was not carrier mediated, or the carrier was not acting in source tissue.

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

Molecular changes associated with tuber formation [PU 26(e)]

A number of quantitative and qualitative changes in polypeptide profiles were observed coincident with the first visible signs of tuberisation following 2D SDS-PAGE separation of total protein extracts from stolon tips at various stages during the tuberisation process. Immunoblotting with monoclonal antibodies raised against ∝ and ß tubulin showed changes in the expression of ∝ and ß tubulin isozymes as the stolen tip starts to tuberise. At later stages of tuberisation, gene expression was dominated by patatin isoenzymes.

Changes in protein phosphorylation patterns during tuberisation were demonstrated and calmodulin antagonists (chlorpromazine, fluorperazine) were shown to inhibit tuber formation reversibly.

(M. A. Taylor, H. V. Davies)

Regulation of hexose accumulation in potato tubers [PU 26(m)]

When discs excised from tubers of cv. Brodick and cv. Record previously stored for 2 months at either 3 or 15°C were incubated at the storage temperature with either U-^{14}C glucose, U-^{14}C glycerol or 1-^{14}C ribose, high percentages of glucose and ribose were incorporated into starch. At the low temperature, a higher percentage of label was incorporated into starch in Brodick compared with Record. The percentage of metabolised ^{14}C glucose and ribose recovered in sucrose was increased by low temperature storage in Record but reduced in Brodick.

The results indicated that starch turnover may regulate cold temperature sweetening. Incorporation of 1-^{14}C ribose into starch and sucrose indicates the presence of a potentially active pentose phosphate pathway in mature tubers, although NMR studies indicated that this pathway was restricted *in vivo*. U-^{14}C glycerol was also incorporated into starch and sucrose in both cultivars.

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

FRUIT CROPS

Blackberry and novel fruit crops [PU 3(e)]

In single row observation plots of blackberry and hybrid Rubus cultivars and selections, the blackberry cultivars Bedford Giant and Ashton Cross continued to outyield all others and some cultivars e.g. Loch Ness and Silvan had longer picking seasons than others.

[1]Short-term Appointment
[2]Research Student

Biennial plots of Ashton Cross yielded fewer and smaller fruits than annual plots, while biennial plots of Tayberry produced slightly more but smaller fruit than annual plots.

Irrigated highbush blueberries yielded more and larger fruit than unirrigated bushes in the dry year but yields were low because of blackbirds feeding on flowers.

(M. R. Cormack)

Raspberry mechanical harvesting [PU 3(g)]

A 'Korvan' machine from Oregon, purchased by a consortium of Inverarity Farms, Premier Brands and the Scottish Development Agency, and leased to an Industry Group, was tested throughout the picking season and a report submitted to the Tayside Regional Industrial Office.

Yields from a long term experiment to compare machine harvesting with hand picking of selection 14/106 grown on the biennial and annual systems were low due to unfavourable seasonal effects. The Littau machine picked 2.2 t/ha of ripe fruit from biennial plots while hand pickers collected 4.9 and 4.3 t/ha from biennial and annual plots respectively.

Initial screening of promising breeders' selections indicated good discrimination between ripe and unripe fruit in IHR-EM selections 5007/7 and 3908/13, over 96% of the fruit picked being ripe. Cv. Glen Lyon and SCRI selections 22D10 and 224 appeared similar to 14-106 and almost as good as the IHR-EM selections.

(M. R. Cormack)

Raspberry National Fruit Trials [PU 3(h)]

Of two NFT First Stage Trials in progress, one completed its final year and the other, planted in 1986, produced its second full crop.

Frost damage to buds in the first trial occurred in April and cultivars Glen Moy and Glen Clova were more severely affected than other advanced selections, resulting in substantial yield reductions. The highest yield, 20.1 t/ha, was harvested from an early ripening selection, 7532RG3.

In the second trial, where establishment had been somewhat variable (*Ann. Rep. 1988*, 142-143), the large-fruited selection 8044C9 (4.46 g/berry) cropped at 16.7 t/ha and was exceeded only by 7815B8 (17.7 t/ha). Cultivars Glen Clova and Leo each produced 9.0 t/ha.

(M. R. Cormack)

Manipulation of vegetative and fruiting phases of raspberry [PU 3(h)]

Sodium monochloracetate and fomesafen were evaluated as potential alternatives to dinoseb-in-oil for cane vigour control. Both effectively desiccated first-flush canes at concentrations with an adequate margin of safety to fruiting canes and second-flush vegetative canes. Both chemicals benefited from the addition of an adjuvant and high volume application

was necessary to ensure adequate coverage of first-flush canes when treated at 10-20 cm high.

Sodium hydroxide and monocarbamide dihydrogensulphate did not desiccate canes satisfactorily at concentrations which did not also injure fruiting canes. Mechanical techniques utilising rotating brushes or fingers failed to remove first-flush canes effectively and severely bruised the bases of fruiting canes.

(H. M. Lawson, J. S. Wiseman)

PROTEIN SEED CROPS

Field bean cultivar evaluation [PU 26(k)]

A trial of faba beans was planted jointly with the EC Faba Bean (Northern) Group to compare growth, yield and nutritional qualities of standard diverse genotypes. Yields ranged from 2.96 t/ha in a high-protein line, through 3.75 t/ha in the standard (cv. Maris Bead) to 4.53 t/ha in a heterozygous synthetic line. The spread in maturity was compressed by the dry growing season and spanned only 14 days.

(D. K. L. MacKerron, H. Taylor)

WEED INVESTIGATIONS

Periodicity and longevity of volunteer barley seeds in soil [PU 23(c)]

Barley seeds harvested from a series of field experiments in August and sown directly into pots at a depth of 3 cm below the soil surface showed no differences in speed of germination or percentage germination in relation to cultural factors imposed on the original experiments and few differences between cultivars. High percentage and uniformity of germination were attributed to the long dry summer and excellent harvesting conditions. No seedlings emerged in pots where the seeds had been sown at 20 cm depth immediately after harvest.

(H. M. Lawson, G. McN. Wright, R. P. Ellis[1])

Weed seedbanks [PU 23(c)]

Data from a survey of seedbanks in arable soils was subjected to hierarchical cluster analysis using GENSTAT 5. Several weed species groupings were identified which could be related to previous husbandry practices, e.g. spring germinating groups, autumn germinating groups and species associated with a pasture phase earlier in the rotation. Interpretation was improved when very commonly occurring species and those which were recorded only rarely were excluded from the analysis.

(H. M. Lawson, G. McN. Wright, P. Dugard[2])

[1]Cereal and Legume Genetics Department
[2]Dundee Institute of Technology

Image analysis [PU 23(c)]

Identification of weed seeds by shape parameters using image analysis is highly reliable for a range of common arable weeds, but several important species are regularly misidentified. The use of decision tree techniques in association with image analysis gave only marginal improvements in accuracy of identification.

(H. M. Lawson, G. McN. Wright, P. Collier[1])

ROOT AND SOIL INVESTIGATIONS

Fractal and non-fractal aggregation [PU 22(a)]

Mathematical analysis of discrete aggregates has shown the presence of fractal (i.e. heterogeneous) and non-fractal (i.e. homogeneous) aggregates within the Carpow soil series. A theoretical model of surface flaw density, developed at SCRI, predicts that the ease of root penetration increases as fractal aggregates increase in size, while it is constant throughout the size range of non-fractal aggregates.

(I. M. Young, J. W. Crawford)

Comparison of plant development and soil physical conditions under two different soil management regimes [PU 22(b)]

The results of a collaborative experiment showed that the growth of potatoes (leaf area and dry weight, tuber dry weight) was greater and that final yields were 20% higher on zero than on conventional traffic plots. Root growth, observed on the soil profile faces of replicated soil pits, was considerably reduced below the compacted layer at the base of each ridge. The compacted layer gave high penetrometer resistances and probably reduced growth by a combination of mechanical impedance and poor aeration. Roots growing in the compacted layer were almost exclusively confined to visible cracks and biopores.

(I. M. Young, A. G. Bengough, J. W. Dickson[2])

Time lapse studies of mechanically impeded roots [PU 22(b)]

A semi-triaxial cell was constructed in which roots were grown in ballotini under varying degrees of mechanical constraint exerted by a rubber membrane compressed by controlled hydrostatic pressure. Changes in growth rate and tip shape of mechanically-impeded root tips were recorded by time lapse photography with infra-red illumination. Increasing mechanical impedance resulted in a low growth rate and some self-inflicted damage to the root tissue.

(D. C. Gordon, I. M.Young, A. G. Bengough, D. Hettiaratchi[3])

[1]Statistics Department, University of Tasmania
[2]Scottish Centre for Agricultural Engineering
[3]Department of Agricultural and Environmental Science, University of Newcastle

Morphological compensation for non-uniform nutrient supplies [PU 22(c)]

Solution-culture techniques were developed to manipulate precisely the availability of nitrate to defined parts of cereal root-systems. These were used to study the effects of nitrate, supplied to localised regions, and for variable exposure times to seminal axes, on lateral root growth. When a seminal root apex grew through zones differing in nitrate concentration subsequent proliferation of lateral roots occurred in nitrate-rich zones, while placing an unbranched axis on nitrate-rich agar did not induce lateral growth. However, reproducibility of lateral root growth in response to localised enrichments of nitrate was poor. Preliminary results indicated that exposure of a root apex to a locally high concentration for nitrate of c. 1 day was necessary to induce the subsequent production of laterals within the nitrate-rich zone.

(D. C. Gordon, D. Robinson, D. J. Linehan)

Phosphorus availability and cortical senescence in cereal roots [PU 22(i)]

The cortical cells of the roots of cereals and other grasses senesce rapidly and the rate is genetically determined. Senescence may occur because of the low amount of phosphorus available for uptake and root growth resulting from the poor mobility of phosphate ions in soil. A simple model of root growth and phosphate diffusion showed that the amount of phosphorus needed to maintain the growth of a root with a non-senescent cortex was greater than that which the root could obtain from the soil. However, if phosphorus was recycled from senescent cortical cells greater than 17 days old (a typical age at which cortical cells start to senesce), root growth would consume less phosphorus than could be absorbed from the soil by the young, non-senescent parts of the root.

(D. Robinson)

Limits to nitrate uptake from soil [PU 22(i)]

Calculations of nutrient uptake rates based on total root length suggested that only very low concentrations (c. 100-200 mmol/m^3) of nitrate in the soil solutions should impose a limitation on the rate of nitrogen uptake by crops. In fact crops respond to fertiliser applications which result in much greater nitrate concentrations in soil solution.

The use of total root lengths as the basis for the original calculations may over-estimate the fraction of the root system active in nutrient uptake and thus under-estimate the nitrate concentration which limits nitrogen uptake. The 'active fraction' of a root system may be estimated by adjusting the value of root length until the theoretical amount of nitrogen that a crop should have taken up from the soil equals the measured uptake. By applying this technique to spring wheat it appears that only 11% of the root length was active in nitrate uptake from unfertilised soil, while the corresponding value was only 3.5% in a soil to which the equivalent of 200 kg N/ha had been applied.

(D. Robinson, D. J. Linehan, S. Caul)

Exudation of amino acids by roots of crop species [PU 22(j)]

Various methods for collecting root exudates from sterile and non-sterile plants of wheat, barley and oilseed rape grown in solution or solid cultures have been developed.

Individual hydroponically grown sterile wheat and rape plants exuded 16 nmol/h and 50 nmol/h total amino acids, respectively, over the first 35 days of growth, while non-sterile rape and wheat exuded rates of 400 nmol/h and 245 nmol/h, respectively. Serine and glycine predominated but there was a higher proportion of glutamine and arginine in exudates from young, sterile rape plants.

The major constituent amino acids of potato root exudate were asparagine (4.5%), glutamine (20.4), γ-aminobutyric acid (13.3%), arginine (24.0%) and tyrosine (35.6%).

(T. Shepherd, B. S. Griffiths[1], H. V. Davies, W. M. Robertson[1])

CELL PHYSIOLOGY

Fluid-phase endocytosis in plant cells [PU 26(i)]

Transient osmotic shock to intact onion epidermal cells induced the formation of fluid-phase endocytic vesicles. Plasmolysis in the presence of the membrane-impermeant fluorescent probes Lucifer Yellow CH (LYCH) and Cascade Blue hydrazide resulted in the uptake of these probes by fluid-phase endocytosis. When the cells were subsequently deplasmolysed, they rapidly resumed cytoplasmic streaming and many of the dye-filled vesicles left their parietal positions within the cell and began vigorous streaming in the cytoplasm. Vesicles moved within transvacuolar strands and several subsequently clustered around the nuclear membrane as a result of continuous cytoplasmic streaming past the nucleus.

In further experiments LYCH was endocytically loaded into the cells during the first plasmolytic cycle and Cascade Blue subsequently loaded during a second plasmolytic cycle, producing two populations of endocytic vesicles in the cells.

The work has demonstrated that membrane-impermeant compounds of high-molecular weight or lipophobicity, including xenobiotics, can be introduced into intact plant cells using fluid-phase endocytosis as a means of entry.

(K. J. Oparka, D. A. M. Prior, N. Harris[2])

[1]Zoology Department
[2]University of Durham

PLANT FIBRES

I. M. MORRISON

In view of the current overproduction of various agricultural products within the EEC, it has been recognised that all the present agricultural land will not be required for food production. A study was commissioned by the Institute to explore the potential for a research initiative to develop sources of fibre for industrial uses. The report has highlighted some of the problems in the provision of this material but concluded that there was a clear need for fundamental and strategic research into alternative fibre sources particularly from annual and perennial plants. As a consequence, DAFS agreed to fund an initiative on plant fibres.

The aims of the programme are to identify plant species likely to be of importance from the physical and chemical characteristics of fibre-producing herbs, shrubs and trees; to determine the factors influencing the isolation of fibres, paying particular attention to biotechnological methods and those which cause minimum damage to the environment; and to investigate the control of differentiation, development and deposition of both cellulose and lignin in fibre cells.

Characterisation of plant fibres [PU 21(a)]

Fibres have been extracted from flax, brassicas, New Zealand flax, bamboo and barley straw. They are being characterised by chemical methods involving GC and GC/MS in conjunction with specific methods for lignin and carbohydrates, while the physical techniques of FT-IR, NIR, Raman and NMR spectroscopies are being assessed. Most work has been done on brassicas, some of which produced fibres with similar properties to the desirable eucalyptus fibre.

(I. M. Morrison, D. Stewart)

Control of differentiation and development of fibre cells [PU 21(b)]

A microscopic study of fibre cells in flax during development has been initiated to establish the time scale for phase changes such as the initiation of fibre cells, the onset of secondary wall formation and the start of lignin deposition. Biochemical studies have begun on the extraction and preliminary characterisation of wall-associated peroxidases which are reputed to be involved in lignification. Studies have shown that high levels of peroxidase activity are present in flax.

(G. J. McDougall, I. M. Morrison)

Factors influencing the isolation of fibre [PU 21(c)]

Lignin is the major factor in most plants which inhibits the isolation of cellulosic fibres although the pectin content is important in some species. Methods of lignin removal involving the use of more environmentally acceptable oxidising agents than chlorine-based treatments are being investigated.

(I. M. Morrison, D. Stewart)

CHEMISTRY

M. J. ALLISON

During the year chemical determinations included SMCO in brassica (1,440 samples), thiocyanates in brassica (528 samples), individual glucosinolates in brassica (747 samples), digestibility of brassica (356 samples), reducing sugars in swedes (324 samples), micromalted samples of barley (1,100 samples) Kjeldahl nitrogens in barley (800 samples) microanalysis of nitrogen in barley tissues (2,700 samples), stable isotope analysis (756 ^{15}N and 50 ^{13}C samples), total glycoalkaloid content of potato tubers (20 samples), the individual sugars, sucrose, glucose and fructose (2,800 samples) and elemental analyses (744 plant and soil samples).

A Perkin-Elmer thermal adsorption unit acquired during the year was commissioned by the company in November. This instrument can be used to separate and detect low amounts of relatively volatile compounds e.g. those relating to pest resistence. The fixed-filter NIR analyser was upgraded this year to a Bran+Lübbe 260 NIR analyser.

The software package for principal components (PC) analysis of NIR spectra (*Ann. Rep. 1987,* 167 and *1988,* 152) became commercially available in the USA and Britain in November 1989 through NIR Systems Inc. formerly Pacific Scientific Inc. of Silver Springs, Maryland, USA.

Collaborative work with other institutes included an IFS project with ESCA on the underlying biochemistry of crisping quality in potatoes, and an IFS project with NSCA on the effects of the environment on oilseed rape seed glucosinolates.

Techniques for the separation of useful biochemical markers in barley [PU 28(c)]

A new method developed for extracting and separating high molecular weight proteins (90 to 180 kD) in wheat was successfully applied to barley. This is an HPLC reversed-phase method making use of size exclusion, partition and adsorption chromatographies. It is possible to emphasise the size exclusion aspect to resolve higher molecular weight aggregates. This advance facilitates research on the polymorphism of these proteins and the high molecular weight proteins in barley can be evaluated for their usefulness as chromosomal biochemical markers, and for their role in determining the quality of barley.

(M. J. Allison)

Development of rapid tests for the malting quality of barley [PU 28(f)]

Studies were initiated to locate absorption areas in the NIR spectrum that relate to malting quality. A technique combining NIR with PC analysis of the data was used. The weightings derived with the PCS were combined with regression coefficients from PC regression equations to predict malting quality. These combined weights provide a means of amplifying the variation specific for a grain constituent (quality attribute). When the combined weights for hot water extract (HWE) were plotted over the spectrum a number of peaks and troughs were observed. This procedure was repeated for populations of barley samples differing in the cultivars represented, sites and years grown. Similar reconstructions for HWE were observed in each case, strengthening the likelihood of obtaining a robust NIR prediction equation for the rapid estimation of hot water extract of malt (the major component of malting quality) from resting grain measurements.

(M. J. Allison)

Variation in the glucosinolate concentrations in forage rape roots [PU 4(s)]

Work at SCRI has revealed that insect damage can affect significantly the relative concentrations of individual glucosinolates in the roots of brassica crops (*Ann. Rep. 1988*, p. 125). However, little information on the natural fluctuations in root glucosinolate content is available. The levels of both individual and total glucosinolates were therefore determined in root samples taken at weekly intervals from three forage rape cultivars (*Brassica napus*).

The levels of glucosinolates found in the root samples (approximately 20 mM/Kg) were broadly similar to that in the stems when averaged over all dates and varieties. However, in studies on the cultivars Bonar and Hobson and the breeding line 84411 the total glucosinolate content of the roots varied with time by over 100% with the highest values being found 17-19 weeks post sowing. The proportion of aliphatic glucosinolates varied significantly both between varieties and harvest dates with the lowest values (32.7% of the total glucosinolates when averaged over all harvest dates) being associated consistently with the breeding line 84411. Although the predominant aliphatic glucosinolate differed between the three genotypes the predominant aromatic glucosinolate was phenylethyl glucosinolate in each case. A 50% difference between genotypes in the relative proportion of total aromatic glucosinolates was of particular interest because of their possible role in plant defence mechanisms.

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

[1]Potato and Brassica Genetics Department

SPECTROMETRY

Near infrared analysis

A number of improvements and additional features were made to the software package for principal components analysis of near infrared spectra. This package was used to analyse continuous spectra and also data from the new Bran+Lübbe InfraAlyzer 260 fixed filter NIR analyser. Using facilities in the package to convert PCA equations to wavelength form, a hybrid PCA/wavelength equation for moisture in freeze dried kale leaves has been produced and is undergoing long term evaluation.

(I. A. Cowe, D. C. Cuthbertson, J. W. McNicol[1], J. Hall[1])

Organic mass spectrometry

During the year departmental facilities were used to advanced a wide range of research projects. The BTG project on the pesticidal activity of natural plant products continued with analysis by gas chromatography mass spectrometry of complex extracts produced 'in house'. Gas chromatography was also used to determine the quality of chemicals supplied from outwith the Institute. Approximately 100 samples were analysed, yielding valuable information on their chemical composition and purity.

Single ion monitoring (SIM) is a technique used in Mass Spectrometry to detect trace levels of compounds of interest in a complex mixture. The mass spectrometer can function as a sensitive selective detector by monitoring selected masses characteristic of the compounds under investigation and detection limits of picogram (10^{-12} g) levels can be achieved under favourable circumstances. In collaboration with the Macaulay Land Use Research Institute a series of PCB (polychlorinated biphenyl) standards were analysed to correlate retention time with identity. Although normally analysed by electron capture detection, the positive identification of PCBs in an extract of peat was achieved using both scan and SIM techniques. Other analyses included standard mixtures of sugars converted to peracetylated aldononitrile derivatives, the soluble and fatty acid content of chickpea plants and the identification of terpenoids in leaf extracts of black currants.

(G. W. Robertson)

Stable isotope mass spectrometry

Preliminary results of the inter-laboratory trial with the Atomic Energy Agency in Vienna (*Ann. Rep. 1988*, 154) have now been made available. Its purpose was to validate enriched isotope reference materials for medical and biological studies. The isotopic compositions of the following materials were determined.

[1]SASS

IAEA-303	Sodium Bicarbonate	100 and 500‰ ^{13}C Vs PDB
IAEA-309	UL-Glucose	100 and 600‰ ^{13}C Vs PDB
IAEA-310	UREA	50 and 200‰ ^{15}N
IAEA-311	Ammonium Sulphate	2 atom % ^{15}N

In the exercise, involving 35 laboratories, data from the Department fell within the 95% confidence interval calculated on all accepted results, and displayed good reproducibility over all samples tested.

In conjunction with the Soil Plant Dynamics Group a method for the isotopic analysis of labelled nitrous oxide at concentrations <0.2% in soil incubation gas samples was developed and 340 gas samles were analysed to provide information on nitrification and denitrification.

Employing the combustion method of analysis the nitrogen content of very small samples of barley plants were analysed. Isotope analytical services were again provided for the University of Dundee (Departments of Geological Sciences and Biological Sciences).

(G. W. Robertson, W. M. Stein)

Inductively coupled plasma optical emission spectrometry

A total of 6020 determinations of elements were completed for 744 samples of widely varying types.

Methods of analysis were devised for determination of macro- and micro-nutrients in plant nutrient solutions and in soil solutions and for corrosion metals and additives in boiler waters. In addition, trace and major component elements were determined in potatoes and other crops.

A method of analysis was established to determine sodium residues in leaves, stems and fruit of raspberries following treatment with various strengths of sodium monochloracetate solution to inhibit secondary growth.

(W. Matheson)

DATA PROCESSING

R. J. CLARK

Following the announcement that the EMAS service is to close plans were made to install a Local Area Network (LAN) with computing services on site at SCRI during 1990. This change will have a major effect on computer use at SCRI where staff frequently use EMAS, the operating system unique to Edinburgh University.

Partly in consequence of this, a five year plan for computing was written at the request of the Computer Steering Group and submitted to DAFS. It is planned to provide some two hundred connections covering the main laboratory and office buildings, to network personal computers. Preparatory work started in reviewing the software and hardware needs in general and considering the standards to be adopted and maintained on the new system.

Hardware and communications

Major acquisitions in hardware were an additional PAD, an inkjet printer and an eight pen A3 plotter. The PAD, formerly at Pentlandfield, increased the number of ports to 64. An additional British Telecom line to EDNET was rented so that two PADS could be allocated per line and at Blythbank the farm was provided with a link to EDNET for their PC, using a dial-up service over a telephone line via a modem.

More than twenty old Apricot 'F' series micros were replaced by IBM PCs because of age and incompatibility with the standard, increasing the number of IBM compatible PCs to 66. The number of registered users of EMAS, and other EUCS services, increased from 112 to 116 but usage remained about the same.

Training

Training continued to be a major responsibility and many courses given were well attended. Following training some software packages become a standard in every department. Such was the case with the Microsoft 'WORKS' integrated package containing word processor, spreadsheet and database. Courses were run several times through the year. The departmental User Area was arranged to accommodate two people per PC. Instruction was given with the aid of two large colour monitors connected to a PC, and the users gained 'hands on' experience through practical exercises.

A Minitab course given by SASS staff was well attended and eight terminals connected to EMAS allowed a large number of staff to participate in the practical exercises.

Advice on the ergonomics of computer use was offered, at the request of AFRC. Staff who sit at PCs or terminals for lengthy periods were visited and given recommendations on posture, chair and desk height, and viewing angles to help reduce strain and preventable injuries and to increase efficiency.

(R. Kidger, I. Black)

Software support and development

Conversion of the Pascal programs was completed using Borland Turbo Pascal V4; the new version should make conversion easier and help overcome problems encountered previously. New software has facilitated the development of extensive communications links for the Library. This permits staff to access remote library catalogues from a PC, increasing the efficiency of library searches while reducing the cost to the institute.

A request from the Tissue Culture department for a program from an institute in America provided an opportunity to use the UNIX operating system on a Gould NP1 supercomputer based in Edinburgh University. Later in the year, a short introductory course was given by EUCS training staff on the UNIX operating system and the graphics package, Uniras. Attendance was restricted to DP and SASS staff and user numbers were acquired on the UNIX mainframe in preparation for the transfer from EMAS.

A program to aid the measurement of plant virus concentration in leaf sample was developed with H. Barker (Virology). Using output from an ELISA technique it increased accuracy and considerably decreased the labour needed for the assay. The program, originally written in BBC Basic, has proved so effective that it is to be re-written in 'C' to run on an IBM PC.

Graphics support continued at a high level with co-operation between Visual Aids and the Department. Posters for conferences were rapidly produced to a high standard through Supercalc and the new A3 plotter. Harvard Graphics and the Easygraph package on EMAS were also used extensively.

Graphics packages formed the topic for a meeting of the Computer Liaison Group. Members from Scottish Institutes and Colleges demonstrated the packages used at their site enabling comparisons to be made.

(R. Kidger, P. Smith, I. Black)

Databases

Work continued in collaboration with the Physiology and Crop Production department at SCRI, Biometry, Agricultural Botany and Computer Science departments at Queen's University, Belfast and DANI making

HERBREX information available to the structured text retrieval program, MICROHERB. The query structures were developed for arable, horticultural and ornamental crops using the cereals and grassland procedures as a model. The resulting program provided rapid access to information on all UK-approved herbicides and desiccants with recommendations for use on all major and minor crops. It is proposed to market the programs with minor enhancements.

The raspberry breeding database (*Ann Rep. 1988*, 158) was converted into a WORKS file and consequently there was a decrease in demand for Foxbase database applications. Using WORKS the user now has direct control of the information and confidence to change the searches etc without the need for additional routines to be written in the database language.

(P. Smith, R. J. Clark)

SCOTTISH AGRICULTURAL STATISTICS SERVICE

R. A. KEMPTON

The Scottish Agricultural Statistics Service (SASS) provides statistical and mathematical support to the five SARIs, SAC and DAFS Agricultural Scientific Services.

During the year, further progress was made in establishing new research areas in image analysis, chemometrics, environmental studies, food technology and expert systems. Our growing reputation in these application areas is recognised by an increase in external research contracts and consultancies. This widens the experience of staff and provides essential additional funds to supplement our DAFS grant. Our programme of training courses was expanded during the year. A new computer system was purchased for SASS Headquarters.

New statistical methods and applications

In image analysis, progress was made in analysing electromicrographs of soil aggregates. A Boolean model was used to infer the three-dimensional connectivity of soil pores from two-dimensional cross-sections. The effectiveness of magnetic resonance imaging (MRI) for making *in vivo* measurements of the body fat of pigs was investigated. SASS is collaborating with MLURI to build an ultrasound imager to measure sheep backfat and eye muscle depths, with the aid of an SDA grant. A World Health Organisation project with the Genetics Department of Edinburgh University, involves automating the interpretation of 2D electrophoretograms of malaria strains. Collaboration with the remote sensing group of Institute Nacional de Investigaciones Agrarias, Madrid continued with British Council Funding. Synthetic aperture radar and Landsat MSS images were shown to predict land usage in central Spain more accurately when used together than either could achieve separately.

In environmental studies, a sampling strategy was devised for obtaining ground truth information to produce a land cover map of Scotland from aerial photography for the Scottish Development Department. Advice was given on setting up a monitoring scheme for Environmentally Sensitive Areas. Work is in progress developing computer routines to model and predict distribution of land area, crops, animal or plant species and other local variables from incomplete survey data, and for various scenarios of climate or socio-economic change. SASS work in the environmental area was also strengthened by external contracts, particularly with the Institute of Terrestrial Ecology and a number of marine research organisations.

Methods of experimental design and analysis used for research and development in the chemical industry were successfully applied to problems in food technology. Multivariate analysis was found to aid the interpretation of results of sensory experiments. SASS has secured funds under the EC FLAIR programme to build collaborative links with statisticians in European food research laboratories, including FRI, Reading laboratory.

An EC-sponsored three-year project on the development of expert systems for forecasting was begun. The project, which is led by SASS, involves six other European research organisations and an international software-house.

SASS provides mathematical and statistical support for researchers involved in modelling biological processes and a review early in the year revealed over 50 DAFS funded projects which contained a large modelling component. SASS has been involved in several such projects including dynamic population models of potato cyst nematode and models for cost benefit analysis of dairy cow management. Methodology was developed for performing sensitivity studies on many parameters simultaneously.

Training

The five training courses, 'Statistics for Biologists using Minitab', 'Introduction to Genstat 5', 'Experimental Design and Analysis of Variance', 'Regression and Curve Fitting', and 'Graphical Methods for Multivariate Data' were revised and presented to SARIs and SAC on several occasions during the year. In addition, three new courses: 'An Introduction to Mathematical Modelling', 'The Analysis of Unbalanced Data using Residual Maximum Likelihood Estimation' and 'Statistics for Food Technologists' were developed.

The teaching of two undergraduate courses was undertaken for Aberdeen University.

Statistical computing

The REML algorithms developed by SASS were incorporated in the Genstat statistical package (version 5.2). This allows the analysis of unbalanced designs and substantially increases the range of problems that can be tackled with Genstat. SASS acted as local organiser of the 6th International Genstat Conference held in Edinburgh.

The Coordinated Variety Trial Software used for the UK variety testing programme was substantially modified to interface with the Oracle database management system. A PC version has been produced for use by trials officers and overseas clients.

Software for computing in molecular biology has been investigated and advice provided to scientists on using the SEQNET facilities at SERC Daresbury Laboratory. SEQNET provides national access to the latest DNA and protein databases and also to a large range of sequence analysis software. The MAPMAKER package for mapping genomes is also being investigated.

The SUN 4 computer

A new computer system has been purchased to replace the Prime computer at SASS Headquarters. The new system comprises a SUN SPARC 4/330 server and two SUN 4/60 workstations. The workstations and existing PCs will be connected to the server by high speed Ethernet. One workstation will be used for image processing, the other for software development and training. This move to a distributed UNIX-based computer system is in line with long term strategy for SARIs and SAC and for the Edinburgh University Computer Service.

Statistical support for SCRI

A method of presenting and analysing RFLP data was developed in collaboration with the Tissue Culture and Zoology departments. This involves a simple re-ordering of the tracks and bands and the use of principal coordinates analysis.

Agreement was reached with Perstrop (formerly the Pacific Scientific Company) on the final version of the near infrared principal components software which is being written jointly with the Chemistry department. The package is now being marketed and sold in the United States and will shortly be made available in Europe.

Work was started on a contract with ADAS to analyse data from their potato physiology trials. This contract is a consequence of a wider collaborative exercise between ADAS and SCRI.

In a joint project with the Crop Genetics department a CASE student with SASS and Heriot Watt University started work on modelling the effect of competition in variety trials.

In collaboration with the Virology department, a multivariate analysis was performed on a data set consisting of 76 isolates of Cassava mosaic virus from East Africa, West Africa and India. The reactions of the isolates with 25 antibodies were measured using the ELISA technique. Linear discriminant analysis successfully allocated almost all the isolates to their correct geographical origin using only few of the antibodies.

Statistical support for other organisations

Details of SASS collaboration with other SARIs and SAC can be found in their annual reports.

ESTATE

W. I. A. JACK

The weather adversely affected cropping performance. 1989 was an extremely dry year with no rain during the critical growing months of April to July, which desiccated crops before ripening, resulting in yield and quality of all crops, with the exception of hay, well below the 5 year average for the Institute.

In line with Institute policy of an integrated glasshouse facility, another phase in the building programme was completed with the commissioning of two ranges of spore-proof glasshouses. Upgrading of facilities within several glasshouse units was undertaken providing new mobile bench layouts, irrigation and biological pest control systems which have resulted in more effective use of limited resources.

The scale of crop spraying inputs to field trials, and the introduction of COSHH Regulations 1988, necessitated an assessment of spraying practices undertaken at the Institute. The Institute is responsible for implementing safe practice using methods both sympathetic to the locale and to staff servicing field trials.

Farm Crops

Farm Crops included 12 ha winter barley, 80 ha spring barley, 4 ha field bean, 2.6 ha potato, 0.5 ha turnip, 12 ha grass (of which 5.5 ha was a hay crop), and 15 ha fallow; this is an increase of 0.4 ha from 1988.

Sowing of spring barley cultivars Camargue and Tyne although initiated on 16 March was delayed by wet conditions until 28 March and not completed until 5 April. Early germination, emergence and satisfactory plant stands were recorded. Winter barley cv. Magie, sown in mid-September 1988, overwintered well but was subjected to early attacks by powdery mildew (*Erysiphe graminis*) as was the spring barley. Both crops received fungicide sprays.

Harvesting of winter barley commenced on 19 July and was completed by 27 July. Harvesting of Spring barley followed on 3 August and was completed by 4 September. Light soils and the extreme dry conditions resulted in the barley crops burning-up before ripening. Yields were poor and, with a high proportion of screenings, few of the samples achieved malting standard. A small area (0.8 ha) of spring barley cv. Tyne, however, produced 4.5 t/ha of good quality grain which was retained for seeding in 1990. Baling of straw followed close behind combining and was completed by 6 September all being marketed straight from the field in good condition.

Hay was made from an early cut on 13 June and baling was finished by 20 June. The hay was of excellent quality and sold readily.

Field bean crops suffered badly in the prolonged dry season. At Mylnefield farm, the early growth of cv. Syn 3 in a capped seedbed was poor. Emergence was uneven and the plants stunted. At Gourdie farm, cv. Herz Freya was more successful in better ground conditions. Combining started very early, on 2 August, but the unevenness of the crops necessitated several cuts until 6 October. Overall yield was low at 1.8 t/ha.

Potato cultivars Maris Bard (0.3 ha) and Cara (2.3 ha) were grown. Yields were not high but quality was good. Samples were even in size with a low percentage of out-grades. Harvest conditions were excellent and the crops were marketed from store promptly.

Autumn work progressed without hindrance. Lime was spread over 50 ha and 37 ha were sub-soiled. The ploughing of all areas free from experiments was completed by the end of the year. Both winter barley cv. Magie (1.6 ha), and winter wheat cv. Avalon (12.5 ha), were sown on 12 and 26 September, respectively.

During 1989, Gowrie West field was surrounded with vermin-proof fencing (750 m), and hedges and trees were removed, allowing a greater area to be reclaimed for arable cropping. The boundary fence of Laboratory field (360m) was removed and replaced with vermin-proof, security fencing and major repairs to 120 m of security fence in West Quarry field were undertaken.

A complete ground drainage system was installed by contractor in the eastern section of North Bullion field.

(R. W. Reid)

Field Experiments

There was a total of 264 field experiments and off-station trials. The crops grown included 9.7 ha raspberry, 6.5 ha black currant, 2.5 ha strawberry, 1.8 ha black- and hybridberry, 14.5 ha cereal, 9 ha brassica, 6.5 ha potato, 0.5 ha field bean, with a miscellany of minor crops occupying a further 8 ha. Although the total number of trials fell dramatically (1988-330 : 1989-264), the total area of trials on-station was only slightly less (1988-61.5 ha : 1989-59 ha). The number of trials off-station were decreased by 50%. On-station, the areas of cereal stocks and winter trials diminished markedly and there were smaller reductions in the areas occupied by field bean, cane fruit and potato trials. These reductions were largely offset by the accession of potato breeders' plots transferred from Pentlandfield and The Murrays.

At Gourdie farm significant improvements in the water supply to serve field irrigation lines were provided by the installation of water tanks, pump and a power supply adjacent to the steading. As 1989 was one of the driest summer seasons on record the irrigation facilities proved vital to the successful maintenance of potato experiments at Gourdie farm.

The weather was a major factor affecting trials. Cereals dried out rather than ripened. Raspberries aborted flowers and fruit and then appeared to enter dormancy resulting in a considerable reduction in the volume and quality of new cane produced. There were early influxes of aphids onto potatoes, and successive generations of root fly, caterpillars and mealy bugs attacked brassicas.

(G. Wood)

Soft Fruit

Reasonably mild weather enabled the winter maintenance work to be completed on schedule. Fruit picking of strawberries commenced on 28 June and raspberries on 3 July. Due to the extreme drought the season was very short and the volume of fruit well below average. The high winds and drought experienced over the last few seasons resulted in the raspberry canes being considerably shorter than normal this autumn. There was a small hand-pick of black currants on 23 July with the remainder of the harvest being undertaken by machine on 11 August. Black- and hybridberry picking started on 2 August and continued until the end of September.

(D. S. Petrie)

Brassica

Sowing commenced 28 May and favourable weather conditions enabled completion on schedule in mid-June. Germination was sparse and irregular resulting in three or four noticeably different flushes of plants in some of the earlier drilled plots. Although the soil was dry, application of pre-emergence herbicide seals produced good weed control throughout. Pests, particularly mealy aphids, were more difficult to contain during the drought conditions. Irrigation was applied to areas that were particularly under stress and thereafter, the crops remained healthly, though the yields were below average. Harvesting was completed by early December.

(C. C. Carrie)

Potato

Potato planting started on 18 April and was completed by 28 April. Harvesting commenced 3 October and finished 12 October. Timing of the routine pre-emergence herbicide spray was difficult as windy conditions prevailed. Weeds, especially fat hen, were a problem in some areas of the main field. Blight prevention sprays commenced in May and ended in the middle of September, the crop remaining healthy throughout. Irrigation was applied to trials areas, if requested, and there was sufficient water to include most of the breeder's plots during the driest periods.

(C. C. Carrie)

Cereal and field bean

Sowing of spring cereal trials was initiated on 17 March. Adverse weather, however, almost immediately disrupted the schedule. Sowing recommenced on 29 March and continued under excellent conditions until completed on 20 April. Action taken in the preceding year to control infestations of couch grass was successful and the growing crop was clean, annual weeds also presented no problems. The area of spring field bean trials was much smaller than in previous years. The dryness of the soil hindered the effectiveness of the herbicide seal and weed control was not good. All the plots were harvested by hand this year. Sowing of winter barley and winter oat trials started on 11 September and was completed on schedule. The complete area was surrounded with electric fencing to protect the crops against rabbits and hares, and the trials entered the winter in good condition.

(D. G. Pugh)

Spraying and irrigation

The mild winter allowed an earlier than normal start to be made to spraying schedules. Herbicides were applied in the soft fruit areas before the end of February and well before bud burst. Groundsel and thistle emerged early and were quickly brought under control with appropriate chemicals. An extensive spraying campaign against perennial weeds in field boundaries and windbreaks was undertaken to prevent them spreading, establishing and seeding into rotation and trial areas. The weather conditions through the season favoured insect pests and the preponderance of sprays needed in trials areas reflected this.

At Gourdie farm borehole the submersible pump delivered 10,000 litres of water per hour, 6 hours a day, 5 days a week, from 12 June to 11 August. This was essential for the maintenance of the potato trials in Home Park North field.

(A. W. Mills)

Glasshouses

The increased use of both heated and unheated glasshouses was reflected both by the numbers of jobs processed 1988-1126, 1989-1203) and plants produced 1988-175153, 1989-206,651). The percentage of time allocated to each Scientific Department to complete these jobs were:

Brassica Genetics	22.8%
Cereal & Legume Genetics	9.5%
Potato Genetics	8.6%
Soft Fruit Genetics	6.1%
Mycology & Bacteriology	11.7%
Zoology	11.0%
Physiology & Crop Production	2.8%
Tissue Culture	2.6%
Virology	24.9%

Early in the year, an extension to the Mycology & Bacteriology glasshouse was commissioned, providing an additional 550 m^2 of high grade glass. Seven of the 12 cubicles are of a spore-proof design and fungal infection of plant material can be carried out under strictly controlled conditions. Special features to prevent external contamination include the provision of positive pressure cubicles and refrigerated air-conditioning.

In the Cereals glasshouse the replacement of old sand beds by modern roller benches has been initiated. These benches include capillary-mat irrigation and a new plant support system, both of which should significantly reduce labour requirements.

Biological control of pests has been introduced into several glasshouses. The most successful has been *Phytoseilus persimilis*, a predator of the two-spotted spider mite. *Encarsia formosa* and *Aphidoletes aphidimyza*, predators of whitefly and aphid respectively failed to give adequate control, possibly the result of late introduction.

(P. A. Gill)

INFORMATION SERVICES

R. J. A. EXLEY

The transfer of library material from Pentlandfield to Invergowrie was completed and recataloguing and reclassification undertaken with help from a temporary professional librarian.

Installation of an IBM microcomputer allowed storage of loans information, a catalogue of the institutional reports, and applications for interlibrary loans through the British Library's computerised system ARTTel. Online access was obtained to the catalogues of Britain's university libraries through the JANET network.

Fiscal constraints led to a reduction in book purchases, interlibrary loans, literature searches and translations. There were 2179 interlibrary loans from the British Library and other sources. There were 1284 internal loans and 99 literature searches compared with 1124 and 135 for 1988.

The Librarian attended two meetings of the Scottish Agricultural Librarians' Group, and several meetings of the Tayside Chief Librarians' Committee. She also served on the latter's Working Party on a Library and Information Plan for Tayside. The Library Administrative Officer gained an ONC in Library and Information Science from Telford College, Edinburgh.

(U. M. McKean)

VISUAL AIDS

Production increased by 6% over that in 1988.

	PHOTOGRAPHY				GRAPHICS	
	Jobs	Colour	Monchrome	Diazo	Jobs	Graphics
1988	2498	9598	15600	513	349	5402
1989	2740	9545	14502	872	317	8079

A greater awareness of staff to the benefits of good presentation in talks, poster sessions and display material was evident in the amount of requests received for Diazochrome slides and Graphics.

A Desk Top Publisher has proved to be a worthwhile investment; many prestigious reports were produced throughout the year, as well as graphics which are favourable in quality compared to those from traditional methods and require much less time to prepare. Specialised photography e.g. photomicrography and macrophotography, accounted for approximately 50% of the photographic workload, the others requests being mainly video

recordings, reproduction of colour and monochrome originals and printing of negatives for records, reports and publication purposes.

With an ever-increasing number of customers, increased investment is necessary in technological equipment to offset the shortfall in staffing levels and many items of electronic equipment were assessed for suitability and cost effectiveness throughout the year.

(T. G. Geoghegan)

SCOTTISH SOCIETY FOR CROP RESEARCH

Directory for 1989/90

Trustees

George B. R. Gray, Smeaton, East Linton, East Lothian, EH40 3DT
Angus Pattullo, MC, 6 Castle Way, St. Madoes, Glencarse, Perthshire, PH2 7NY
A. G. M. Forbes, Omachie, Kingennie, Nr Dundee, DD5 3RE

Chairman

J. G. Porter, Balhungie, Monifieth DD5 4HY

Vice-Chairman

A. M. Jacobsen, Mains of Catterline, Catterline, Stonehaven, Kincardineshire AB3 2UL

Members of Committee of Management

D. Craib, Stynie, Fochabers, Morayshire, IV32 76E
W. P. Laird, Cairnie Lodge, Cupar, Fife, KY15 4QD
J. R. Love, 11 Old Manse Road, Eddleston, Peebles-shire, EH45 8RE
D. Morrison, Slatefield, Forfar, DD8 1XD
G. Rennie, Edington Mains, Chirnside, Berwickshire, TD11 3LE
M. S. Smith, 8 Borrowfield Road, Montrose, Angus, DD10 9BE
T. P. M. Thomson, 2 Keith Bank, Balmoral Road, Blairgowrie, PH10 7HU

Secretary & Treasurer

D. L. Hood, 25 North Balmossie Street, Monifieth, Dundee, DD5 4QL

Registered Office

C/o Scottish Crop Research Institute, Mylnefield, Invergowrie, Dundee DD2 5DA

Report by the Committee of Management

The Committee of Management met on two occasions (30 March, and 8 November) for the transaction of Society business. There were also meetings of the Crop Sub-Committees at various times throughout the year.

During the year the Committee authorised the payment of grants for travel as listed below:–

From the General Fund:

(i) £216 Dr D. J. F. Brown (SCRI Zoology Department) attending Wageningen and Ghent in April.

(ii) £200 to Dr M. C. M. Pérombelon (SCRI Mycology and Bacteriology Department) attending the 7th International Conference on Plant Pathogenic Bacteria, Budapest, 11-14 June.

(iii) £200 to R. J. McNicol (SCRI Soft Fruit Genetics Department) attending the 5th International Rubus Ribes Symposium, North America, 24 June-2 July.

(iv) £200 to H. M. Lawson (SCRI Cellular and Environmental Physiology Department) attending the 5th International Rubus and Ribes Symposium, North America, 24 June-2 July.

(v) £200 to Dr B. Williamson (SCRI Mycology and Bacteriology Department) attending the 5th International Rubus and Ribes Symposium North America, 24 June-2 July.

From the Thyne Bequest:

(vi) £100 to Dr R. Jefferies (SCRI Cellular and Environmental Physiology Department) attending the BPGRG Conference, 13-15 September.

(vii) £207 to Dr D. K. L. MacKerron (SCRI Cellular and Environmental Physiology Department) attending 70th Anniversary Conference of the Agricultural University of Brno, Czechoslovakia, September.

Reports of these visits are available from the Secretary.

A Conference was held in Dundee in November entitled, "Potatoes — getting them right". This was well supported by members and visitors who were addressed by Mr William Sprigge, Chief Executive of the Potato Marketing Board who gave the keynote speech entitled, "What the market wants".

The other speakers and their subjects were "Fresh potatoes — the supermarkets' needs" by Mr John Pickering, Trading Manager Fresh Produce, Safeway plc; "Future seed requirements for the crisping industry" by Mr J. F. Gibson, Managing Director K. P. Agriculture; "New methods for testing tuber health" by Dr D. A. Perry, Scottish Crop Research Institute;"Temperature control for seed and ware potato storage" by Mr F. J. Pirie, F. J. Pirie & Co. Ltd, and "Minitubers — a new approach to seed production" by Dr D. T. Coombs, Technical Manager, Nickerson Seeds Ltd. These will be published in a Bulletin.

The members of the Committee who will retire by rotation with effect from the Annual General Meeting held in 1990 are T. P. M. Thomson, G. Rennie and A. Jacobsen.

During the year the Society ended its association with the site at Pentlandfield, Roslin, Midlothian when remaining SCRI staff transferred to Mylnefield on 31 March 1989.

As at 31 December 1989 the membership of the Society stood at 317.

Temperature
The warm conditions of December 1988 (see previous report) continued with the mildest January and the second mildest February on record and the temperature for the three-month period was 3.2°C above average. The sustained higher air temperatures led to warmer soil temperatures between January and July. The average temperature from May to August was 2.1°C above average.

Rainfall
Total rainfall for the year was 470.6 mm and the third lowest on record. It was above the average in only two months. July was particularly dry and the period from April to September was the driest recorded (60% of average). The soil had not returned to field capacity at the end of the year.

Sunshine and Solar Radiation
Sunshine and solar radiation in July were the second highest on record at 152% and 123% of their respective averages. Sunshine over the year was more than 200 hours above average.

Wind
The first two months of the year were very windy and windspeeds in February were the highest recorded for that month. In contrast, winds in the last two months were much lower than average.

Potential Evaporation
Potential evaporation from May to August was 16% above average and in July it was 125% of that month's average, the highest value calculated here.

(D. K. L. MacKerron, G. Dunlop)

MYLNEFIELD

Month	Temperature										Days ground frost	Potential evap-oration mm	Rainfall		Bright sunshine hours		Mean daily solar radiation	Windspeed	
	Daily air maxima		Daily air minima		0.1m Soil		0.3m Soil		Accumulated degree days										
	Mean °C	DFA *	Mean °C	DFA *	Mean °C	DFA *	Mean °C	DFA *	Above 6°C	Below 6°C			Total mm	DFA *	Total	DFA *	mWh/cm²	Mean km/h	DFA †
January	9.3	+3.8	4.1	+4.1	5.3	+3.8	6.4	+3.9	45.8	24.0	11	14.5	26.3	−36.5	56.3	+ 3.2	42	18.9	+6.0
February	8.4	+2.8	2.3	+2.3	3.6	+2.0	5.7	+3.1	28.2	47.6	16	22.6	52.0	+ 4.0	101.9	+30.3	117	20.3	+8.1
March	9.3	+1.4	1.8	+0.1	4.0	+0.7	5.5	+1.2	33.3	47.3	21	36.5	48.2	− 0.7	136.0	+30.7	217	16.3	+1.5
April	9.4	−1.6	3.0	−0.3	6.2	−0.1	7.3	+0.4	40.5	34.1	14	49.5	30.1	−10.0	125.2	−32.2	310	11.2	−3.0
May	15.6	+1.9	6.6	+0.4	12.1	+1.9	10.8	+0.7	163.0	5.8	9	97.9	19.7	−35.9	218.0	+35.8	490	12.2	−0.3
June	17.6	+0.7	8.6	+0.1	14.8	+0.9	13.0	+0.5	215.8	3.5	5	97.9	33.5	−16.8	195.2	+16.8	513	9.4	−2.4
July	21.5	+3.0	11.5	+1.3	17.6	+2.3	15.2	−0.1	325.3	0.0	0	115.1	13.5	−48.0	265.2	+90.3	542	10.2	−0.5
August	18.8	+0.5	10.4	+0.3	14.2	−0.2	14.4	−0.5	267.1	0.7	1	81.2	77.0	+12.6	157.4	+ 4.4	352	12.4	+3.4
September	16.0	+0.1	8.6	0.0	11.2	−0.3	12.7	0.0	189.9	1.5	1	44.9	28.6	−34.5	108.9	− 9.2	240	11.2	−0.1
October	13.8	+1.3	7.2	+1.0	9.0	+0.9	10.7	+1.0	142.6	4.0	5	20.4	56.8	− 4.9	101.5	+10.8	128	10.8	−0.8
November	8.8	+0.4	3.4	+1.2	4.5	+0.4	7.0	+1.1	41.6	41.0	14	4.9	30.5	−25.5	79.5	+12.5	68	7.5	−4.6
December	5.4	−0.9	−0.4	−1.2	1.0	−1.3	3.2	−0.4	6.4	115.5	22	4.0	54.4	−15.4	50.9	+10.5	36	6.7	−6.0

*Deviation from 1954-1983 average

†Deviation from 1959-1983 average

REVIEW

The Mathematical Art of Nature

JOHN CRAWFORD

---

art is a lie
that lets us recognise the truth.
Pablo Picasso.

Mathematics has until now, played an important yet back-seat role in biological science. Unlike the physical sciences where great strides have been made since Newton's time, the application of mathematics (statistical analysis aside) to biology has been limited to simulating empirical results. Whilst a worthwhile pursuit, it does not in itself lead to any understanding of the underlying mechanisms. However, recent developments in mathematics have lead to breakthroughs in the understanding of some very complex biological systems. These developments have required a novel approach to mathematical analysis which replaces the intuitive picture provided by the traditional techniques and tends toward a more pictorial representation of concepts. New geometries have had to be contemplated and classical philosophies on the mechanisms of Nature abandoned.

Impressionism

Biology is traditionally an empirical science in essentially the same way that physical science was in the pre-rennaisance period, over 300 years ago. It has not opened itself to theoretical analysis to anything like the extent of physics. Part of the reason for this perhaps lies in the great complexity of biological organisms. All forms of life, from viruses to human beings are composed of a complex hierarchy of intercommunicating subunits. For example a plant is made up of units responsible for light-gathering, nutrient uptake, and reproduction on the macroscopic scale; and functional units at the cellular level responsible for photon trapping, ion transport, and cell division. All of these units are coordinated by a highly complex communication network to optimise the reproductive capacity of the whole plant. It is not possible to study a particular part of the system in isolation, a common simplification used in the physical sciences, since the essence of its function lies in its contextual role within the organism as a whole. Thus we cannot study the development of a leaf in ignorance of the particular species under study, the age structure of the leaf population, the nutrient

uptake of the root, the mass of root, the developmental stage of the plant, the external environment, etc. It is for this reason that most of the headway in biological mathematics to date has been in simulation modelling. A simulation model is basically a mathematical synthesis of a number of experimental results which is so composed to allow extrapolation and interpolation: it simulates the behaviour of the system. Since there is no inherent understanding of the underlying mechanisms built into the model, the range of reliability is bounded by the range of experimentation on which the model is based. Nevertheless experiments can only be carried out under a very few number of circumstances due to constraints of time and money, and therefore a simulation model is an essential tool for predicting how a system will perform under a novel set of conditions. However, the major derivable benefit from simulation modelling is in highlighting critical areas of uncertainty, where a concentration of effort would lead to a significant improvement in the understanding of the whole system.

SCRI is currently developing a number of simulation models, in particular crop models describing the development and yield of potato and barley. The barley model is being developed in conjunction with a number of field trials to simulate development, tillering, yield and grain size as well as the distribution of nitrogen in the plant, with the goal of predicting malting quality under different nitrogen supply scenarios. The model comprises a fusion of experimental knowledge relating to each aspect of the interaction. Since nitrogen uptake is the only external variable which can be controlled by the farmer through the application of fertilisers, the model is designed to predict yield and malting quality as a function of timing and quantity of fertiliser application.

Potato is a non-deterministic crop in the sense that there is no intrinsic end to development and the crop can be harvested over an extended period of time. This is in contrast to the growth of barley which is marked by temperature driven stages of development which determine the beginning and end of the production of organs. In the SCRI potato model, the growth of biomass can therefore simply be calculated from a measure of total light energy absorbed and an experimentally derived relation between intercepted radiation and plant matter production. This relation is found to depend on the amount of soil water available to the plant, and account of this is taken by the model. The production of tubers is simulated by a partitioning of a fraction of this new growth to tuber development, and a good estimate of yield is obtained.

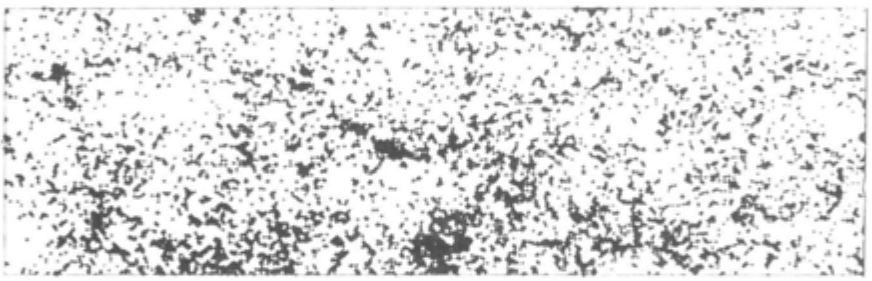
One aspect of agriculture which most of us are acutely aware of is weather. It dictates when the farmer can get on the land to cultivate, sow and harvest, and can have the strongest influence on the development and yield of the crop. Since long-range forecasts tend to be unreliable, and local weather variability tends to be significant, the decision of when to sow and when to harvest usually rests with the farmers experience and local

knowledge. This knowledge has to be built up over generations and depends on the general climatic trends remaining constant over that time. However, it is possible that man's continuous pollution of the atmosphere has brought about a potentially devasting circumstance that may soon alter that situation. This is what has become known as the 'greenhouse effect': the perturbation of the Earth's radiation budget by the steady accumulation of infrared absorbing gases, principally carbon dioxide, in the atmosphere. Although the predictions from climate simulation models are at present uncertain and contradictory, the concensus is that within the next two decades, temperatures in Northern Britain could be 1 to 2°C warmer. The accompanying change in the other weather variables are even more uncertain, but rainfall is predicted to increase and the distribution of precipitation throughout the year is likely to change. At the moment it is not known how significant these changes are likely to be for agriculture. SCRI has received a significant amount of funding to research the agricultural implications of global warming. The programme includes a sensitivity analysis of crop performance in relation to feasible future climate scenarios. This study will draw on simulation models to predict the effect on yield of higher carbon dioxide levels in conjunction with raised temperatures and different rainfall regimes. The potential impact of pests will also be quantified through the use of mathematical models which simulate the influence of accelerated plant development and altered cropping patterns in addition to weather, on the spread and impact of pests and diseases. This knowledge will then be incorporated into an artificial intelligence based decision-making tool which will help to advise the farmer on how to optimise productivity within the bounds of uncertainty presented by the novel climate. It makes maximum use of the information contained in models in conjunction with risk analysis to aid the farmer in management decisions where many interdependent factors contribute. In essence, the outcome of each possible decision is predicted by models and some measure of feasability attached to it. When every reasonable scenario has been simulated and a broad perspective obtained, a decision is made based on the scenario which had the best compromise between level of confidence and the most favourable outcome. SCRI currently has an active research area in this application of 'artificial intelligence'.

Simulation models are clearly very powerful tools for biological science in their ability to predict, as an aid to decision-making and to identify important areas of uncertainty. They are nevertheless only descriptions, and do not lead to an understanding of the mechanisms which give rise to the observations on which they are based. They can only be applied in limited situations unlike Newton's 'laws' which are apparently universal. To reach a deeper understanding we must use more powerful mathematics and approach the problems with a new philosophy.

Abstractionism

The 'Euclidean' geometry which the ancient Greeks held in so much esteem and with which we are all familiar, is composed of simple regular forms: 1-dimensional lines, 2-dimensional squares, 3-dimensional spheres and so on. These simple shapes form the basis of most man-made structures from railway lines to tower-blocks. Yet when we look at Nature, such simplicity of form is surprisingly absent. Waves, as they rise up and curl and crash onto the shore are made up of a complex hierarchy of superposed curves and folds down to the smallest ripple. Distant trees display an apparent regularity which breaks up upon closer inspection, into a multitude of branches of decreasing size from trunk to branch tip. The distribution of mass in the Universe is also far from homogenous. It seems that if mathematics is relevent to understanding Nature at even the simplest level, we must abandon the geometrical concepts handed down to us by the Greeks. Recent expositions of ideas that were around at the turn of the century suggest that the complex shapes of Nature can be studied using the most general unconstrained extension of the concepts of Euclidean geometry.



The distribution of brighter galaxies shows a non-homogenous clustering pattern. The fractal dimension of the distribution of mass in the Universe may relate to the mechanisms of galaxy-formation.

When the distances to galaxies are determined and their clustering properties analysed, it is found that the mass-density of the Universe is not independent of the size of the volume of space being studied. Nevertheless, the material is highly organised. If the distribution homogenously filled 3-dimensional space, then the mass of galaxies within a hypothetical box would double if the volume of the box containing them also doubled. However, the actual distribution of galaxies is clustered in a well ordered hierarchy. Our own galaxy is quite tightly gravitationally bound to a local group of galaxies. Groups such as these are somewhat less tightly bound to much larger galaxy clusters. On a larger scale, these clusters are themselves more loosely bound still to giant super-clusters, and so on. Since the clusters become more loosely bound as the scale of the clustering increases, the mass contained within a hypothetical box increases by only a factor of around

30% when the volume of the box is doubled — in other words the Universe is 1.2-dimensional! The fractional or 'fractal' dimension of an object describes the degree to which the mass of that object fills space, and is a fundamental characteristic of its geometry. Thus the distribution of mass in the Universe occupies the 3-dimensional Euclidian volume more effectively than a line but somewhat less than a plane. This is why it is called space.

At SCRI, we are currently studying the fractal properties of soil aggregates with the aim of understanding the processes of soil aggregation and the structural strength of different soil types. Only when these aspects of soil structure are understood can the dependence of root penetration and crop performance on soil type and tillage be exploited efficiently. According to the Griffith theory, the mechanism of structural failure is the propagation of a crack across the pores in an aggregate. Now, experimentation has shown that for dry soil aggregates at least, the strength of the aggregate decreases with its size: larger aggregates crack more easily. This observation can be reconciled with the Griffith theory if the pores in large aggregates represent a larger fraction of the total volume than in small aggregates i.e. if the aggregates are fractal. Measurements we have made support the fractal model with measured dimensions ranging from 2.7 to nearly 3 depending on soil type and tillage. However, the strength of an aggregate is irrelevent to crop processes if the root cannot gain purchase. Calculations based on the fractal nature of the soil suggest that roots should find larger aggregates easier to penetrate.

Recent work at the Institute has also revealed a fractal structure underlying the spatial pattern of certain soil fungi. Fungi are an important link in the chain of soil-borne organisms which play a vital role in nutrient cycling in the soil. Many types of fungi form mycelia composed of branching hyphae, and experiments indicate that the growth and production of branches is related to the spatial distribution of their food. Work has concentrated on the species *Trichoderma viride* grown on the surface of a homogenous nutrient substrate. Despite the homogeneity of the substate, the fungal colony developed a heterogenous structure which was fractal. The measured dimensions ranged from 1.4 to 2.0 and always increased with time for a particular colony. For the case where the dimension is 2, the colony had become a homogenous, space-filling structure which was no longer fractal. The fractal dimension of colonies reflects a compromise between explorative and exploitative foraging strategies. When the dimension is low, the structure is relatively unbranched and open, therefore distributing a given amount of mass across a larger area — exploration. For a higher dimension, the structure is highly branched and fills space more effectively with available mass — exploitation. The fractal structure of the colony is also the most effective for adapting to a dynamic nutrient environment. We have shown that a colony growing with a fractal branching pattern is capable of producing a self-perpetuating fractual structure which could automatically adapt the dimension across its extent

Photograph of a species of soil fungus grown on the surface of a thin nutrient film. The fractal dimension of this structure is around 1.8.

to exploit the distribution of nutrient in the soil with maximum efficiency. Fungi growing in this way would be particularly effective at exploiting heterogenously distributed food bases.

The architypal biological branching structures are of course trees. A great number of studies have concerned themselves with possible teleological strategies which determine the branching structures in a variety of trees. Some of these strategies are postulated to give rise to the observed patterns through a dynamical interation with the environment, whereas some others propose that the structure should have a genetic base. In reality both are

probably true, yet it has not been possible to isolate those genetic factors from purely environmental ones. By a subtle application of fractal statistical analysis, we were able to determine elements of the structure which are conserved within a given species of oak, independent of the environment of the particular part of the tree. Other elements appear to be subject to environmental modification. An underlying order was revealed in the structure, based on a minimal-code algorithm, the fractal nature of which may reveal the compactness of the genetic code. This analysis is currently being applied to root systems.

Kinetic Art

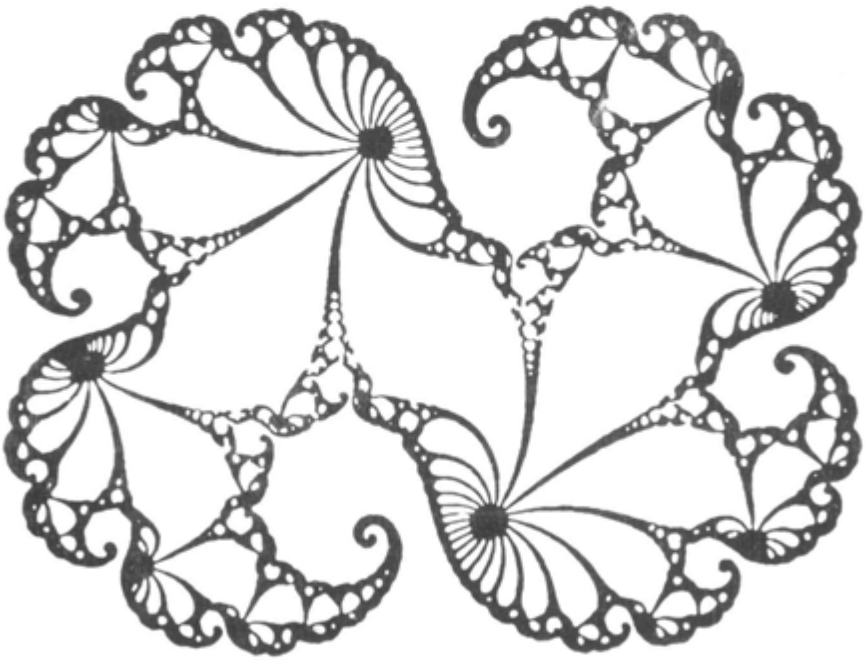
Anything which may be said in words relating to the physical qualities of a system, may be cast in mathematical form. Indeed most mathematical theories begin with some verbal hypothesis regarding the system. Mathematics may simply be regarded as an encapsulation of the logic of Nature. It is the self-consistency and formality of mathematics which are the key to its analytic power. Physical systems are characterised by 'state variables', i.e. those properties of the system which are of consequence and which may change with time. For example, the temperature and pressure of a gas completely define the state of the gas at a particular time. The temporal evolution of a system is described by differential equations which determine how the state variables change with time. Differential equations fall into two classes: linear and non-linear. In practical terms, the main distinction between the two is that the former can be solved analytically, whereas the latter generally cannot. An analytic solution is one which is expressible in algebraic form and is therefore directly translatable into words. For example, the solution of the linear differential equation of motion of a simple pendulum yields an algebraic expression relating the period T to the length l of the pendulum of the form:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

where g is the acceleration due to gravity. Now the value of such a form of solution is that it provides immediate access to an understanding of the rules which operate in the system: a 4-fold increase in the length of the pendulum doubles its period, *irrespective of the mass of the pendulum.* Unfortunately, the overwhelming majority of non-linear differential equations do not admit themselves to analytic solution, and even worse almost all of Nature is non-linear. To 'solve' a non-linear equation requires a great deal of tedious calculation. To begin, an initial state for the system is set by assigning values to the state variables. The evolution of the system is studied by applying the differential equations iteratively to generate a time sequence of numbers which represent the time evolution of the state variables. This technique when applied to the linear equations of motion of

the pendulum would yield a list of numbers giving the position of the mass as a function of time for the particular length l. The process would have to be repeated for many values of l and considerable time would have to be spent poring over the numbers before one could deduce that a 4-fold increase in length results in a 2-fold increase in period. Even then one could not be sure that a new value of l, or a different pendulum mass would result in disparate behaviour. The impractability of this method of solution is the reason why historically only the simplest, linear phenomena in Nature have yielded to theoretical insight. However, since the arrival of available computing power, the type of tedious calculation outlined above has become labour-free, and the non-linear picture of Nature is beginning to cystallize. To obtain this picture however, it has been necessary to develop visual tools to replace the descriptive power of the analytic solution: a sort of mathematical painting-by-numbers.

The recent flurry of work on non-linear theory has revolutionised our understanding of Nature and has given birth to a new science — chaos. Most non-linear systems, even very simple ones, have the propensity to generate irregular and unpredictable behavour which presumably reflects the apparent complexity in Nature. To gain insight into this behaviour, a



A Julia Set. Contained in this diagram is information relating to the stability of population levels in a simple ecological system. The intricacy of the shape which is fractal, is reflected in the complex dynamics of the ecosystem.

new type of pictorial representation of the evolution of a system has evolved. By plotting out the various state variables against one another, it is possible to define a 'state-space' for the system. A gas which has two state variables, can be represented by a two dimensional state-space with a point in that space representing a particular state of the system. The evolution of the system is then represented by the motion of that point in time, tracing out a curve in the state-space. For non-linear systems, the curves usually have highly complex and aesthetic geometric forms, possessing strange properties. For example, irrespective of the initial starting conditions of a system, the state is quickly attracted into a subset of the available state-space of the system where it remains. Once in this region, the system evolves along a well-defined but tortuous path, never returning to the same point twice — tracing a fractal curve of infinite length confined within a finite volume of space. Adjacent points in the state-space evolve rapidly away from one another, meaning that the future evolution of the system is impossible to predict when there is the slightest uncertainty in the initial state. The geometry of these 'strange attractors' is the essence of the observed behaviour of the system, and the ubiquitous fractal provides the insight. Fractal geometry has a role even in the most abstract representation of the mechanisms which underlie natural systems.

The Ikeda attractor. Embedded in a 2-dimensional state-space, this fractal attractor characterises the chaotic evolution of the population of a predator (x-axis) and the population of its prey (y-axis).

Chaos challenges the Newtonian dogma of clockwise determinism. Systems which evolve according to well-defined rules are not necessarily predictable in practice and this has serious implications for some areas of research. Theoretical ecology is concerned with understanding the population structure of ecosystems and what influences it. These studies are not only of fundamental importance in themselves, but are also of practical importance if we wish to understand the implications of some modification of the ecosystem either directly by man, or indirectly by anthropically induced climate change. Until quite recently it was assumed that population structures would remain constant in the absence of external perturbations on their environment such as caused by weather. However, controlling factors which depend on the population density such as overcrowding, introduce non-linear effects which result in non-steady and chaotically fluctuating population levels. Such density-dependent factors are generic to even the most simple ecosystem and make the job of understanding the population structure of flora and fauna, including pests and the incidence of disease, very difficult. Despite this, the existence of highly geometric strange attractors in the dynamical evolution of non-linear systems is the key to unravelling the under-lying mechanisms. The signature of an attractor in the dynamics is distinct from that of environmental noise, and allows some progress to be made in filtering out the overlying noise to study the dynamics underneath. The attractor is the fingerprint of the driving mechanisms, and therefore any theory which professes to offer some understanding of the system must also be able to reproduce the attractor. In the meantime the existence of chaotic behaviour warns the experimentor to design his or her experiment to minimise the impact of the dynamics, and to look to those aspects of the system which may cast some light on the sort of density-dependent effects which give rise to non-linearity.

It is clear that non-linearity is the key to understanding dynamical biology, and that even very simple systems can exhibit complex behaviour. Perhaps this type of constrained irregularity is the origin of the controlled randomness in ecosystems which creates the required diversity in species, through which adaptation via natural selection can take place. To study the possibilities offered by this new science, a non-linear dynamics group has recently been established at SCRI. Studies of the population dynamics of soil micro-organisms are underway, with the aim of understanding nutrient (especially nitrogen) cycling in the soil. We anticipate extending the study to the dynamics of aphid populations, the propagation of crop diseases, and to plant growth. An understanding of all these processes is fundamental to agriculture and indeed to biology in the wider view.

Futurism

Compared with the physical sciences, mathematics in biology is still in its infancy. In its own way, biological science may be experiencing a

Rennaisance some 300 years after the Newtonian revolution. Perhaps universal biological 'laws' may begin to turn up, leading to a whole new set of constants of Nature. Chaos theory may already have produced one in the Feigenbaum number δ, associated with the universal rate of transition from order into chaos. However in this context it is interesting that the current trend in physics is towards a unification of the plethora of laws into a single grand unified theory. Over the last 20 years or so, there has been a steady erosion of the so-called universal laws of Nature in physics. The electromagnetic and weak nuclear forces have been shown to be different realisations of the same phenomenon, for example. Many of the conservation laws have been found only to hold when experiments are conducted at the relatively low, unhostile temperatures at which they had been discovered. At millions of degrees celsius they break down. Even gravitation has come under scrutiny, with some experiments indicating that there may be a component of the gravitational force which acts as a short range repulsion between two masses. While some scientists argue that there has only ever been one fundamental law of Nature, others propose that there were none when the Universe was young, and show that the present order we observe may be an illusion created by the particular evolutionary stage of the Universe which is fit for the development of life. If this is the real picture of Nature, then mathematics may indeed be a lie, but one which will have let us recognise the truth.

REVIEW

Scottish Agricultural Statistics Service

ROB KEMPTON

The provision of statistical and mathematical support to SARIs and SAC is the responsibility of the Scottish Agricultural Statistics Service. Prior to 1987 a fragmented statistical service operated with some organisations relying on the AFRC Unit of Statistics at Edinburgh University, some on their own local statisticians and some getting by with no professional help. An AFRC review in 1985 recommended that there should be a single, centrally managed, service so that all SARIs and SAC could benefit from having access to a wider pool of statistical and mathematical expertise. As a consequence, the Scottish Agricultural Statistics Service (SASS) was established by DAFS in April 1987 as an administrative unit of SCRI, with its Headquarters on the King's Buildings science campus of Edinburgh University and with statistical units based at research institutes in Aberdeen, Ayr and Dundee.

Over the last three years, the unified service has improved the effectiveness of the statistical consultancy, research and training provided to SARIs and SAC. It has also attracted a large number of externally funded contracts and extensive international contacts.

Consultancy

About 80% of the DAFS grant to SASS is used to provide a consultancy service to SARIs and SAC. Consultancy is the prime responsibility of 15 statistical staff, 12 of whom are allocated to the five SARIs and 3 to SAC. Each statistical consultant is thus responsible for supporting approximately £2 million of DAFS R & D.

Statisticians do not provide a routine data processing service to SARIs and SAC but rather advise on appropriate statistical techniques and software for scientists to use in analysing their own data. This policy, which is supported by a programme of statistical training, allows statisticians the time to make a more innovative contribution to research programmes by tackling non-standard problems and identifying new areas of biological research requiring statistical or mathematical support.

For successful collaboration, it is essential that scientists should have close and informal contacts with the statistical consultants. This has been achieved by basing statisticians at institutes, or making regular weekly

visits. The success of this collaboration is reflected by the 41 papers published jointly with DAFS-funded scientists in refereed journals over the past three years.

Training

A major benefit coming from SASS has been the introduction of a programme of training courses for scientists. Courses, available as one or two-day modules, cover both basic statistics and more advanced techniques. These held in the past two years include: Basic Statistics in Minitab; Introduction to Genstat 5; Regression and Curve Fitting; Experimental Design and Analysis of Variance; Graphical Methods for Multivariate Data; Analysis of Unbalanced Data using REML; Experimental Design for Food Technology; Statistics for Quality and Introduction to Mathematical Modelling. Most courses provide hands-on computing experience with the statistical packages Minitab or Genstat, so that the techniques learnt can be put to immediate use. The use of audio-visual techniques for training has also been explored.

In a parallel development, SASS has been involved in the formation of a consortium of statistical groups, "Edinburgh Statistics Courses", which provides training for industry, commerce, the public services and research organisations. Twenty courses have taken place in the first two years, including two commissioned by ADAS.

With its strong university links and direct involvement with agricultural research, SASS is also well-placed to provide tuition and work experience in the application of statistics and data management techniques to statisticians and scientists from the developing world. With British Council support, we have recently received trainees from Brazil, China, Nepal and Sri Lanka.

Research

Some problems arising from statistical consultancy lead to collaborative research projects and often to joint publication with the scientists concerned. SASS has also initiated work in several key areas of agricultural, environmental and food science.

Two areas of increasing importance for DAFS are molecular biology and environmental studies. Molecular biology presents a new challenge for statisticians. There is a need to understand the biological processes and specialist terminology, and to handle the large quantities of data generated. The initial data handling problem has been solved by providing SARI/SAC scientists with access to the SEQNET service for molecular biology computing at SERC Daresbury Laboratory. SASS is now looking at some of the inferential and computational problems involved in comparing individual sequences against a large data base. Most work to date has been carried out by medical statisticians. An AFRS initiative is long overdue.

Environmental research also involves large quantities of data and the use of data bases. Here interest is moving from providing a simple description of the ecosystem, where multivariate methods have proved useful, to developing models to predict the effect of environmental change. Environmental data pose problems not normally found with agricultural data. Most environmental data is observational rather than experimental and interpretation may be complicated by many confounding factors. It is also often difficult to characterise data variability which makes statistical inference more problematical. An extreme example of this is the area of risk assessment where interest centres on estimating extremely small probabilities. SASS work is centred on MLURI and is strengthened by external contracts with environmental agencies in both terrestrial and marine science.

Another new area of SASS research concerns the analysis of data from sophisticated instruments, principally spectroscopes and imagers. At present, analysis of spectroscopic data relates primarily to near-infrared spectra. Work in image analysis is more wide ranging, including data from medical imaging equipment, satellite sensors and microscopes. The problem may be one of smoothing the image, segmenting the image into regions, matching sets of images or inferring a three-dimensional image from one or more two-dimensional cross-sections. While spectroscopic data provides a multivariate description of an object at a single point where the variables are ordered by wavelength, images provide a spatial representation of the object in two or three dimensions for a single variable. Multivariate images which combine these two factors could soon be produced, eg. in satellite remote sensing. These would provide an interesting area for further research.

Imaging and spectroscopic applications arise in many DAFS research programmes and thus represent appropriate research areas for a coordinated statistical approach by SASS. In a similar way, one statistician has taken responsibility for supporting mathematical modelling across SARIs and SAC. A recent survey showed that more than 50 DAFS-funded projects, from a wide range of research areas, include a large modelling component. A number of common problems exist which require further research. These include the accumulation of errors in large-scale systems models and the sensitivity of model prediction to model parameters.

Another area where the importance of the statistician is increasingly recognised is that of statutory regulations. Statistical procedures provide an effective way of matching the biological and technical realities with the objectives which underlie statutory obligations. In recent years SASS staff have been contributing to the development of national and international quality standards in areas such as crop production.

The development of a statistical theory for experimental design and analysis has led to enormous improvements in the efficiency of crop and animal experimentation throughout the world. Many of the important

principles and methods came from work at Rothamsted in the 1920s and 1930s, but the advent of inexpensive, high-speed computers has led to further developments including, in Edinburgh, the production of efficient, generalised designs for controlling variation and general methods of analysis for non-orthogonal data. Further work is required to deal with specialised problems in field experimentation, especially in relation to the wide variety of crops, cropping practices and environmental conditions met in the developing world.

There is, however, greater scope for introducing improved techniques of experimental design and analysis into other areas. One such area is food technology where SASS is involved with HRI in developing techniques of response surface design and sensory analysis.

In the next decade one can foresee major developments in the interface between molecular biology, physics and chemistry in which computers will play a key role in managing and interpreting the explosion of data coming from sources such as bio-sensors, image analysers and new analytical techniques. To meet these challenges the role of the statistician in computing is changing: statisticians increasingly work as part of multi-disciplinary teams, developing and implementing new computational methods for modelling and interpreting data. Early on, SASS recognised these challenges and staff have been working with colleagues in the SARIs, SAC and the universities to develop tools which will assist in the exploration of the new sources of information. Examples of such work include: developments of statistical software for interpretation of near infrared reflectance data on silage quality; and direction of an EC consortium on application of artificial intelligence and probabilistic reasoning in government forecasting.

Other Clients

In addition to its primary role of supporting DAFS-funded R & D in the SARIs and SAC, SASS carries out work, on a contract basis, for other organisations in the agricultural, environmental and food sectors. As well as attracting much needed additional income, SASS statisticians and the DAFS-funded work undoubtedly benefit from the experience gained from these wider contacts. Indeed a number of external contracts form part of larger commissions placed with a SARI or SAC.

Major contracts involve support for the DAFS statutory and regulatory work carried out by the Agricultural Scientific Services Division, East Craigs and for the UK plant variety testing authorities. SASS has also carried out work for other government departments, the European Commission, plant breeding companies, environmental agencies and other research organisations.

Other income is raised by the sale of SASS software and by training courses. External income is expected to exceed 25% of the total SASS budget in 1990/91.

The Way Ahead

Statisticians are facing a major challenge in adapting to the rapid scientific and technological developments in biology. Statisticians are now required to demonstrate greater mathematical expertise, as well as being at the forefront of computing developments. They may also need to show greater specialisation in the application of their expertise, if they are to gain a sufficient understanding of the biological and technical complexities of the research to make a significant contribution.

SASS provides the necessary structure for achieving these aims. With over twenty statistical staff, the group is of sufficient size to include a wide range of specialist expertise and also to provide opportunities for career development of staff. The university location of SASS Headquarters helps staff keep up to date with developments in statistics, mathematics and computing, while the permanent location of consultants at institutes ensures close attention is paid to the requirements of scientific researchers. SASS is already proving to be a key resource for DAFS research and is now set on building its reputation in agricultural, environmental and food science, throughout the UK and the international scientific community.

REVIEW

Recent Research on the Aetiology of Groundnut Rosette Disease

A. F. MURANT

The groundnut or peanut (*Arachis hypogaea*) originated in South America but is now grown throughout the tropical and warm temperate regions of the world. It is an important crop throughout Africa where it is the most widely grown grain legume. It is valued as a food and cash crop, not least because of its high content of digestible protein (25-34%) and oil (44-56%). It also provides an important source of foreign currency; for example in Malawi, groundnuts are the fourth most important export crop after tobacco, sugar and tea.

The most destructive virus disease of groundnut in Africa is rosette. The disease was first described from East Africa by Zimmermann (1907) and the most thorough early studies were by Storey & Bottomley (1928) in South Africa and Storey & Ryland (1955, 1957) in East Africa. They found that the causal agent is transmitted by the aphid *Aphis craccivora* and could also be transmitted experimentally, though with some difficulty, by rubbing sap from infected groundnut plants on to etiolated healthy groundnut plants. Rosette is now known to occur throughout Africa south of the Sahara, including Madagascar, but is not reported from other parts of the world. In some regions and in some years rosette occurs in devastating epidemics. Thus in 1975 it affected over 1 million hectares of groundnut in Nigeria, the overall yield loss being estimated at about 560,000 tonnes (Reddy, 1985). Because of the importance of the disease the Virology Department of SCRI has received research funding since 1986 from the Overseas Development Administration (Research Project No. R4148) and the Natural Resources Institute (Research Project No. X0011) to find out more about the viruses responsible and to develop diagnostic probes and control measures. In this work SCRI has collaborated with Dr K. R. Bock at the Malawi regional centre of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

Symptoms of rosette disease

Two main forms of rosette disease have been described, chlorotic rosette and green rosette (Hayes, 1932; Smartt, 1961; Hull & Adams, 1968). Chlorotic rosette is reported from most African countries south of the

Sahara, but green rosette is reported only from West Africa and Uganda. In chlorotic rosette the leaves show a bright yellow chlorosis which may affect the whole leaf or only parts of the leaf, in the latter event causing a mosaic. The symptoms may appear over almost the entire plant, or only in parts of the plant, affecting perhaps some shoots but not others, or the distal portions of shoots but not the proximal portions. In green rosette the leaves are darker green than normal, or show a light green/dark green mosaic, and are much reduced in size. In both forms there is stunting of the plants and this is especially severe in green rosette. Storey & Bottomley (1928) described a variant of chlorotic rosette from East Africa, called 'mosaic', in which the relative proportion of the green areas compared with the chlorotic areas is increased.

Causal agents

Symptoms of all these types of rosette are associated with infection by groundnut rosette virus (GRV; Okusanya & Watson, 1966; Reddy *et al.*, 1985*b*). Hull & Adams (1968) showed that transmission of GRV by *A. craccivora* depends on the additional presence in the source plants of a second virus, called groundnut rosette assistor virus (GRAV; Murant, 1989) which itself causes no obvious symptoms in groundnut. GRAV is a member of a plant virus taxonomic group called the luteoviruses (Casper *et al.*, 1983; Reddy *et al.*, 1985*a*) which characteristically are transmitted in a persistent (circulative) manner by aphids (i.e. for many days after acquisition, and after moulting) but are not transmissible by manual inoculation of sap; the virus particles are largely restricted to the phloem tissue of host plants and are isometric, about 28 nm in diameter. In contrast, GRV is manually transmissible, but no virus-like particles have been seen in plant sap. Its infectivity is associated with single-stranded RNA, of M_r 1.5 x 10^6 (4.6 kb) (Reddy *et al.*, 1985*b*). It is thought that, in mixed infections of GRAV and GRV, GRV RNA becomes packaged in shells composed of numerous subunits of GRAV coat protein to form particles that possess the infectivity of GRV but are transmissible by the aphid vector of GRAV.

(a) *GRAV*

In the early stages of the work at SCRI (Rajeshwari, Murant & Massalski, 1987), GRAV was found to react with several monoclonal antibodies (MAbs) that had already been prepared at SCRI to the distantly related virus, potato leafroll. One of these MAbs proved very useful in ELISA as a diagnostic probe for GRAV. Moreover this MAb was used to develop for the first time a purification procedure for GRAV (Rajeshwari & Murant, 1988), and this enabled us to raise a specific polyclonal antiserum to GRAV. The 28-nm diameter paticles of GRAV were shown to possess one species of single-stranded (ss) RNA (the genomic RNA) of M_r about 2.1 x 10^6 and a single species of protein of M_r about 24,000.

(b) *GRV and its satellite RNA*

It has not been possible to purify any virus particles from plants infected with GRV alone, or to obtain its RNA free from contamination with host plant RNA. However, plants infected with GRV from both the green and the chlorotic forms of rosette contain abundant double-stranded (ds) RNA not found in healthy plants (Reddy *et al.*, 1985*b*; Murant, Rajeshwari, Robinson & Raschké, 1988). Electrophoretic analyses (Murant *et al.*, 1988) show that such dsRNA preparations contain three major dsRNA species, two of which (dsRNA-1 and dsRNA-2) seem to be ds forms of genomic and sub-genomic ssRNA molecules of GRV; the other (dsRNA-3) can be eliminated from GRV cultures and has been shown to be a *satellite* RNA, i.e. a RNA species that cannot replicate on its own but depends on the replicase enzyme of another ('helper') virus, and is not essential for the multiplication of the helper virus.

(c) *Role of GRV satellite RNA in symptomatology of rosette*

Murant *et al.* (1988) found that a satellite-free isolate of GRV caused few or no symptoms in groundnut, but that reintroduction of dsRNA-3 restored the ability of the virus to induce rosette. This suggested that the satellite is the main cause of rosette disease. To investigate this further, Murant & Kumar (1990) obtained GRV cultures from a Nigerian groundnut plant with green rosette and from a Malawian groundnut plant with chlorotic rosette. They derived satellite-free isolates from each of them and then reintroduced the satellite RNA species from the two cultures in all possible homologous and heterologous combinations. The two satellite-free isolates induced only faint and transient symptoms in groundnut but the isolates into which the satellite RNA species were reintroduced induced rosette symptoms: both cultures containing the satellite RNA from Nigerian green rosette induced green rosette, and both cultures containing the satellite RNA from Malawian chlorotic rosette induced chlorotic rosette. Thus the different forms of rosette are mainly caused, not by different strains of GRV as had been thought previously, but by different forms of the satellite RNA.

The chlorotic form of rosette occurs throughout sub-Saharan Africa, whereas the green form is found only in West Africa and Uganda, and this suggests that the two forms of the satellite must have corresponding differences in geographical distribution. The reason for this is not clear, but, in our experiments, the satellite RNA from green rosette in Nigeria multiplied in association with satellite-free GRV from Malawi, showing that GRV isolates from East Africa are able to support the multiplication of the green rosette satellite. Although the symptoms of chlorotic rosette and green rosette are very different, they were considered to be caused by strains of the same virus long before Okusanya & Watson (1966) obtained evidence for this from cross-protection experiments. Our results, showing that the major difference between the two forms of the virus lies not in the

viruses themselves but in the satellite RNA molecules associated with them, suggest that the cross-protection observed by Okusanya & Watson (1966) actually occurs between the two satellites.

Other variants of the GRV satellite RNA

Storey & Ryland (1957) found that plants from Tanzania showing a 'mosaic' form of chlorotic rosette yielded two types of isolate, one, apparently a pure culture, causing faint mottle symptoms, and the other, probably not a pure culture, causing normal chlorotic rosette. They showed that plants infected with the 'mottle' isolate 14-35 days before inoculation with the chlorotic rosette isolate failed to develop chlorotic rosette, from which they inferred that the two viruses were related. Plants inoculated simultaneously with the two isolates developed mosaic rosette. Storey & Ryland (1957) concluded that mosaic rosette was caused by simultaneous infection with two strains (mild and chlorotic) of the same virus. Variations in the proportion of green areas in the mosaic were thought to depend on the relative prevalence of the two strains. We too have obtained a 'mottle' isolate, from Malawian groundnut plants exhibiting a mosaic form of rosette, and have shown that it resembles other GRV isolates in its dsRNA electrophoretic band pattern, including the presence of dsRNA-3. Our interpretation of these data is that the 'mottle' isolate contains a mild form of the satellite which induces only faint mottle and stunting symptoms in groundnut. This leads us to modify Storey & Ryland's (1957) conclusions by suggesting that plants with mosaic rosette contain a mixture of 'mottle' and 'chlorotic' forms of the satellite, rather than two forms of the same virus.

The satellite RNA used in the experiments of Murant *et al.* (1988) induced relatively mild rosette symptoms in groundnut, possibly because it was derived from a GRV culture that had been propagated continuously in *Nicotiana clevelandii* for 3 years. We have also discovered a further variant of the satellite which induces striking yellow blotch symptoms in *N. benthamiana* (I. K. Kumar, A. F. Murant & D. J. Robinson, unpublished data). These observations point to the existence of, not only 'green' and 'chlorotic', but of several other variants of the GRV satellite RNA ('mottle', 'mild', 'yellow blotch').

Role of the GRV satellite RNA in aphid transmission of GRV

A further twist in the complicated aetiology of rosette disease was discovered (Murant, 1990) when plants infected with the various satellite-containing and satellite-free GRV cultures described above were co-infected with GRAV and then used as sources for transmission experiments with *A. craccivora*. Aphid transmission of GRV occurred only from plants that also contained both GRAV and the satellite RNA. This was true

whether the satellite was from GRV cultures from Nigeria or Malawi, or from plants with the green or chlorotic forms of rosette. All the isolates transmitted were found to possess satellite RNA, as shown by the presence of dsRNA-3 in dsRNA preparations from infected plants. Thus aphid transmission of GRV depends on the presence in the source plants not only of GRAV, as already reported (Hull & Adams, 1968), but also of the satellite RNA. This probably explains why the satellite has been found in all naturally occurring GRV isolates so far examined. This discovery of an essential role of the satellite RNA in the biological survival of GRV is intriguing because in no other instance has a satellite nucleic acid been shown to be necessary for the aphid transmission of a plant virus.

Resistant groundnut cultivars

An important way of controlling rosette disease is to grow resistant groundnut cultivars. Resistance to rosette was first found in groundnut germplasm originating from adjacent regions of Burkino Faso and Cote d'Ivoire (Sauger & Catharinet, 1954*a*, *b*; De Berchoux, 1958) and material from this region has been the source of resistance for all rosette-resistant cultivars developed since (Dhéry & Gillier, 1971). The resistance, which seems to be effective against both chlorotic rosette (De Berchoux, 1960) and green rosette (Harkness, 1977), does not amount to immunity (Sauger & Catharinet, 1954*a*, *b*; De Berchoux, 1960; Nutman, Roberts & Williamson, 1964). It is governed by two independent recessive genes (De Berchoux, 1960; Nigam & Bock, 1990). Because of these factors and the elaborate screening procedures involved, breeding for this form of resistance is slow and laborious, and cultivars that possess resistance along with other desirable agronomic characters are difficult to obtain. Resistant cultivars are therefore still not widely grown in most parts of Africa. One piece of information that would be of some help in the breeding work is to know towards which of the viral agents associated with rosette the resistance is directed. Because groundnut plants infected by GRAV are symptomless, and those infected by satellite-free isolates of GRV are either symptomless or show only a transient mottle, and because some forms of the satellite RNA induce only mild symptoms in groundnut, plants that show no symptoms could nevertheless be infected by one or more components of the virus complex.

Armed with knowledge about the various viral agents involved in groundnut rosette disease, and with means of detecting them, we have now shown (Bock, Murant & Rajeshwari, 1990) that groundnut genotypes possessing resistance to rosette disease are fully susceptible to GRAV, and become readily (and symptomlessly) infected with it in the field, but are highly resistant (though not immune) to GRV and therefore to its satellite RNA.

Future work

Much of the work done so far at SCRI on rosette disease has been concerned with unravelling its aetiology, which has proved unexpectedly complicated. The next phase of the work will be to learn more about the molecular biology of the causal agents. Apart from the light this will shed on the way these viruses replicate and interact with each other, we hope this work will enable us to develop better diagnostic tools and to employ the newer techniques of genetic engineering to introduce new types of resistance into groundnut. We are grateful to the Overseas Development Administration, the Natural Resources Institute and and the Centre for Arid Zone Studies for continuing funding for this work.

References

BOCK, K. R., MURANT, A. F. & RAJESHWARI, R. 1990. The nature of the resistance in groundnut to rosette disease. *Annals of Applied Biology* **117,** (in press).

CASPER, R., MEYER, S., LESEMANN, D.-E., REDDY, D. V. R., RAJESHWARI, R., MISARI, S. M. & SUBBARAYADU, S. S. 1983. Detection of a luteovirus in groundnut rosette diseased groundnuts (*Arachis hypogaea*) by enzyme-linked immunosorbent assay and immunoelectron microscopy. *Phytopathologische Zeitschrift* **108,** 12-17.

DE BERCHOUX, C. 1958. Étude sur la résistance de l'arachide a la rosette en Haute-Volta. Premiers résultats. *Oléagineux* **13,** 237-239.

DE BERCHOUX, C. 1960. La rosette de l'arachide en Haute-Volta. Comportement des lignées résistantes. *Oléagineux* **15,** 229-233.

DHÉRY, M. & GILLIER, P. 1971. Un nouveau pas dans la lutte contre la rosette de l'arachide. Résultats obtenus en Haute-Volta avec les nouveaux hybrides. *Oléagineux* **26,** 243-251.

HARKNESS, C. 1977. The breeding and selection of groundnut varieties for resistance to rosette virus disease in Nigeria. In *Submission to the African Groundnut Council, June 1977, Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria,* pp. 1-45.

HAYES, T. R. 1932. Groundnut rosette disease in the Gambia. *Tropical Agriculture, Trinidad* **9,** 211-217.

HULL, R. & ADAMS, A. N. 1968. Groundnut rosette and its assistor virus. *Annals of Applied Biology* **62,** 139-145.

MURANT, A. F. 1989. Groundnut rosette assistor virus. *AAB Descriptions of Plant Viruses* No. 345, 4 pp.

MURANT, A. F. 1990. Dependence of groundnut rosette virus on its satellite RNA as well as on groundnut rosette assistor virus for transmission by *Aphis craccivora*. *Journal of General Virology* **71,** (in press).

MURANT, A. F. & KUMAR, I. K. 1990. Different variants of the satellite RNA of groundnut rosette virus are responsible for the chlorotic and green forms of groundnut rosette disease. *Annals of Applied Biology* **117,** (in press).

MURANT, A. F., RAJESHWARI, R., ROBINSON, D. J. & RASCHKÉ, J. H. 1988. A satellite RNA of groundnut rosette virus that is largely responsible for symptoms of groundnut rosette disease. *Journal of General Virology* **69,** 1479-1486.

NIGAM, S. N. & BOCK, K. R. 1990. Inheritance of resistance to groundnut rosette virus in groundnut (*Arachis hypogaea*). *Annals of Applied Biology* **117,** (in press).

NUTMAN, F. J., ROBERTS, F. M. & WILLIAMSON, J. G. 1964. Studies on varietal resistance in the groundnut, (*Arachis hypogaea* L.) to rosette disease. *Rhodesian Journal of Agricultural Research* **2,** 63-77.

OKUSANYA, B. A. M. & WATSON, M. A. 1966. Host range and some properties of groundnut rosette virus. *Annals of Applied Biology* **58,** 377-387.

RAJESHWARI, R. & MURANT, A. F. 1988. Purification and particle properties of groundnut rosette assistor virus and production of a specific antiserum. *Annals of Applied Biology* **112,** 403-414.

RAJESHWARI, R., MURANT, A. F. & MASSALSKI, P. R. 1987. Use of monoclonal antibody to potato leafroll virus for detecting groundnut rosette assistor virus by ELISA. *Annals of Applied Biology* **111,** 353-358.

REDDY, D. V. R. 1985. Groundnut rosette virus disease: the present situation and research needs. In *Collaborative Research on Groundnut Rosette Virus: Summary Proceedings of the Consultative Group Meeting, 13-14 April, 1985, Cambridge, U.K.*, pp. 8-10. Eds D. V. R. Reddy, D. McDonald & R. W. Gibbons. ICRISAT, Patancheru, India.

REDDY, D. V. R., MURANT, A. F. DUNCAN, G. H., ANSA, O. A., DEMSKI, J. W. & KUHN, C. W. 1985*a*. Viruses associated with chlorotic rosette and green rosette diseases of groundnut in Nigeria. *Annals of Applied Biology* **107,** 57-64.

REDDY, D. V. R., MURANT, A. F., RASCHKÉ, J. H., MAYO, M. A. & ANSA, O. A. 1985*b*. Properties and partial purification of infective material from plants containing groundnut rosette virus. *Annals of Applied Biology* **107,** 65-78.

SAUGER, L. & CATHARINET, M. 1954*a*. La rosette chlorotique de l'arachide et les lignées selectionnées. *L'Agronomie Tropicale* **9,** 28-36.

SAUGER, L. & CATHARINET, M. 1954*b*. Nouvelles observations sur la rosette chlorotique de l'arachide et les lignées selectionnées. *Annales du Centre de Recherches Agronomiques de Bambey au Sénégal. Année 1953. Bulletin Agronomique* **11,** 204-216.

SMARTT, J. 1961. The diseases of groundnuts in Northern Rhodesia. *Empire Journal of Experimental Agriculture* **29,** 79-87.

STOREY, H. H. & BOTTOMLEY, A. M. 1928. The rosette disease of peanuts (*Arachis hypogaea*). *Annals of Applied Biology* **15,** 26-45.

STOREY, H. H. & RYLAND, A. K. 1955. Transmission of groundnut rosette virus. *Annals of Applied Biology* **43,** 423-432.

STOREY, H. H. & RYLAND, A. K. 1957. Viruses causing rosette and other diseases in groundnuts. *Annals of Applied Biology* **45,** 318-326.

ZIMMERMANN, A. 1907. Über eine Krankheit der Erdnüsse (*Arachis hypogaea*). *Der Pflanzer* **3,** 129-133.

REVIEW

Potato Cyst Nematodes — A Perspective of Past, Present and Future Trends in Research

DAVID TRUDGILL

Historical

Potato cyst nematodes (PCN) were introduced into Europe along with potatoes from their centres of origin in S. America and there may have been several separate introductions. The first could have been with potatoes brought into the Canary Islands by the Spanish as early as the mid 1550s. However damage to crops by PCN was not recorded in Europe until the 1880s, initially in Germany and later in England.

As PCN spread throughout Europe, its full potential as a pest became recognised and measures to control it began to be formulated. It was soon realised that PCN was spread on infected seed and in Scotland a seed certification scheme was introduced in 1944 to limit its distribution. Nevertheless PCN was present in most ware growing areas by the 1950s. Methods were developed to detect the presence of cysts in the soil and in the 1950s and 1960s the Government Advisory Services processed thousands of soil samples each year to advise farmers planning to plant potatoes on likely levels of damage. At that time the only method of control which could be recommended was the adoption of long rotations.

Research which was commenced in the 1950s showed that potatoes and tomatoes were the only hosts and that in the absence of a host, the juvenile nematodes lay dormant within the dead body of the female which forms the cyst. Substances exuded from the roots of the hosts stimulated mass hatch and the juveniles (up to 400 from each cyst) invaded the growing roots. The damage to the root systems associated with invasion is responsible for the reduction in plant growth and consequent loss of crop yield. Once in the roots, the juveniles induce the formation of special, multinucleate, enlarge cells (syncytia) which supply them with all their nutrition. Juveniles associated with large syncytia become female, while those which, through the effects of over crowding or other adverse factors (e.g. resistance), induce only small syncytia become males.

It was thought that isolation and characterisation of the 'hatching factor' and its application to soil to artificially stimulate hatching in the absence of the host offered potential for control but, in spite of much research effort,

nothing effective was developed. Chemicals were also tested for nematicidal activity and these included toxic compounds such as mercuric oxide and dichloropropene, a fumigant which was expensive and of only limited effectiveness in cool, wet soils. More recently two highly effective, granular nematicides (aldicarb — Temik and oxamyl — Vydate) have been produced which are highly effective at low recommended dose rates (3 to 5 kg a.i./ha) and largely prevented PCN from multiplying.

In the early 1950s resistance to PCN was discovered in a clone of *Solanum tuberosum* subsp. *andigena* in the Commonwealth Potato Collection and it was quickly realised that it would revolutionise the control of the nematode. The resistance was shown to be controlled by a single dominant gene (coded H1), the effect of which was to prevent the proper induction of the feeding syncytia and the development of females. The gene was incorporated into new varieties amongst which Maris Piper produced at the Plant Breeding Institute and Pentland Javelin from the Scottish Plant Breeding Station were the most successful.

However, it soon became clear that some populations of PCN, including one from Duddington, near Edinburgh, completely overcame the H1 resistance and bred normally. Subsequently, J. Dunnet at the Scottish Plant Breeding Station discovered a second gene (named H2) which was effective against the Duddington population. Other populations able to overcome both the H1 and H2 resistance genes were soon discovered and a pathotype scheme was developed to describe the increasingly complex relations between host and nematode genotypes. Those populations which could not reproduce on cultivars with the H1 gene were called pathotype A, those which overcame the H1 but not the H2 gene were pathotype B and those which overcame both genes were designated pathotype E. Subsequently, it was noticed that adult females of pathotype A turned yellow, whereas those of pathotypes B and E remained cream or white. Electrophoretic analysis of their proteins confirmed that A differed from B and E populations and it was shown that pathotype A would not interbreed with B or E. This resulted in the genus name being changed from *Heterodera* to *Globodera* and to pathotype A being recognised as a separate species (*G. rostochiensis*) from pathotypes B and E (*G. pallida*).

Recent research

The production of new cultivars with resistance to *G. pallida*, which was found to be widely distributed in northern England, has been a major objective of the plant breeder. The main sources of resistance were *Solanum vernei* and a clone of *S. tuberosum* subsp. *andigena*. It was shown that the resistance from both these sources was inherited in a quantitative (polygenic) manner. As a consequence, the progeny had only partial resistance and were less resistant than their parents. Much back-crossing and inter-crossing has been required to produce clones with both good levels of resistance and commercial qualities and the programme has been

very protracted. However, three cultivars with partial resistance to both *G. pallida* and *G. rostochiensis* have been released; Morag, bred at SCRI Sante, bred in the Netherlands, and Nadine from Caithness Potatoes.

The breeding of partially resistance cultivars brought a series of new problems which included the need for an accurate means of assessing the level of partial resistance. A small scale "canister test" was developed at SCRI and is now used at several centres. There was also a growing realisation that populations of *G. pallida* and *G. rostochiensis* differed in their ability to reproduce on partially resistant clones and this led in 1977 to a new pathotype scheme which recognised three pathotypes of *G. pallida* and five of *G. rostochiensis*. However, we showed that the test conditions strongly influenced the multiplication rates of PCN on partially resistant clones, creating problems in classifying new cultivars and anticipating their performance when grown in the field. In addition, studies on the relationship between numbers of PCN at planting and damage to the plant showed that whilst some resistant cultivars were less damaged (i.e. more tolerant) than susceptible cultivars, others were much more intolerant, especially some with *S. vernei* resistance.

A series of international trials, co-ordinated by SCRI, established that partially resistant clones generally ranked in the same order of resistance. The European Plant Protection Organisation is likely to adopt this principle as a basis for classifying the resistances of new clones by comparing them to known partially resistant standard cultivars using a 1-9 scale. The research also showed that in the UK there was a continuous range in the virulence of *G. pallida* populations on ex *vernei* clones and that most populations could not be readily assigned to distinct pathotypes.

The method of screening for tolerance developed at SCRI eliminated a number of intolerant ex *vernei* clones and equally, it identified others with both good resistance and tolerance. The research revealed the importance of both top and root growth characteristics in relation to tolerance, and field trials established the relationship between tolerance and the effects of PCN in reducing nutrient uptake and rates of fertiliser application. Further research showed how yield losses and PCN multiplication rates can be modelled on cultivars with different levels of tolerance and resistance and how tolerant, partially resistance cultivars can be treated with reduced rates of nematicides in an integrated pest control strategy.

Present and future research

A 'Topic Review' for PCN held at SCRI in 1988 produced a consensus amongst nematologists, plant breeders, farmers and others that a more basic approach was required to find durable solutions to the problems posed by PCN, and especially by *G. pallida*. The existing nematicides have a high mammalian toxicity and may be seen as environmentally hazardous and, where they have been used repeatedly, there is increasing evidence that they are providing less effective control. Furthermore, producing

resistant cultivars was seen as a race against the nematode, their repeated growing selecting virulent PCN against which the potato breeders have to find and incorporate new genes for resistance. Hence, in the UK the growing of cultivars with the H1 gene has led to widespread replacement of avirulent *G. rostochiensis* (pathotype Ro1) with virulent *G. pallida* and in the Netherlands, a virulent pathotype (Ro3) of *G. rostochiensis* has also been selected. Furthermore, a population of *G. pallida* has been found recently which can overcome completely the partially resistant cv. Morag.

Because of the weaknesses in our present control strategies, there will be a greater emphasis on more basic investigations which might lead to novel means of control. One such area of research involves 'recognition' studies which attempt to understand how PCN recognises host roots; how resistant plant recognise avirulent nematodes but fail to recognise virulent nematodes; how fungi which are potential biocontrol agents recognise their nematode prey; and how viruses which are transmitted by nematodes recognise and stick to their site of retention in the nematode stylet. Lectins are being used to aid many recognition studies. A lectin is a naturally occurring protein which recognises and binds to a specific carbohydrate and there are a range of lectins which bind to different carbohydrates. When lectins are labelled with a fluorescent marker, or with ferretin, they can be used with light or electron microscopy to localise different carbohydrates on a nematode. They are being used to study the nature of the exudate from nematode amphids (a pair of sense organs on the nematode head which are thought to be chemo-sensory). Blocking the amphids with a specific lectin has been shown to greatly reduce the ability of PCN juveniles to find its host root and invade, and at least one agrochemical company is investigating the possibility of incorporating a lectin gene into potato as a means of controlling PCN. Interestingly, juveniles of the wheat ear cockle nematode (*Anguina tritici*) are completely covered by a carbohydrate to which wheat lectin specifically binds. As a consequence, invading juveniles are covered by the wheat lectin and probably masked from the host, thereby avoiding recognition and the triggering of host defence mechanisms.

Understanding the mechanisms and genetic basis of the interactions between PCN and resistant and susceptible plants are high priorities. Monoclonal and polyclonal antibodies are being used to identify both nematode surface components and gland cell secretions. Another objective is to identify the different introductions of PCN, their virulence characteristics and their associated gene pools by analysing their isozymes using electrophoresis and their DNA by restriction fragment length polymorphisms. Part of this programme will involve interbreeding virulent and avirulent nematodes so that particular isozymes or pieces of labelled DNA can be linked to virulence, the eventual aim being to identify avirulence genes and the nature of resistance. Mitochondrial DNA, which is cytoplasmic rather than nuclear and which is exclusively maternally inherited, will be a

priority target as evidence has already been obtained that there are differences which can be used to identify the different introductions of PCN.

These approaches should identify the different virulence groups of PCN and hence appropriate populations can be chosen for use in screening potato clones from breeding programmes. It should enable us also to determine whether recently discovered populations of *G. pallida* which totally overcome the resistance of cv. Morag derive from a different introduction to the bulk of populations to which Morag has a good level of resistance. If this proves to be the situation, we should then be able to produce highly sensitive probes capable of identifying the introduction present in any given field, and from this information choose the most appropriate resistant cultivar.

The Zoology Department collaborates closely with the Department of Cellular and Molecular Genetics in efforts to identify and isolate resistance genes for engineering into existing susceptible cultivars. With the Crop Genetics Department, we are planning to identify the distinct genes giving resistance to *G. pallida* and to understand the genetics of PCN virulence. Equally, we have close contacts with the Colleges of Agriculture and the Agricultural Development and Advisory Services in England. Together we have a grant from the Potato Marketing Board to investigate the use of partially resistant cultivars in the field. The results will be used to extend to PCN the potato yield models developed by the Cellular and Environmental Physiology Department.

Two PhD students are also investigating aspects of PCN; one is studying host finding by juvenile nematodes and the other is comparing the virulence and biochemical and molecular characteristics of populations from the Canary Islands with populations from northern Europe.

Research on PCN at SCRI spans almost the full range of potential areas of relevant investigation. In the short to medium term the outlook is for *G. pallida* to become a more widespread problem and for increased reliance on partially resistant cultivars used, where possible, in an integrated control programme with the judicious use of nematicides. We have already shown that such cultivars will select for increased virulence in PCN, but our results suggest this will be relatively slow and, in part, will tend to be specific to the cultivars grown. In the longer term we are exploiting several new and exciting possibilities which will add greatly to our basic knowledge and provide novel and more durable means of control.

PUBLICATIONS

ACOSTA, O. & MAYO, M. A. 1989. Particles and proteins of raspberry ringspot nepovirus. *Abst. Xth Congress Ascolfi, Vth Reunion AIF & XXIXth Reunion Annual APS-CD*, Cali, Colombia p. 75.

ACOSTA, O. & MAYO, M. A. 1990. Accumulation of different types of raspberry ringspot nepovirus particle in infected *Nicotiana* protoplasts. *Journal of General Virology* **71,** 713-717.

ACOSTA, O. & MAYO, M. A. 1990. Unusual electrophoretic properties of the coat protein of raspberry ringspot nepovirus. *Intervirology* **31,** 31-37.

AITON, M. M., MUNIYAPPA, V., ROBERTS, I. M. & HARRISON, B. D. 1989. Recognition and serological relationships of seven whitefly-transmitted geminiviruses from India. *Abstracts Association of Applied Biologists Meeting*, Norwich, 1989, 15.

ALLISON, M. J., BROWN, A. T. & FREEMAN, P. L. 1989. Rapid prediction of malting quality in barley using a novel technique of Near Infrared plus principal components analysis. *Proceedings of the 22nd European Brewing Convention*, Zurich, 1989, 229-234.

ANDERSON, H. A., BRACEWELL, J. M. FRASER, A. R., JONES, D., ROBERTSON, G. W. & RUSSELL, J. D. 1988. 5-Hydroxymaltol and mycophenolic acid, secondary metabolites from Penicillium echinulatum. *Transactions of the British Mycological Society* **91**(4), 649-651.

ANGANUZZI, A. A. & BUCKLAND, S. T. 1989. Reducing bias in estimated trends from dolphin abundance indices derived from tuna vessel data. *Report of the International Whaling Commission*, **39,** 323-334.

ARTHUR, J. R., McPHAIL, D. B. & GOODMAN, B. A. 1989. The effect of selenium and vitamin E deficiences on the spin trapping of free radicals in homogenates of rat heart. In: Hurley, L. S., Keen, C. L., Lonnerdal, B. & Rucker, R. B. Trace Elements in Man and Animals 6, Plenum Press, New York, 257-258.

BAIN, R. A., PÉROMBELON, M. C. M., TSOR, L. & NACHMIAS, A. 1990. Blackleg development and tuber yield in relation to number of *Erwinia carotovora* subsp. *atroseptica* on seed potatoes. *Plant Pathology* **39,** 125-133.

BALL, B. C., LANG, R. W., O'SULLIVAN, M. F. & FRANKLIN, M. F. 1989. Cultivation and nitrogen requirements for continuous winter barley on a gleysol and a cambisol. *Soil and Tillage Research* **13,** 333-352.

BARKER, H. 1989. Specificity of the effect of sap-transmissible viruses in increasing the accumulation of luteoviruses in co-infected plants. *Annals of Applied Biology* **115,** 71-78.

BARKER, H. 1989. Analysis of polygenically controlled resistance in potato to potato leafroll virus. *Abstracts 4th International Plant Virus Epidemiology Workshop*, Montpellier, France, 1989, 56-59.

BARKER, H. & SOLOMON, R. M. 1990. Evidence of simple genetic control in potato of ability to restrict potato leafroll virus concentration in leaves. *Theoretical and Applied Genetics* (in press).

BENGOUGH, A. G. 1990. The penetrometer in relation to mechanical resistance to root growth. In *Soil Analysis: Physical Methods* (eds. K. A. Smith and C. E. Mullins), Marcel Dekker inc., New York (in press).

BIRCH, A. N. E. 1989. Interactions between root flies and brassica roots — clues to alternative control strategies. *Aspects of Applied Biology* **22,** 289-296.

BIRCH, A. N. E. 1989. A field cage method for assessing resistance to turnip root fly in brassica. *Annals of Applied Biology* **115,** 321-325.

BIRCH, A. N. E. 1989. Resistance and susceptibility to turnip root fly in brassicas. *Proceeding 5th IOBC/WPRS/Eucarpia Working Group Breeding for Resistance to Insect and Mites*, Morges, Switzerland, 1989 (in press).

BIRCH, A. N. E. & JONES, A. T. 1989. Resistance to the virus vector aphid *Amphorophora idaei* in raspberries. *Proceedings 5th IOBC/WPRS/Eucarpia Working Group Breeding for Resistance to Insects and Mites*, Morges, Switzerland, 1989 (in press).

BIRCH, A. N. E., JONES, A. T. & ROBERTSON, G. 1989. Further studies in resistance in raspberry genotypes to raspberry aphid biotypes. *Aphid Resistance Newsletter* **4,** 2.

BIRCH, A. N. E., JONES, A. T., ROBERTSON, G. W. & HARRINGTON, M. 1989. Further studies on the chemical basis for resistance to *Amphorophora idaei* in red raspberry. *International Society for Horticultural Science Working Group on Virus Diseases of Small Fruits Newsletter* No. 7, 5.

BIRCH, A. N. E. GRIFFITHS, D. W. & MACFARLANE SMITH, W. H. 1990. Changes in forage and oilseed rape (*Brassica napus* L.) root glucosinolates in response to attack by turnip root fly (*Delia floralis*). *Journal of the Science of Food and Agriculture* **51** (3), 309-320.

BOAG, B. 1989. Factors controlling plant-parasitic nematodes under agricultural conditions. *Aspects of Applied Biology* **22,** 315-322.

BOAG, B. 1990. The unusual geographical distribution of the plant-parasitic nematode *Longirus vineacola*. *Hebridean Naturalist* **10,** (in press).

BOAG, B. & BROWN, D. J. F. 1989. Field sampling for detecting virus transmitting nematodes and their associated viruses. *Mededelingen van de Faculteit Landbouwwetenschappen Rijksuniversiteit, Gent* **54/36,** 1125-1132.

BOAG, B., BROWN, D. J. F. & BANCK, A. S. G. 1989. Optimising sampling strategies for nematode-transmitted viruses and their vectors. *EPPO/OEPP Bulletin* **19,** 491-499.

BOAG, B., MACFARLANE SMITH, W. H. & GRIFFITHS, D. W. 1989. Effects of double low varieties of oilseed rape on mammalian wildlife. *Aspects of Applied Biology* **23,** 287-293.

BOAG, B., MACFARLANE SMITH, W. H. & GRIFFITHS, D. W. 1989. Effect of the wild rabbit (Oryctolagus cuniculus) on the growth and yield of oilseed and fodder rape (*Brassica napus* ssp. *oleifera* L.). *Crop Protection* **9,** 155-159.

BOAG, B., TOPHAM, P. B. & WEBSTER, R. 1989. Spatial distribution on pasture of infective larvae of gastro-intestinal nematode parasites of sheep. *International Journal of Parasitology* **19,** 681-685.

BOAG, B., BROWN, D. J. F. & NEILSON, R. 1990. Spatial distribution of plant-parasitic nematodes. *Aspects of Applied Biology* **22,** 307-314.

BOAG, B., MACFARLANE SMITH, W. H. & GRIFFITHS, D. W. 1990. Observations on the grazing of double low oilseed rape and other crops by roe deer. *Applied Animal Behaviour Science* **26,** (in press).

BRADSHAW, J. E. & GRIFFITHS, D. W. 1990. Selection for high and low thiocyanate ion content in kale (*Brassica oleracea* var. *acephala*). *Annals of Applied Biology* **116,** 157-167.

BRADSHAW, J. E. & GRIFFITHS, D. W. 1990. Sugar content of swedes for stockfeeding. *Journal of the Science of Food and Agriculture* **50,** 167-172.

BRADSHAW, J. E., BIRCH, A. N. E., GEMMELL, D. J. & WILLIAMSON, C. J. 1989. Progress at SCRI in breeding swedes (*Brassica napus* L. ss. *rapifera*) with improved disease and pest resistance. *Aspects of Applied Biology* **23,** 15-21.

BRENNAN, R. 1989. The new releases — black currants from SCRI. *Grower* **112** (16), 23-27.

BRENNAN, R. M. & CORMACK, M. R. 1989. Evaluating alternative fruit crops for the UK. *AFRC Science for Growers*, 4-5.

BRENNAN, R., DAVIDSON, D., WILSHIN, A. & MILLAM, S. 1989. An assessment of the in vitro multiplication rates of fourteen black currant cultivars. *Journal of Horticultural Science* **64,** 679-681.

BRENNAN, R., MILLAM, S., DAVIDSON, & WILSHIN, A. 1989. The establishment of an in vitro Ribes germplasm collection and preliminary investigations into low temperature storage for use in a Ribes genetics programme. *Acta Horticulturae* (in press).

BROWN, D. J. F. 1989. Viruses transmitted by nematodes. *EPPO/OEPP Bulletin* **19,** 453-461.

BROWN, D. J. F. 1989. Specificity of transmission of nepoviruses by *Longidorus* and *Xiphinea* vector nematodes. *Proceedings of the Dutch Virologists Meeting*, Wageningen, The Netherlands, p. 4.

BROWN, D. J. F. & BOAG, B. 1989. Field sampling for detecting virus transmitting nematodes and their associated viruses. *Proceedings of the 41st International Symposium on Crop Protection*, Gent, Belgium, p. 78.

BROWN, D. J. F. & TRUDGILL, D. L. 1989. Evolution of transmission of nepoviruses by longidorid nematodes. *Aspects of Applied Biology* **22,** 73-81.

BROWN, D. J. F. & TRUDGILL, D. L. 1989. The occurrence and distribution of nepoviruses and their associated vector *Longidorus* and *Xiphinema* nematodes in Europe and the Mediterranean basin. *EPPO/OEPP Bulletin* **19,** 479-489.

BROWN, D. J. F., PLOEG, A. T. & ROBINSON, D. J. 1989. The association between serotypes of tobraviruses and *Trichodorus* and *Paratrichodorus* species. *EPPO/OEPP Bulletin* **19,** 611-617.

BROWN, D. J. F., PLOEG, A. T. & ROBINSON, D. J. 1989. Specificity of transmission of tobravirus variants by their vector (*Para*)*Trichodorus* nematodes. *Journal of Nematology* **21,** 553.

BROWN, D. J. F., PLOEG, A. T. & TRUDGILL, D. L. 1989. Specificity of transmission of nematode transmitted viruses. *Mededelingen Faculteit van de Landbouwwetenschappen Rijksuniversiteit Gent* **54/3b,** 1105-1113.

BROWN, D. J. F., PLOEG, A. T. & TRUDGILL, D. L. 1989. Specificity of transmission of nematode transmitted viruses. *Proceedings of the 41st International Symposium on Crop Protection*, Gent, Belgium, p. 74.

BROWN, D. J. F., TAYLOR, C. E. & TRUDGILL, D. L. 1989. Variation in virus transmission among longidorid vector nematode populations. *Journal of Nematology* **21,** 553.

BROWN, J. W. S. & WAUGH, R. 1989. Maize U2snRNAs: gene sequence and expression. *Nucleic Acids Research* **17,** No. 22, 8991-9001.

BROWN, J. W. S., SIMPSON, C. & WAUGH, R. 1989. Pre-mRNA processing in monocots: UsnRNA and intron sequences. *EMBO Molecular Communication in Higher Plants, Heidelberg.*

BROWNE, M. J., CHAPMAN, C. G., DODD, I., REAVY, B., ESMAIL, A. & ROBINSON, J. H. 1989. The role of tissue-type plasminogen activator A-chain domains in plasma clearance. *Fibrinolysis* **3,** 207-214.

BUCKLAND, S. T. 1989. Modelling perpendicular distance data from line transect surveys. In Donovan G. P. (ed.). *The Comprehensive Assessment of Whale Stocks: the early years*, International Whaling Commission, Cambridge. Pp 63-68.

BUCKLAND, S. T. & DUFF, E. I. 1989. Analysis of the Southern Hemisphere minke whale mark-recovery data. In Donovan G. P. (ed.). *The Comprehensive Assessment of Whale Stocks: the early years*, International Waling Commission, Cambridge. 121-143.

BURCH, L. R. & HORGAN, R. 1989. The purification of cytokinin oxidase from *Zea mays* knals. *Phytochemistry* **28,** 1313-1319.

CALIGARI, P. D. S. & POWELL, W. 1989. Variability in response of potato cultivars to micropropagation. I. *In vitro* performance. *Annals of Applied Biology*. **115,** 121-128.

CARNEGIE, S. F., GANS, P. T. JELLIS, G. J., LITTLE, G., LOGAN, C. & WASTIE, R. L. 1989. The susceptibility of potato cultivars to gangrene in laboratory tests in relation to origin of tubers, damage, method of inoculation and test centre. *Potato Research* **32,** 301-309.

CARROLL, C. P. & DEMAINE, M. J. 1989. The agronomic value of F1 hybrids between potatoes of Group Tuberosum and Group Phureja/Stenotomum. *Potato Research* **32,** 447-456.

CHAMBERS, R. D., SHEPHERD, T., TAMURA, M. & BRYCE, M. R. 1989. Novel synthesis and regiospecific cycloaddition reactions of perfluoro-3-methylbut-1-yne. *Journal of the Chemical Society, Chemical Communications* **21,** 1657-1658.

CHAMBERS, R. D., SHEPHERD, T. & TAMURA, M. 1990. Photochemistry of Halogencarbon Compounds, Part 5. Photolysis of fluorinated 1,2,3-Triazine derivatives. *Journal of the Chemical Society, Perkin Transactions* **1** (in press).

CHAMBERS, R. D., SHEPHERD, T., TAMURA, M. & HOARE, P. 1990. Photochemistry of Halogenocarbon Compounds, Part 6. Direct observation of fluorinated azetes. *Journal of the Chemical Society, Perkin Transactions* **1** (in press).

CLEMENTS, R. O. & BOAG, B. 1990. Effects of pesticides on white clover (*Trifolium repens*) establishment, nematodes and weeds. *Tests of Agrochemicals and Cultivars* No. 11 (*Annals of Applied Biology* **116,** Supplement) (in press).

COIRO, M. I., ALPHEY, T. J. W. & AGOSTINELLI, A. 1988. A bivulval female of *Trichodus viruliferus*. *Nematologia Mediterranea* **116,** 239-240.

COIRO, M. I., ALPHEY, T. J. W. & AGOSTINELLI, A. 1989. Distribution of trichodorids in the vineyards of the province of Trento (North-eastern Italy). *Nematologia Mediterranea* **17,** 45-53.

COIRO, M. I., LAMBERTI, F., BORGO, M. & BROWN, D. J. F. 1988. I. Longidoridae nei vigneti provincia di Treviso. II. Contributo: Il genere *Longidorus* (Micoletzky) Filipjev. *Nematologia Mediterranea* **16,** 189-195.

COOPER-BLAND, S. C., BAIRD, E., DE,MAINE, M., KUMAR, A., FORSTER, B. P. WAUGH, R. & POWELL, W. 1989. Towards somatic hybridisation of dihaploid potato lines. *In: Proceedings of the 1st International Symposium on "The molecular biology of the potato"*, Bar Harbour, Maine, USA.

COOPER-BLAND, S., BAIRD, E., DE,MAINE, M., KUMAR, A., FORSTER, B. P., WAUGH, R. & POWELL, W. 1989. Towards somatic hybridisation of dihaploid potato lines. In: Proceedings of the 49th Easter School Conference 'Genetic Engineering of Crop Plants' Nottingham University, UK.

CORMACK, M. R. 1989. Growers and processors in Scotland set to meet the challenge. *Grower* **112,** No. 20, 14-15.

CORMACK, M. R. & GORDON, S. L. 1989. Report of trials with the Korvan harvester 1989. Report commissioned by Tayside Region Industrial Office.

CORMACK, M. R. 1989. Raspberry harvester about to go on trial. *The Scottish Farmer*, **96,** 5047, 20.

CORMACK, M. R. & GORDON, S. L. 1990. Raspberry cultivar trial 1980-85. SSCR Occasional Publication No 9.

COWE, I. A., CUTHBERTSON, D. C. & SWANSTON, J. S. 1989. The effect of moisture and nitrogen levels on milling energy of barley. *Journal of the Institute of Brewing* **95,** 423-425.

COWE, I. A., McNICOL, J. W. & CUTHBERTSON, D. C. 1989. Reconstruction of constituent spectra for individual samples through Principal Component analysis of near-infrared spectra. *Analyst* **114,** 683-687.

DALE, M. F. B. & BROWN, J. 1989. The use of foliage assessment to improve the identification of tolerance to damage by nematodes (*Globodera pallida*) in potatoes. *Annalsof Applied Biology* **115,** 313-319.

DALE, A., McNICOL, R. J. MOORE, P. P. & SJULIN, T. J. 1989. Pedigree analysis of red raspberry. *Acta Horticulturae No. 262*, 35-39.

DALE, M. F. B. 1989. Advances in breeding for Tobacco Rattle Virus insensitivity in potatoes. *Aspects of Applied Biology* **22,** Roots and the Soil Environment, 87-92.

DAVIES, H. V. & TALBOT, L. S. 1989. Studies on the physiological basis for genotypic variation in susceptibility of tubers to Internal Rust Spot- a calcium related disorder. *American Potato Journal* **66,** 514.

DAVIES, H. V., MACKERRON, D. K. L., MARSHALL, B. & BAYLIS, A. 1989. Effect of paclobutrazol-nitrogen interactions on tuber yield and quality. *American Potato Journal* **66,** 513-514.

DAVIES, H. V., RICHARDSON, D. L., ROSS, H. A. & MACKAY, G. R. 1989. Invertase and hexose accumulation in stored tubers. *American Potato Journal* **66,** 514-515.

DE,MAINE, M. J., STEWART, H. E. & PHILLIPS, M. S. 1989. The production of dihaploids and tetraploids with combined quantitative resistance to potato cyst nematode (*Globodera pallida*) and foliage blight (*Phytophthora infestans*). *Potato Research* **32,** 425-430.

DERRICK, P. M. 1989. An investigation into the mode of action of the herbicide M & B 39279. *Ph.D. Thesis,* Nottingham Polytechnic.

DIGARD, P., BLOK, V. C. & INGLIS, S. C. 1989. Complex formation between influenza virus polymerase proteins expressed in *Xenopus* oocytes. *Virology* **17,** 162-169.

DIXON, G. R., KERSHAW, C. D. & HUNTER, E. A. 1989. Crop yields from lucerne (*Medago sativa*) cultivars displaying gradations in resistance to wilt (*Verticillium albo-atrum*). *Journal of Agricultural Science,* **112,** 387-394.

DUNCAN, J. M., KENNEDY, D. M. & SCOTT, P. H. 1990. Relationships between non-papillate soilborne species of Phytophthora: root rot of raspberry. *British Mycological Society Symposium* **17:** Phytophthora (in press).

DUNCAN, J. M. 1990. *Phytophthora* species attacking strawberry and raspberry. *EPPO/ OEPP Bulletin* **20,** 107-115.

DUTHIE, G. G., McPHAIL, D. B., ARTHUR, J. R., GOODMAN, B. A. & MORRICE, P. C. 1990. Spin trapping of free radicals and lipid peroxidation in microsomal preparations from malignant hyperthermia susceptible pigs. *Free Radical Research Communications* **8,** 93-99.

ELLIS, R. P., SWANSTON, J. S. TAYLOR, K. & BRUCE, F. M. 1989. Environmental constraints on the efficiency of selection for malting quality in barley. *Annals of Applied Biology* **114,** 349-357.

ELSTON, D. A. & GLASBEY, C. A. 1989. Simulating from a mixture of exponential distributions with some negatively weighted components. *Journal of Statistical Computation and Simulation,* **33,** 1-9.

ELSTON, D. A., GLASBEY, C. A. & NEILSON, D. R. 1989. Non-parametric lactation curves. *Animal Production* **48,** 331-339.

FARGETTE, D., McGRATH, P. F., McNICOL, J. W., AITON, M. M. & HARRISON, B. D. 1989. Multivariate analysis of antigenic variation among geminivirus isolates associated with cassava mosaic disease. *Proceedings of the IVth International Plant Virus Epidemiology Workshop,* Montpellier, France, 1989, 281-283.

FARMER, M-J. 1989. Studies on monoclonal antibodies to the particle proteins of a potyvirus and a nepovirus. *Ph.D. Thesis,* University of Dundee.

FASSEAS, C., ROBERTS, I. M. & MURANT, A. F. 1989. Immunogold localization of parsnip yellow fleck virus particle antigen in thin sections of plant tissue. *Journal of General Virology* **70,** 2741-2749.

FINNIE, S. J., CAWSTON, D., FORSTER, B. P., MILLAM, S. & POWELL, W. 1989. Studies on the development and utilisation of barley anther culture techniques. In: *Proceedin of the International Conference "The impact of biotechnology in agriculture",* Amiens, France.

FINNIE, S. J., POWELL, W., & DYER, A. F. 1989. The effect of carbohydrate composition and concentration on anther culture response in barley (*Hordeum vulgare* L.). *Plant Breeding* **103,** 110-118.

FORREST, R. S. & LYON, G. D. 1989. Release of phytoalexin eliciting oligogalacturonides from potato cell walls by polygalacturonic acid lyase. *Proceedings Fifth Cell Wall Meeting,* Edinburgh, 1989, Abstract No. 125.

FORREST, R. S. & LYON, G. D. 1990. Substrate degradation patterns of polygalacturonic acid lyase from *Erwinia carotovora* and *Bacillus polymyxa,* and release of phytoalexin-eliciting oligosaccharides from potato cell walls. *Journal of Experimental Botany* **41,** 481-488.

FORSTER, B. P. 1988. Wide corsses in wheat. Project No. R3798 Report 1988 to the United Kingdom Overseas Development Administration.

FORSTER, B. P. & MILLER, T. E. 1989. Genome relationship between *Thinopyrum bessarabicum* and *Thinopyrum elongatum*. *Genome* **32,** 930-931.

FRAME, J., HARKESS, R. D. & TALBOT, M. 1989. The effect of cutting frequency and fertiliser nitrogen rate on herbage productivity from perennial ryegrass. *Research and Development in Agriculture* **6,** 99-105.

FRITSCH, C. & MAYO, M. A. 1989. Satellites of plant viruses. In C. L. Mandahar, (ed.). *Plant Viruses. Vol. I. Structure & Replication*. CRC Press: Boca Raton, Florida, 289-321.

GOODMAN, B. A. 1989. The use of Mossbauer spectroscopy in the study of colloidal materials. In: De Boodt, M. F. L., Hayes, M. H. B. & Herbillon, A.(eds). *Soil Colloids and their Associations in Aggregates*, D. Reidel, Dordrecht, 119-140.

GOODMAN, B. A. & NADEAU, P. H. 1989. Electron paramagnetic resonance study of non-exchangeable vanadium (IV) in rectorites. *Clay Minerals* (in press).

GOODMAN, B. A., McPHAIL, D. B. & DUTHIE, D. M. L. 1989. Electron spin resonance of some irradiated foodstuffs. *Journal of the Science of Food and Agriculture* **47,** 101-111.

GORDON, S. C. & LAWSON, H. M. 1989. The double dart moth, a target for urgent control. *Grower* **112,** 38-40.

GORDON, S. C. & MILLER, P. C. H. 1989. Spraying into the 1990s in Northern Britain. *Scottish Farming Leader*, May 17-18.

GORDON, S. C., BARRIE, I. A. & WOODFORD, J. A. T. 1989. Predicting spring oviposition by raspberry cane midge from accumulated derived soil temperatures. *Annals of Applied Biology* **115,** 419-427.

GORDON, S. C. & WOODFORD, J. A. T. & BARRIE, I. A. 1990. Monitoring pests of red raspberry in the United Kingdom and the possible implementation of an integrated pest management system. *In:* Monitoring and Integrated Managements of Arthropod Pests of Small Fruit Crops. Ed. N. J. Bostanian, L. T. Wilson & T. J. Dennehy. Intercept Ltd, Andover, pp. 1-26.

GRAHAM, J., McNICOL, R. J. & KUMAR, A. 1989. Development and utilisation of genetic transformation method in the genus *Rubus*. In: *Proceedings of the Horticultural Biotechnology Symposium (Abstracts)*, University of California, Davis, USA.

GRAHAM, J., McNICOL, R. J. & KUMAR, A. 1990. Use of the GUS gene as a selectable marker for *Agrobacterium* mediated transformation of *Rubus*. *Plant Cell, Tissue and Organ Culture* **20** (in press).

GRANT, S. A., BARTHAM, G. T. & ELSTON, D. A. 1989. Problems of estimating tissue turnover on grass swards in the presence of grazing animals. *Grass and Forage Science*, **44,** 47-54.

GRIFFITHS, D. W. 1989. Polyphenolics and their possible effect on nutritional value. In: D'Mello, J. P. F., Duffus, C. M. & Duffus, J. N. (eds). Antinutritional Factors, Potentially Toxic Substances in Plants. *Aspects of Applied Biology* **19,** 93-103.

GRIFFITHS, D. W. & MacFARLANE SMITH, W. H. 1989. Variation in S-methyl cysteine sulphoxide concentration with harvest date in forage rape (*Brassica napus*). *Journal of the Science of Food and Agriculture* **47,** 249-252.

HARRISON, B. D. 1989. Transgenic virus resistance: approaches, efficacy and durability. *Abstracts Association of Applied Biologists Meeting*, Norwich, 1989, 7.

HARRISON, B. D. 1989. Book review: The Plant Viruses, Vol. 4, The Filamentous Plant Viruses, R. G. Milne (ed). *Society for General Microbiology Quarterly* **16,** 93.

HARRISON, B. D. 1990. Book review: Viruses with Fungal Vectors, J. I. Cooper & M. J. C. Asher (eds). *Plant Pathology* **39,** 210.

HARRISON, B. D. & AITON, M. M. 1989. Detection and differentiation of whitefly-transmitted geminiviruses with monoclonal antibodies. *Summaries of the International Symposium on Crop Protection*, Gent, 1989, 51.

HARRISON, B. D. & MURANT, E. A. 1989. Prospects for satellite-mediated transgenic virus resistance. *Proceedings of the IVth International Plant Virus Epidemiology Workshop*, Montpellier, France, 1989, 17-19.

HARRISON, B. D., BARKER, H. & DERRICK, P. M. 1990. Intercellular spread of potato leafroll luteovirus: effects of co-infection and plant resistance. In Fraser, R. S. S. (ed). *Recognition and Response in Plant-Virus Interactions*. Heidelberg, Springer-Verlag, 405-414.

HARRISON, J. G. BARKER, H., LOWE, R. & REES, E. A. 1990. Estimation of amounts of *Phytophthora infestans* mycelium in leaf tissues by enzyme-linked immunosorbent assay. *Plant Pathology* **39** (in press).

HEIBERG, N., DUNCAN, J., KENNEDY, D. M. & SEMB, L. 1989. Raspberry root rot in Norway. *Acta Horticulturae* **262,** 189-191.

HEILBRONN, T. D. & MACKERRON, D. K. L. 1989. The relative importance of sources of variance in the grade distribution of potato tubers. *Abstracts AAB meeting on "Variability in Plant Monocultures — Physiology, Ecology and Economic Aspects"*.

HEILBRONN, J. & LYON, G. D. 1990. The ineffectuality of potato protease inhibitor on the extracellular protease from *Erwinia carotovora* subsp. *carotovora*. *Journal of Applied Bacteriology* **69** (in press).

HINTON, J. C. D., SIDEBOTHAM, J. M., HYMAN, L. J., PÉROMBELON, M. C. M. & SALMOND, G. P. C. 1990. Genetic analysis of *Erwinia carotovora* subsp. *atroseptica* pathonicity factors. *General Molecular Genetics* **217** 141-148.

HODGSON, J. C., KING, T., HAY, L. & ELSTON, D. A. 1989. Biochemical and haematological evidence for the involvement of endotoxin in the pathogenesis of watery mouth disease in lambs. *Research on Veterinary Science*, **47,** 119-124.

HODGSON, V. J., MILLAM, S. & CRAIG, W. E. 1989. Effects of a range of maltose and sucrose concentrations on morphogenic response in floral internodes of *Brassica oleracea*. *Cruciferae Newsletter* **14** (in press).

INNES, N. L. 1989. Breeding for resistance to soil-borne pests and diseases. *Aspects of Applied Biology* **22,** 153-164.

JEFFERIES, R. A. 1989. Water-stress and leaf growth in field-grown crops of potato (*Solanum tuberosum* L.). *Journal of Experimental Botany* **40,** 1375-1381.

JEFFERIES, R. A. 1990. Water-stress, leaf growth and radiation interception in potato crops. Abstract of paper given at EAPR Physiology Section Meeting, Gross Lusewitz 1989. *Potato Research* **33,** (in press).

JEFFERIES, R. A. & MACKERRON, D. K. L. 1989. Radiation interception and growth of irrigated and droughted crops of potato (*Solanum tuberosum* L.). *Field Crop Research* **22,** 101-112.

JEFFERIES, R. A., HEILBRONN, T. D. & MACKERRON, D. K. L. 1989. Estimating tuber dry matter concentration from accumulated thermal time and soil moisture. *Potato Research* **32,** 411-417.

JENNINGS, D. L. & BRYDON, E. 1989. Further studies on resistance to *Leptosphaeria coniothyrium* in the red raspberry and related species. *Annals of Applied Biology* **115,** 499-506.

JENNINGS, D. L. & BRYDON, E. 1989. Further studies on breeding for resistance to *Botrytis cinerea* in red raspberry canes. *Annals of Applied Biology* **115,** 507-513.

JENNINGS, D. L. & JONES, A. T. 1989. Further studies on the occurrence and inheritance of resistance in red raspberry to a resistance-breaking strain of raspberry bushy dwarf virus. *Annals of Applied Biology* **114,** 317-323.

JENNINGS, D. L. & McNICOL, R. J. 1989. Black raspberries and purple raspberries should be spine-free and tetraploid. *Acta Horticulturae* No. 262, 89-92.

JENNINGS, D. L. & McNICOL, R. J. 1989. Segregation of plants with abnormal flowers in a blackberry breeding programme. *Crop Research* **29,** 51-54.

JONES, A. T. 1989. A new virus detected in 'Himalaya Giant' blackberry. *International Society for Horticultural Science Working Group on Virus Diseases of Small Fruits Newsletter* No. 7, 2.

JONES, A. T., BIRCH, A. N. E., HARRINGTON, M. & ROBERTSON, G. W. 1989. Characterisation of resistance in raspberry to the virus vector aphid, *Amphorophora idaei*. *Proceedings of the IVth International Plant Virus Epidemiology Workshop*, Montpellier, France, 1989, 96-98.

JONES, A. T., MITCHELL, M. J., BIRCH, A. N. E., BROWN, D. J. F. & JENNINGS, D. L. 1989. Recent research on the control of virus infections in raspberry in Britain. *Acta Horticulturae* **236,** 81-89.

JONES, A. T., MITCHELL, M. J. & BROWN, D. J. F. 1989. Infectibility of some new raspberry cultivars with arabis mosaic and raspberry ringspot viruses and further evidence for variation in British isolates of these two nepoviruses. *Annals of Applied Biology* **115,** 57-69.

JONES, A. T., BIRCH, A. N. E. & CORMACK, M. R. 1990. Levels of resistance to *Macrosiphum euphorbiae* infestation in raspberry genotypes differing in resistance to *Amphorophora idaei*. *Tests of Agrochemicals and Cultivars* No. 11 (*Annals of Applied Biology* **115,** Supplement), pp. 104-105.

JONES, A. T., KOENIG, R., LESEMANN, D-E., HAMACHER, J., NIENHAUS, F. & WINTER, S. 1990. Serological comparison of isolates of cherry leaf roll virus from diseased beech and birch trees in a forest decline area in Germany with other isolates of the virus *Journal of Phytopathology* (in press).

KENNEDY, D. M. & THOMSON, M. 1989. End of an era for raspberry growers? *Tayside Farmer* **63,** 42.

KENNEDY, D. M. & DUNCAN, J. M. 1990. Fungicidal control of red stele in strawberry cultivars differing in resistance to the disease. *Advances in Strawberry Production* **9,** 24-26.

KNIGHT, V. H., JENNINGS, D. L. & McNICOL, R. J. 1989. Progress in the UK raspberry breeding programme. *Acta Horticulturae* No. 262, 93-103.

KUMAR, A., REAVY, B. & MAYO, M. A. 1989. Production of transgenic potato plants containing the coding sequences for coat protein of potato leafroll virus. *Abstracts of the Horticulture Biotechnology Symposium*, Davis, California, 1989, p. 68.

KUMAR, A. & FORREST, J. M. S. 1990. Reproduction of the potato cyst nematode *Globodera rostochiensis* on transformed root cultures of *Solanum tuberosum* cv. Desiree. *Journal of Nematology* **22** (in press).

LANHAM, P. G. & HOUGHTON, J. A. 1988. The isolation and partial characterization of UV sensitive mutants of Synechococcus PCC7943 (*Anacystis nidulans* 602). *Photochemistry and Photobiology* **48,** 73-76.

LANHAM, P. G. & HOUGHTON, J. A. 1988. Weigle-reactivation in a cyanobacterium (Synechococcus PCC7934) is induced by UV but not by mitomycin-c or naladixic acid. *Photochemistry and Photobiology* **48,** 473-475.

LAWSON, H. M. 1989 Prospects for weed control in fodder brassicas. *Aspects of Applied Biology* **23,** 245-250.

LAWSON, H. M. & WISEMAN, J. S. 1989. Alternatives to dinoseb-in-oil for cane desiccation in red raspberry in Scotland. *Acta Horticulturae* **262,** 373-379.

LAWSON, H. M. & WISEMAN, J. S. 1989. Tolerance of potato seedlings to a range of cereal herbicides. *Tests of Agrochemicals and Cultivars* No. 10, (*Annals of Applied Biology* **114,** Supplement), 118-119.

LAWSON, H. M. & WISEMAN, J. S. 1989. An evaluation of four possible desiccant treatments for cane vigour control in raspberry. *Tests of Agrochemicals and Cultivars* No. 10, (*Annals of Applied Biology* **114,** Supplement), 120-121.

LAWSON, H. M., WISEMAN, J. S. & WRIGHT, G. McN. 1989. Tolerance of seed potato to two new residual herbicide mixtures. *Proceedings of 1989 Brighton Crop Protection Conference — Weeds*, Brighton, 1989, 847-852.

LESEMANN, D-E., KOENIG, R., TORRANCE, L., BUXTON, G., BOONEKAMP, P. M., PETERS, D. & SCHOTS, A. 1990. Electron microscopical demonstration of different binding sites for monoclonal antibodies on particles of beet necrotic yellow vein virus. *Journal of General Virology* **71,** 731-733.

LINEHAN, D. J. 1989. Mobilisation of nutrients in the rhizosphere and their uptake by plants. Roots and the Soil Environment, *Aspects of Applied Biology* **22,** 183-189.

LYON, G. D. & McGILL, F. M. 1989. Inhibition of polygalacturonase and polygalacturonic acid lyase from *Erwinia carotovora* subsp. *carotovora* by phenolics *in vitro*. *Potato Research* **32,** 267-274.

LYON, G. D., NEWTON, A. C., & REGLINSKI, T. 1990. A novel approach to the control of plant diseases using non-toxic yeast extracts. *The Grower* **113** (12), 25-26.

MACFARLANE SMITH, W. H. & CALIGARI, P. D. S. 1989. The potential for cross-prediction in forage rape (*Brassica napus* L.). *Aspects of Applied Biology* **23,** 51-65.

MACKERRON, D. K. L. 1989. Quantified responses of the potato crop to water stress. *Proceedings of the Potato Research Symposium*, Warmbaths, RSA. Addendum, 1-5.

MACKERRON, D. K. L. 1990. Agrometeorology of the potato crop. *Conference Proceedings: Application of Remote Sensing to Agricultural Statistics*, October 1989, Varese, Italy (in press).

MACKERRON, D. K. L. & GILL, P. A. 1989. Tuberizace a rust hliz (Tuberization and growth of tubers). *Conference Proceedings: Fysiologie Rustu A Dormance Brambor (Physiology of Growth and Dormancy in the Potato)*, September 1989, Jihlava, Czechoslovakia, 128-149.

MACKERRON, D. K. L. & PENG, Z. Y. 1989. Genotypic comparisons of potato root growth and yield in response to drought. *Aspects of Applied Biology* **22,** 199-206.

MACKERRON, D. K. L. & PENG, Z. Y. 1989. Relations between root and shoot growth: Genotypic differences in response to water-stress. (Abstract) *Potato Research* **33** (in press).

MACKIE-DAWSON, L. A., BUCKLAND, S. T., DUFF, E. I., PRATT, S. M., REID, E. J. MILLARD, P. 1989. The use of in-situ techniques for the investigation of root growth. *Aspects of Applied Biology 22, Roots and Soil Environment,* 349-356.

MAYO, M. A. 1990. Book review: Virology: Directory and Dictionary of Animal, Bacterial and Plant Viruses. *Plant Pathology* **39,** 339.

MAYO, M. A. & REAVY, B. 1989. DNA sequence encoding the coat protein gene of potato leafroll virus. *European Patent Application* No. 89311941.2.

McDOUGALL, G. J. & FRY, S. C. 1989. Anti-auxin activity of xyloglucan oligosaccharides: the role of groups other than the terminal ∝-L-fucose residue. *Journal of Experimental Botany*, **40,** 233-239.

McDOUGALL, G. J. & FRY, S. C. 1989. Structure-activity relationships for xyloglucan oligosaccharides with anti-auxin activity. *Plant Physiology* **89,** 883-887.

McDOUGALL, G. J. & FRY, S. C. 1989. Xyloglucan oligosaccharides, cellulase and growth. (abstract). *Proceedings of the 5th Cell Wall Meeting*, Edinburgh, UK, **52.**

McDOUGALL, G. J. & FRY, S. C. 1990. Xyloglucan oligosaccharides promote growth and activate cellulase: evidence for a role of cellulase in cell expansion. *Plant Physiology* (in press).

MCGECHAN, M. B., SAADOUN, T., GLASBEY, C. A. & OSKOUI, K. E. 1989. Estimation of combine harvesting work-days from meteorological data. *The Agricultural Engineer*, **44,** 66-71.

McGRATH, P. F. 1989. Vector relationships and disease epidemiology of barley yellow dwarf virus in Northern England. *Ph.D.Thesis*, University of Leeds.

McGRATH, P. F. & BALE, J. S. 1989. Cereal aphids and the infectivity index for barley yellow dwarf virus (BYDV) in Northern England. *Annals of Applied Biology* **114,** 429-442.

McNICOL, R. J. & GRAHAM, J. 1989. Genetic manipulation in Rubus and Ribes. *Acta Horticulturae* No. 262, 41-46.

McNICOL, R. J. & WILLIAMSON, B. 1989. Systemic infection of black currant flowers by *Botrytis cinerea* and its possible involvement in premature abscission of fruits. *Annals of Applied Biology* **114,** 243-254.

McNICOL, R. J., WILLIAMSON, B. & YOUNG, K. 1989. Ethylene production by black currant flowers infected by *Botrytis cinerea*. *Acta Horticulturae* No. 262, pp. 209-215.

McNICOL, R. J. WILLIAMSON, B. & DOLAN, A. 1990. Effects of inoculation, wounding and temperature on post-harvest grey mould (*Botrytis cinerea*) of red raspberry. *Journal of Horticultural Sicence* **65,** 157-165.

MILLAM, S. 1988. Applications of the biotechnology of oilseed rape. *Ph.D.Thesis*, The Polytechnic, Wolverhampton, UK.

MILLAM, S. 1989. Agrobacterium mediated transformation of Brassica species. *Aspects of Applied Biology* **23,** 23-30.

MILLAM, S. 1989. Induction of Agrobacterium tumours on seedlings and in vitro plantlets of *Brassica napus*. *Cruciferae Newsletter* **14** (in press).

MILLAM, S., DAVIDSON, D., DICK, H., CRAIG, W. & POWELL, W. 1989. Transformation of Brassica lines using rapid-cycling material and lines containing marker genes. In: *Proceedings of the 49th Easter School Conference, "Genetic Engineering of Crop Plants"*, Nottingham University, UK.

MILLAM, S., DAVIDSON, D. & POWELL, W. 1989. Applications of the transformation of rapid-cycling lines of Brassica. In: *Proceedings of the International Conference "The impact of biotechnology in agriculture"*, Amiens, France.

MILLAM, S., FRYER, S. & DAVIDSON, D. 1989. A comparison of the regeneration efficiencies of different explant sources using a rapid-cycling accession of *Brassica oleracea*. *Cruciferae Newsletter* **14** (in press).

MILLARD, P., ROBINSON, D., & MACKIE-DAWSON, L. A. 1989. Nitrogen partitioning within the potato (*Solanum tuberosum* L.) plant in relation to nitrogen supply. *Annals of Botany* **63,** 289-296.

MORRIS, P. C., KUMAR, A., BOWLES, D. J. & CUMING, A. C. 1990. Osmotic stress and abscisic acid induce expression of the wheat Em gene. *European Journal of Biochemistry* (in press).

MORRISON, I. M., BRICE, R. E. & MOUSDALE, S. A. 1989. Biodegradation of lignocellulosic materials: present status and future prospects. In Jayasuriya, N. (ed). *Feeding strategies for improving productivity of ruminant livestock in developing countries*. IAEA, Vienna, Austria, 191-204.

MOUSDALE, S. A. & MORRISON, I. M. 1989. Development of the warty layer — "A near death experience of a barley cell wall?" (abstract). *Proceedings of the 5th Cell Wall Meeting*, Edinburgh, UK, 163.

MOWAT, W. P., DAWSON, S. & DUNCAN, G. H. 1989. Production of antiserum to a non-structural potyviral protein and its use to detect narcissus yellow stripe and other potyviruses. *Journal of Virological Methods* **25,** 199-210.

MOWAT, W. P., DAWSON, S. & DUNCAN, G. H. 1989. The use of antiserum to a non-structural viral protein to detect narcissus yellow stripe potyvirus. *Abstracts Association of Applied Biologists Meeting*, Norwich, 1989, 18.

MURANT, A. F. 1990. Specificity and recognition events in the transmission of plant viruses by vectors. In Fraser, R.S.S. (ed.), *Recognition and Response in Plant-Virus Interactions*, Heidelberg, Springer-Verlag, 53-70.

MURANT, A. F. & KUMAR, I. K. 1989. Role of a satellite RNA in green and chlorotic forms of groundnut rosette. *Abstracts IVth International Plant Virus Epidemiology Workshop*, Montpellier, France, 1989, 259-260.

MURANT, A. F. & KUMAR, I. K. 1990. Different variants of the satellite RNA of groundnut rosette virus are responsible for the chlorotic and green forms of rosette disease. *Annals of Applied Biology* (in press).

MURANT, A. F., BOCK, K. R. & RAJESHWARI, R. 1989. Resistance of groundnut to components of rosette disease. *Abstracts IVth International Plant Virus Epidemiology Workshop*, Montpellier, France, 1989, 67-69.

MURRAY, J., FIXTER, L. M., GRAHAM, D. C., HAMILTON, I. D., PEROMBELON, M. C. M. & QUINN, C. E. 1990. Serogroups of potato pathogenic *Erwinia carotovora* stain identification by ipopolysaccharide electrophoretic patterns. *Journal Applied Bacteriology* **68,** 231-240.

NEWMAN, E. I., RITZ, K. & JUPP, A. P. 1989. The functioning of roots in the grassland ecosystem. *Aspects of Applied Biology* **22,** 263-269.

NEWTON, A. C. 1989. Measuring cell wall sterol of mildew (*Erysiphe graminis* f. sp. *hordei*) as a means of assessing partial resistance. *Plant Pathology* **38,** 534-540.

NEWTON, A. C. & LYON, G. D. 1988. Enhancement of barley mildew resistance using yeast cell wall extracts. *Barley Newsletter* **32,** 117-119.

NEWTON, A. C., REGLINSKI, T. & LYON, G. D. 1990. Elicitors of resistance: durability and specificity. In: *Integrated control of cereal mildews: virulence patterns and their change.* Riso National Laboratory (in press).

OPARKA, K. J. & WRIGHT, K. M. 1989. How the devil does Lucifer Yellow enter plant cells? *Abstracts SEB Plant Transport Group Meeting,* Rothamsted.

OPARKA, K. J., WRIGHT, K. M. & PRIOR, D. A. M. 1989. Osmotic regulation of sucrose partitioning in potato tuber storage tissues. *In 21st International Potash Institute Colloqium,* Louvain-la-Neuve, Belgium. Methods of K-research in plants, 189-201.

OPARKA, K. J., WRIGHT, K. M. & PRIOR, D. A. M. 1989. Control of starch synthesis in potato tubers by turgor-sensitive sucrose transport at the plasmalemma. In *Plant membrane transport: the current position* (eds. Dainty, J, de Michelis, M. I., Marre, E., Rasi-Coldogno, F.) Elsevier, 629-632.

OPARKA, K. J., PRIOR, D. A. M. & HARRIS, N. 1990. Osmotic induction of fluid-phase endocytosis in onion epidermal cells.*Planta* **181** (in press).

PATERSON, E., GOODMAN, B. A. & FARMER, V. C. 1989. The chemistry of manganese, iron and aluminium oxides in acid soils. In: Ulrich, B. & Sumner, M. E. (eds). *Soil Acidity,* Springer — Verlag, Heidelberg (in press).

PÉROMBELON, M. C. M. 1990. Ecology and pathogenicity of soft rot erwinias: an overview. In. Klement, Z. (ed) *Proceedings 7th International Conference on Plant Pathogenic Bacteria 1988,* Budapest 751-757.

PÉROMBELON, M. C. M. 1990. Bacteria as Plant Pathogens. (Book review). *Plant Pathology* **39** 209-210.

PERRY, D. A. & WILLIAMS, N. A. 1989. Anaerobic pectolytic clostridia in the rhizosphere of crop plants and implications for nitrogen transformations. *Aspects of Applied Biology* **22,** 207-212.

PLOEG, A. T. & BROWN, D. J. F. 1989. Factors affecting problems caused by tobacco rattle virus. *Aspects of Applied Biology* **22,** 67-72.

PLOEG, A. T. & BROWN, D. J. F. 1989. Specificity of transmission of tobraviruses by (*Para*)*Trichodorus* nematodes. *Proceedings of the Dutch Virologists Meeting,* Wageningen, The Netherlands, p. 5.

PLOEG, A. T., ASJES, C. J. & BROWN, D. J. F. 1989. Factors involved in transmission of tobraviruses by trichodorid nematodes in bulb fields. *Proceedings of the Association of Applied Biology Meeting,* Imperial College, London, p. 4.

PLOEG, A. T., BROWN, D. J. F. & ROBINSON, D. J. 1989. Transmission of tobraviruses by trichodorid nematodes. *EPPO/OEPP Bulletin* **19,** 605-610.

POWELL, W. BROWN, J. & CALIGARI, P. D. S. 1989. Variability in response of potato cultivars to micropropagation. II. Subsequent field performance. *Annals of Applied Biology.* **115,** 123-128.

POWELL, W. & CALIGARI, P. D. S. 1989. The use of hormonal and osmotic growth retardants in media used for storage of potato germplasm in vitro. *Potato Research* **32,** 57-64.

POWELL, W., ELLIS, R. P., MACAULAY, M., McNICOL, J. & FORSTER, B. P. 1990. The effect of selection for protein and isozyme loci on quantitative traits in a doubled haploid population of barley. *Heredity* (in press).

RAMSAY, G. & KUMAR, A. 1990. Transformation of Vicia faba cotyledon and stem tissues by Agrobacterium rhizogenes: Infectivity and cytological studies. *Journal of Experimental Botany* **41** (in press).

REAVY, B., KUMAR, A. & MAYO, M. A. 1989. Manipulation of the coat protein gene of potato leafroll virus for transformation of potato. *Abstracts of Society for Experimental Biology Meeting*, Edinburgh, 1989, 27.

REGLINSKI, T., NEWTON, A. C., & LYON, G. D. 1990. Effectiveness of elicitor-active yeast cell wall components as a novel crop protectant. *Proceedings Crop Protection in Northern Britain 1990*, Association for Crop Protection in Northern Britain, 213-218.

RHIND, S. M., McKELVEY, W. A. C., McMILLEN, S., GUNN, R. G. & ELSTON, D. A. 1989. Effect of restricted food intake, before and/or after mating, on the reproductive performance of Greyface ewes. *Animal Production*, **48,** 149-155.

RICHARDSON, D. L., DAVIES, H. V., ROSS, H. A. & MACKAY, G. R. 1990. Invertase activity and its relation to hexose accumulation in potato tubers. *Journal of Experimental Botany* **41,** 95-99.

RITZ, K. & WHEATLEY, R. E. 1988. Freezing as a means of preserving samples in a soil respiration study. *Soil Biology and Biochemistry* **8,** 95-96.

RITZ, K. & WHEATLEY, R. E. 1989. Effects of water amendment on basal and substrate-induced respiration rates of mineral soils. *Biology and Fertility of Soils* **8,** 242-246.

RITZ, K., GRIFFITHS, B. S. & WHEATLEY, R. E. 1989. Microbial biomass C, N and respiration under a potato crop receiving N fertilisation with and without C amendment. *Proceedings of a Conference on Microbiology and Chemistry of Nitrogen Turnover in Soils, Reading* No. 3, British Society of Soil Science and Royal Society of Chemistry, 27.

ROBERTS, I. M. 1989. Indian cassava mosaic virus: ultrastructure of infected cells. *Journal of General Virology* **70,** 2729-2739.

ROBERTSON, W. M. & FORREST, J. M. S. 1989. Factors involved in host recognition by plant parasitic nematodes. *Aspects of Applied Biology* **22,** 129-133.

ROBERTSON, W. M. & GRIFFITHS, B. S. 1989. A comparative study of cellular changes in galls induced in *Longidorus elongatus* and *Xiphinema diversicaudatum*. *Aspects of Applied Biology* **22,** March 1901.

ROBERTSON, W. M., FORREST, J. M. S. & STEWART, D. 1989. Production of antisera to the surface of *Longidorus elongatus* and *L. attenuatus*. *Journal of Nematology* **21,** 583.

ROBERTSON, W. M., SPIEGEL, Y., JANSSON, H-B., MARBAN-MENDOZA, N. & ZUCKERMAN, B. M. 1989. Surface carbohydrates of plant parasitic nematodes. *Nematologica* **35,** 180-186.

ROBINSON, D. 1989. Can the nutrient demand of a plant be sustained by an increase in local inflow rate? *Journal of Theoretical Biology* **138,** 551-554.

ROBINSON, D. 1989. Phenotypic plasticity in roots and root systems: compensations, constraints and compromises. *Roots and the Soil Environment, Aspects of Applied Biology* **22,** 49-55.

ROBINSON, D., GRIFFITHS, B. G., RITZ, K. & WHEATLEY, R. E. 1989. Root-induced nitrogen mineralisation: A theoretical analysis. *Plant and Soil* **117,** 185-193.

ROBINSON, D. J. 1989. Tobacco rattle tobravirus: variation among strains and detection by cDNA probes. *EPPO/OEPP Bulletin* **19,** 619-623.

ROBINSON, D. J., PLOEG, A. T. & BROWN, D. J. F. 1989. Determinants of specificity between tobacco rattle virus isolates and their nematode vectors. *Proceedings of the EMBO Workshop on Molecular Biology of Plant Virus Pathogenicity*, Wye College, England, p. 24.

RUSSELL, G., MARSHALL, B. & JARVIS, P. G. 1989. (eds.). Plant Canopies: Their Growth, Form and Function. Society for Experimental Biology, Seminar Series 31, Cambridge University Press.

SINCLAIR, A. H., MACKIE-DAWSON, L. A. & LINEHAN, D. J. 1990. Micronutrient inflow rates and mobilisation into soil solution in the root zone of winter wheat (*Triticum aestivum* L.). *Plant and Soil* **120.**

SOUTHEY, J. F., TOPHAM, P. B. & BROWN, D. J. F. 1990. Taxonomy of some species of *Anguina* Scopoli, 1777 (*sensa* Brzeski, 1981) forming galls on Gramineae: value of diagnostic characters and present status of nominal species. *Revue de Nématologie* **13,** 127-142.

STEWART, H. E. & WASTIE, R. L. 1989. A rapid scoring technique for potato tuber disease assessment. *Potato Research* **32,** 353-357.

SWANSTON, J. S. & COWE, I. A. 1989. A rapid technique to predict malting quality in barley prior to harvest. *Annals of Applied Biology* **115,** 529-532.

SWANSTON, J. S. & TAYLOR, K. 1990. The effects of different steeping regimes on water uptake, germination rate, milling energy and hot water extract. *Journal of the Institute of Brewing*, **96,** 3-6.

TALBOT, M., AITKEN, C. G. G. & GAMMERMAN, A. 1989. Development of expert system tools for routine data monitoring. *EUROSTAT NEWS, Proceedings of DOSES seminar*, Luxembourg 1987, 160-167.

TAYLOR, J. 1989. Colour stability of blackcurrant (*Ribes nigrum*) juice. *Journal of the Science of Food and Agriculture* **49,** 487-491.

THOMAS, W. T. B. 1989. Cross prediction of malting quality in spring barley. Science for plant breeding — *Vortrage fur Pflanzenzuchtung* **15,** 3-11.

TORRANCE, L. & ROBINSON, D. J. 1989. Modern methods of detecting and identifying potato viruses. *AgBiotech News and Information* **1,** 891-896.

TSOR, L. L., NACHMIAS, A., LIVESCU, L., PEROMBELON, M. C. M. & BARAK, Z. 1989. *Erwinia carotovora* subsp. *atroseptica* infection promotes Verticillium wilt development in potato in Israel. *Potato Research* **33,** 3-11.

VAUGHAN, P. F. T., BALMFORTH, A. J., WOODS, M. D., HEDLEY, D., YASUNARI, K. & BALL, S. G. 1990. The use of cell culture to study biochemical mechanisms underlying receptor function in the human control nervous system. In. Winlow, W. (ed) *Studies in Neuroscience: The Basal Ganglia*. Manchester University Press (in press).

VIPOND, J. E., KING, M. E., ORSKOV, E. R. & WETHERILL, G. Z. 1989. Effects of fish-meal supplementation on performance of overfat lambs fed on straw to reduce carcass fatness. *Animal Production* **48,** 131-138.

WALLIS, W. A., SHATTOCK, R. C. & WILLIAMSON, B. 1989. Downy mildew (*Peronospora rubi*) on micropropagated Rubus. *Acta Horticulturae* **262,** 227-230.

WASTIE, R. L., STEWART, H. E., BROWN, J. 1989. Comparative susceptibility of some potato cultivars to dry rot caused by *Fusarium sulphureum* and *F. solani* var *coeruleum*. *Potato Research* **32,** 49-55.

WATKINS, C. A. & JONES, A. T. 1989. Tests for viroid-like RNA in June yellows-affected strawberry. *International Society for Horticultural Science Working Group on Virus Diseases of Small Fruits Newsletter* No. 7, 4.

WATKINS, C. A., ROBERTS, I. M. & JONES, A. T. 1989. Ultrastructural effects of June yellows in strawberry. *International Society for Horticultural Science Working Group on Virus Diseases of Small Fruits Newsletter* No. 7, 5.

WATKINS, C. A., McNICOL, R. J., YOUNG, K. & JONES, A. T. 1990. The effect of heat treatment and meristem-tip culture on June Yellows in strawberry. *Annals of Applied Biology* **116** (in press).

WAUGH, R. & POWELL, W. 1989. Inheritance of RFLP loci in potato. In: *Proceedings of the 1st International Symposium on "The molecular biology of the potato"*, Bar Harbour, Maine, USA.

WAUGH, R., POWELL, W. & BROWN, J. W. S. 1989. Molecular analysis of Dicot (potato) and Monocot (maize) U2snRNA genes. In: *Proceedings of the 1st International Symposium on "The molecular biology of the potato"*, Bar Harbour, Maine, USA.

WAUGH, R., POWELL, W. & BROWN, J. W. S. 1989. The U2snRNA gene family of potato. *Molecular Communications in Higher Plants*, EMBO Heiderlberg.

WAUGH, R., VAN DE VEN, M., MILLAM, S., BRENNAN, R. & POWELL, W. 1989. The potential use of restriction fragment length polymorphism in Rubus breeding. *Acta Horticulturae* (in press).

WAUGH, R., VAN DE VEN, W., MILLAM, S., BRENNAN, R. & POWELL, W. 1989. The potential use of restriction fragment length polymorphism in Rubus breeding. In: *Proceedings of the International Symposium "In vitro culture and horticultural breeding"*, Cessera, Italy.

WAUGH, R., GLENDINNING, D. R., DUNCAN, N. & POWELL, W. 1990. Chloroplast DNA variation in European Potato Cultivars. *Potato Research* (in press).

WAUGH, R., VAN DE VEN, W. T. G., PHILLIPS, M. S. & POWELL, W. 1990. Chloroplast DNA diversity in the genus Rubus revealed by Southern hybridisation. *Plant Systematics and Evolution* (in press).

WEILER, B. E., SHRODER, H. C., STEFANOVICH, V., STEWART, D., FORREST, J. M. S., ALLEN, L. B., BOWDEN, B. J., KREUTER, M.H., VOTH, R. & MULLER, W. E. G. 1990. Sulfoevernan, a polyanionic polysaccharide, and the narcissus lectin potently inhibit HIV infection by binding to viral envelope protein. *Journal of General Virology* (in press).

WHEATLEY, R. E., MacDONALD, R. & SMITH, A. 1989. Extraction of nitrogen from soils. *Biology and Fertility of Soils* **8,** 189-190.

WILKINSON, M. J. 1989. Pollen and climatic change. *Aerobiologa* **5,** 3.8.

WILKINSON, M. J. & STACE, C. A. 1989. A new toxonomic treatment of the *Festuca ovina* L. *aggregate* (Poaceae) in the British Isles. *Journal of the Linnaean Society*.

WILLIAMSON, B., DUNCAN, J. M. KENNEDY, D. M. & McNICOL, R. J. 1989. Improving the control of some diseases of soft fruits. *AFRC Science for Growers* 26-27.

WILLIAMSON, B., McNICOL, R. J. & YOUNG, K. 1989. The botrytis and ethylene connection. *Grower* **112** (16), 21-23.

WILLIAMSON, C. J. 1989. An assessment of the importance of clubroot in oilseed rape. *Aspects of Applied Biology* **23,** 439-449.

WILLIAMSON, C. J. & BLACK, W. J. M. 1989. Index of research and development relevant to organic systems of food production. Scottish Agricultural Colleges and Scottish Agricultural Research Institutes 37pp.

WILSON, R. N., BIRCH, A. N. E. & BRADSHAW, J. E. 1990. Differences in susceptibility of twelve swede genotypes to cabbage root fly (*Delia radicum*). Test of Agrochemicals and Cultivars No. 11 (*Annals of Applied Biology* **116,** Supplement), pp. 116-117.

WOODFORD, J. A. T. & GORDON, S. C. 1990. New approaches for restricting spread of potato leafroll virus by different methods of eradicating infected plants from potato crops. *Annals of Applied Biology* **116,** (in press).

WRIGHT, K. M. & OPARKA, K. J. 1989. Sucrose uptake and partitioning in discs derived from source versus sink potato tubers. *Planta* **177,** 237-244.

WRIGHT, K. M. & OPARKA, K. J. 1989. Sugar transport into potato tuber storage tissue. *Astracts SEB Plant Transport Group Meeting*, Rothamsted.

WRIGHT, K. M. & OPARKA, K. J. 1989. Uptake of Lucifer Yellow CH into plant-cell protoplasts: a quantitative assessment of fluid-phase endocytosis. *Planta* **179,** 257-264.

WRIGHT, I. A., RUSSELL, A. J. F. & HUNTER, E. A. 1989. Compensatory growth in cattle grazing different vegetation types. *Animal Production* **48,** 43-50.

YANG, H., EASTHAM, P. R., PHILLIPS, P. & WHITTEMORE, C. T. 1989. Reproductive performance, body weight and body condition of breeding sows with differing body fatness at parturition, differing nutrition during lactation, and differing litter size. *Animal Production* **48,** 181-201.

YOUNG, I. M. 1989. A drain on Fenland's top asset. The Independent Newspaper — Science and Technology No. 845, 17.

YOUNG, I. M. & BENGOUGH, A. G. 1989. Mechanical constraints to root growth. Roots and the Soil Environment. *Aspects of Applied Biology* **22,** 41-47.

Extracts From The Accounts

INCOME AND EXPENDITURE ACCOUNT
FOR THE YEAR ENDED 31 MARCH 1989

	1989		*1988*	
	£	£	£	£
Grants		5,891,564		5,216,027
Produce crop income		146,861		168,954
Other operating income —				
Rents received	27,943		26,201	
Sundry income	22,922		17,371	
SASS income	105,685		72,711	
Capital grants transferred	298,858		269,956	
		455,409		386,239
		6,493,833		5,771,220
Decrease in stock —				
Chemicals and consumables	(10,726)		(76)	
Farm stocks	(19,852)		(1,910)	
		(30,578)		(1,986)
		6,463,255		5,769,234
Staff costs	4,236,515		3,584,115	
Depreciation of fixed tangible assets	405,710		360,265	
Other operating charges	1,831,879		1,714,438	
(Deficit)/Surplus of income over expenditure for the year		(10,849)		110,416
Balance brought forward at 31 March 1988		844,770		734,354
Balance carried forward at 31 March 1989		833,921		844,770

BALANCE SHEET AS AT 31 MARCH 1989

	1989		*1988*	
	£	£	£	£
FIXED ASSETS				
Tangible assets		9,799,398		8,396,033
CURRENT ASSETS				
Stocks	107,433		138,011	
Debtors	154,978		76,726	
Cash at bank and in hand	159,051		69,259	
	421,462		283,996	
CREDITORS				
Amounts falling due within one year	399,438		140,945	
NET CURRENT ASSETS		22,024		143,051
TOTAL ASSETS LESS CURRENT LIABILITIES		9,821,422		8,539,084
ACCRUALS AND DEFERRED INCOME		8,965,851		7,672,664
		855,571		866,420
CAPITAL AND RESERVES				
Capital reserve		21,650		21,650
General income account		833,921		844,770

Permanent Appointments and Internal Transfers

H. K. Brown	HSO	SASS Edinburgh
S. Burrows	SO	Director's Group
M. A. Catley	HSO	Transferred to Cell and Molecular Genetics Department
S. Clulow	HSO	Crop Genetics Department
P. A. Davie	ASO	Transferred to Crop Genetics Department
A. C. Fuller	EWIV	Estate
B. A. Goodman	UG7	Director's Group
F. Gourlay	ASO	Transferred to Crop Genetics Department
B. S. Griffiths	SSO	Transferred to Cellular and Environmental Physiology Department
J. E. Hall	SO	SASS Dundee
B. E. Harrower	SO	Zoology Department; then transferred to Cell and Molecular Genetics Department
S. M. Knight	EWII	Estate
A. D. Lorimer	ASO	Transferred to Crop Genetics Department
M. Macaulay	ASO	Cell and Molecular Genetics Department
G. J. McDougall	SSO	Director's Group
Wendy S. McGavin	SO	Transferred to Virology Department
K. McIlravey	ASO	Transferred to Crop Genetics Department
M. Myles	EWII	Crop Genetics Department
P. Phillips	SSO	Transferred to SASS Ayr
K. Ritz	SSO	Transferred to Cellular and Environmental Physiology Department
A. M. Smith	ASO	Transferred to Cellular and Environmental Physiology Department
A. M. Smith	EWIV	Estate
M. J. Smith	EWIV	Estate
D. Stewart	HSO	Director's Group
F. E. C. Stewart	ASO	Transferred to Cellular and Environmental Physiology Department
M. Taylor	HSO	Cellular and Environmental Physiology Department
A. Todd	ASO	Crop Genetics Department
D. Todd	ASO	Crop Genetics Department
E. Warden	EWII	Mycology and Bacteriology Department
K. D. Webster	ASO	Transferred to Cellular and Environmental Physiology Department
R. E. Wheatley	HSO	Transferred to Cellular and Environmental Physiology Department
F. G. Wright	HSO	SASS Edinburgh
K. M. Wright	HSO	Cellular and Environmental Physiology Department
M. J. Wilkinson	HSO	Crop Genetics Department

Awards

A. Booth	SCOTVEC Ordinary National Certificate in Biology
E. D. Bowman	B.Sc. in Life Sciences, Napier College
P. M. Derrick	Ph.D. Nottingham Polytechnic
M-J. Farmer	Ph.D. University of Dundee
B. D. Harrison	C.B.E. Honorary Member, Association of Applied Biologists
L. J. Hyman	B.A. Open University
N. L. Innes	Fellow of Royal Society of Edinburgh
H. M. Lawson	Fellow of Institute of Horticulture
L. Lopez-Llorca	Ph.D. University of Dundee
P. F. McGrath	Ph.D. University of Leeds
L. F. McLaren	ONC Librarianship and Information Science
S. Millam	Ph.D. Wolverhampton Polytechnic
M. C. M. Pérombelon	Honorary Research Fellow, Medical Microbiology Department, University of Dundee
D. Robinson	Honorary Lecturer, Department of Biological Sciences, University of Dundee
P. H. Scott	NPTC Certificate of Competence: safe use of pesticides and hand-held applicators (knapsack)
A. Young	NPTC Certificate of Competence: safe use of pesticides and hand-held applicators (knapsack)

Promotions

G. Dow	EWIII	Estate
J. M. S. Forrest	UG7	Zoology Department
A. E. Grant	EWII	Estate
B. S. Griffiths	SSO	Cellular and Environmental Physiology Department
C. A. Jolly	SO	Virology Department
M. J. De,Maine	SSO	Crop Genetics Department
G. R. MacKay	UG6	Crop Genetics Department
M. S. Phillips	UG7	Zoology Department
K. Ritz	SSO	Cellular and Environmental Physiology Department
B. D. Robertson	P&GSE	Estate
J. S. Swanston	SSO	Crop Genetics Department
S. R. Verrall	SO	Cellular and Environmental Physiology Department

Resignations

B. Alexander	ASO	Cellular and Environmental Physiology Department
J. A. Brennan	ASO	Crop Genetics Department

J. Bruce	SO	Zoology Department
Y. Downie	ASO	Crop Genetics Department
A. E. Grant	EWII	Estate
J. G. Guthrie	EWIV	Estate
J. R. T. Hodgkin	UG7	Crop Genetics Department
J. Jenkins	EWII	Mycology and Bacteriology Department
J. Low	ASO	Virology Department
E. Rees	SO	Mycology and Bacteriology Department
H. M. Vint	SO	SASS Aberdeen

Termination of Short-term Appointment

R. S. Forrest	SO	Mycology and Bacteriology Department
T. D. Heilbronn	HSO	Cellular and Environmental Physiology Department
G. MacDonald	EWII	Crop Genetics Department
K. I. McIlravey	ASO	Mycology and Bacteriology Department
F. Ritchie	SO	Crop Genetics Department
L. S. Talbot	HSO	Cellular and Environmental Physiology Department
D. Todd	ASO	Crop Genetics Department
S. C. K. Williams	SO	Soft Fruit Genetics Department

Retirements of Permanent Staff

A. B. Wills, UG7, Head of Brassica Genetics Department (now part of Crop Genetics Department), retired after 34 years' service.

A. Pirie, P&GSE, Estate, retired after 18 years' service.

D. L. Jennings, UG6(IMP), Soft Fruit Genetics Department, retired as Head of Soft Fruit Genetics Department after 31 years' service.

Redundancies, Voluntary and Flexible Retirements

K. Anderson	ASO	Crop Genetics Department
T. G. Archibald	ASO	Crop Genetics Department
E. Brydon	HSO	Soft Fruit Genetics Department
M. M. S. Dugan	EWII	Crop Genetics Department
D. Gemmell	SO	Crop Genetics Department
K. Hamilton	ASO	Crop Genetics Department
J. S. Muir	SO	Crop Genetics Department
S. D. Porter	SO	Crop Genetics Department
D. L. Richardson	HSO	Cellular and Environmental Physiology Department
G. W. Swinney	ASO	Crop Genetics Department
C. Tymkewycz	ASO	Crop Genetics Department
E. M. Wann	EWII	Crop Genetics
C. J. Williamson	SSO	Mycology and Bacteriology Department

Death

I. K. Kumar	Virology Department

Visiting Workers

R. Alonso (Agricultural Technical University, Madrid) spent 6 weeks working on expert systems (SASS Edinburgh).

Ingrid Bahner (Department of Biochemistry and Microbiology, University of St Andrews) spent several months during 1989 studying potato leafroll virus-specific proteins produced in infected protoplasts, as part of the work of a Link Group with St Andrews University (Virology Department).

A. Bano (Quaid-I-Azam University, Pakistan) spent 1 month analysing temperature effects on tuber respiration (Cellular and Environmental Physiology Department).

S. Barr (University of Dundee) worked for 10 weeks on protoplast isolation and hybrid identification (Crop Genetics Department).

J. M. Cuevas-Gozalo (National Institute of Agriculture Research, Madrid, Spain) visited SASS for 1 week to continue collaborative work on synthetic aperture radar data from satellites (SASS Edinburgh).

G. Demangeat (IBMP, Strasbourg, France) spent separate periods of 6 weeks and 4 weeks working on molecular aspects of the multiplication of tomato black ring virus in isolated protoplasts (Virology Department).

D. Fargette (ORSTOM, Ivory Coast) continued his research on cassava viruses (Virology Department).

Mireille Fargette (ORSTOM, Ivory Coast) continued her studies on the biochemical and molecular analysis of populations of root-knot nematode (Zoology Department).

C. Fasseas (Agricultural College of Athens, Greece) completed a sabbatical year learning immunogold labelling techniques and their use to locate virus antigen in plants and vector aphids (Virology Department).

J. Fresno (CIT-INIA, Madrid, Spain) spent 6 weeks assessing different ELISA methods for detecting nepoviruses in nematodes (Virology/Zoology Departments).

Julie Gilbert (University of Reading) spent 2 weeks learning protoplast technology (Cell and Molecular Genetics Department).

T. Helgesson (University of Edinburgh) spent 2 weeks developing DNA isolation and detection of RFLPs in *Pinus* (Cell and Molecular Genetics Department).

D. Jones (Wye College, Kent) spent 2 weeks studying aphid behaviour on susceptible and resistant raspberries (Zoology Department).

D. R. Lynch (Lethbridge, Alberta, Canada), spent 6 months working on *Alternaria solani* infection of potatoes (Crop Genetics Department).

T. Natsuaki (Utsunomiya University, Japan) arrived in September to begin a sabbatical year working on the molecular biology of raspberry bushy dwarf virus (Virology Department).

P. N'Guessan (ORSTOM, Ivory Coast) left in December after completing his work on okra leaf curl virus (Virology Department).

C. Paul (Institut fur Grunland und Futterpfanzenforschung der Bundesforschungsanstalt fur Landwirtschaft (fal), West Germany) spent 6 weeks working on the principal component analysis of near-infrared spectra (Chemistry Department).

Z.-Y. Peng (Chinese Academy of Agricultural Sciences) continued to study drought tolerance in potato (Cellular and Environmental Physiology Department).

G. Perez (INSA, Lyon, France) spent 4 months working on Tn5 mutagenesis of erwinia strains for pectic enzyme secretion mutants (Mycology and Bacteriology Department).

V. Pilarczyk (Research Centre for Cultivar Testing, Poland) visited SASS to work with the Coordinated Variety Trial section (SASS Edinburgh).

P. Purcell (University of Edinburgh) spent 3 days learning tissue culture and microtuberisation (Cell and Molecular Genetics Department).

P. Ricci (INRA, Antibes, France) visited for 3 days to develop collaborative programmes on molecular biology of *Phytophthora* spp. (Mycology and Bacteriology Department).

J. Romero (CIT-INIA, Madrid, Spain) spent 3 weeks testing a cDNA probe for detecting grape fanleaf virus in nematode (Zoology/Virology Departments).

P. Roskothen (University of Gottingen, West Germany) spent 2 weeks sampling roots of field bean for strains of *Rhizobium* (Cellular and Environmental Physiology Department).

S. Singh (Central Potato Research Institute, Shimla, India) arrived in March to work for 9 months on modern serological techniques for virus detection in potato (Virology Department).

W. J. Soppe (Wageningen Agricultural University, The Netherlands) spent 6 months working on the development of *in vitro* screening methods for late blight using microtubers (Crop Genetics Department).

M. Srivastava (Indian Agricultural Research Institute, New Delhi, India) spent 2 months learning electron microscope techniques for detection and identification of plant viruses (Virology Department).

N. Thakur (Government Department of Food and Agriculture, Nepal) spent 3 months learning computing and survey techniques (SASS Edinburgh).

Chantal Vanderperre (Leuven Katholik University, Belgium) spent 5 weeks studying virus transmission by and taxonomy of trichodorid nematodes (Zoology Department).

J. Vos (Department of Field Crops and Grassland Science, University of Wageningen, The Netherlands) spent 2 weeks on the analysis of photosynthesis in relation to nitrogen concentration in potato (Cellular and Environmental Physiology Department).

L. Wen (The Cotton Research Institute, CAAS, Anyang City, China) spent 12 months researching transposon mutagenesis in *Brassica* (Cell and Molecular Genetics Department).

M. W. Young (Walkers Crisps) spent a second year examining relations between cultural and storage factors and levels of reducing sugar in potato (Cellular and Environmental Physiology Department).

H. F. Zhou (Shenyang Agricultural University, China) spent 9 months studying the application of statistical methods in agricultural research (SASS Edinburgh).

Research Students

Karen Backett (SERC-CASE with University of Leeds) continued studies to develop an antibody probe for identifying resistance to potato cyst nematodes (Zoology Department).

R. Bargota (AFRC-CASE with Kings College, London) continued studies on starch synthesis in *Vicia faba* (Cellular and Environmental Physiology Department).

U. Brown (SERC-CASE with Glasgow University) continued studies on amylase genes in potato (Cellular and Environmental Physiology Department).

K. Chalmers (SERC with University of St Andrews) continued studies of molecular genetics of barley (Cell and Molecular Genetics Department).

S. J. Finnie (SERC with University of Edinburgh). Haploid production in barley (Cell and Molecular Genetics Department).

S. Fryer (LCA Wolverhampton Polytechnic). Transformation methods in *Brassica napus* (Cell and Molecular Genetics Department).

A. Gardner (DAFS funded with University of Dundee) continued studies on potato hexokinases (Cellular and Environmental Physiology Department).

A. E. Gleadle (PMB with University of Nottingham). Somatic hybridisation in potato (Cell and Molecular Genetics Department).

J. Gonzalez-Perez (Post-graduate student from the Canary Islands) continued work on the biochemical and molecular identification of potato cyst nematodes (Zoology Department).

R. Hopkinson (MAFF with East of Scotland College of Agriculture) commenced studies on mechanisms of resistance in brassicas to root flies (Zoology Department).

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

J. D. Madulla (British Council funded post-graduate student from Tanzania), started research on non-chemical means of controlling root-knot nematodes (Zoology Department).

Jane Miller (post-graduate student funded by AFRC) arrived in October to study the molecular biology of potato leafroll virus multiplication in a joint project with St Andrews University (Virology Department).

A. Nisbet (DAFS post-graduate student jointly with University of Glasgow), began research on the effect of antifeedant compounds on the transmission of plant viruses (Zoology Department).

Z.-Y. Peng (CIP funded with University of Dundee) continued a study of the physiological basis of drought tolerance in potato (Cellular and Environmental Physiology Department).

L. G. Pereira (Post-graduate student funded by the University of Oporto) arrived in October to study the properties of potato mop-top virus (Virology Department).

J. Phelpstead (SERC-CASE with University of Nottingham). Studies of cell biology of potato (Cell and Molecular Genetics Department).

A. T. Ploeg (Post-graduate student funded by the Flowerbulb Research Institute, Lissa, The Netherlands) continued investigations into the specificity of transmission of tobraviruses by trichodorid nematodes (Zoology Department).

P. Purcell (SERC with University of Edinburgh). Studies of mitochondrial biogenesis in potato (Cell and Molecular Genetics Department).

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

Jenifer Robb (DAFS funded with University of Dundee) started part-time studies on the nature of nematode gland cell secretion (Zoology Department).

M. R. Roberts (SERC-CASE with University of Leicester). Transposon mutagenesis in Flax (Cell and Molecular Genetics Department).

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

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

C. G. Simpson (AFRC-Link with University of Dundee). Splicing of monocotyledonous and dicotyledonous introns in transformed protoplasts and plants (Cell and Molecular Genetics Department).

J. Smart (IFS with University of Dundee) studied the use of artificial intelligence in modelling crop production systems (Cellular and Environmental Physiology Department).

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

M. Taeb (Iranian Government grant with University of Cambridge). Genetics and physiology of salt and waterlogged-stressed wheat (Cell and Molecular Genetics Department).

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

W. T. G. van de Ven (AFRC with University of Dundee). Construction of a genetic linkage map in *Vicia faba* (Cell and Molecular Genetics Department).

R. Viola (EEC with University of Dundee) continued work on the biochemistry of starch-sugar interconvertions (Cellular and Environmental Physiology Department).

Wendy A. Wallis (MAFF post-graduate student jointly with University College of North Wales, Bangor) continued studies on downy mildew of Rubus cane fruits (Mycology and Bacteriology Department).

A. Ward (SERC-CASE with University of Nottingham). Application of protoplast technology in potato improvement (Cell and Molecular Genetics Department).

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

Alison V. Wheelwright (SERC post-graduate student with University of Edinburgh) continued studies on estimating edges in medical images (SASS Edinburgh).

Alison V. Wheelwright (SERC post-graduate student with University of Edinburgh) continued studies on estimating edges in medical images (SASS Edinburgh).

J. R. Wilde (The Biscuit, Cake and Confectionery Alliance with University of Reading). The use of protein and DNA markers to genetically fingerprint Cacao (*Theobroma cacao* L.) germplasm (Cell and Molecular Genetics Department).

Short-Term Appointments

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

Vivian Blok (IFS). Eighteen month study of the genome structure of raspberry ringspot virus (Virology Department).

L. Burch and Edna Cuthbert (ECSA Research Ltd). Three year biochemical/molecular studies on invertase gene expression in potato (Cellular and Environmental Physiology Department).

J. Bruce and Irene Geoghegan (BTG funded). Part of one year study for separation and screening of compounds for nematicidal activity (Zoology and Chemistry Departments).

Isobel Christie (DANI funded). Six month appointment to update the Herbrex data base (Cellular and Environmental Physiology Department.)

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

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

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

L. Fyffe (Beecham Bovril Brands). Eight month study on metabolic profiling and gall mite resistance in black currants (Chemistry and Soft Fruit Genetics Department).

J. F. Guerineau (IFS). Three year study to evaluate the potential of UsnRNA genes as plant transformation vectors (Cell and Molecular Genetics Department).

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

P. Hedley and G. Machray (ECSA Research Ltd). Three year study to investigate mechanisms of reducing low temperature sweetening in cold stored potatoes (Cell and Molecular Genetics Department).

T. D. Heilbronn (EEC funded) worked for 3 months on a project on the agrometeorology of the potato crop in Europe. He also (PMB funded) completed a project on forecasting the yield of the national potato crop from weather and soil data and agronomic practice (Cellular and Environmental Physiology Department).

Y. Hong (EEC funded). One year study on genome structure of geminiviruses (Virology Department).

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

P. Lanham and Hazel Thomson (IFS). Three year study of the molecular genetics of regulation of pectic enzyme production in erwinias (Mycology and Bacteriology Department).

D. Leader and P. Vaux (AFRC) initiated a 3 year programme on the isolation and characterisation of major UsnRNA genes from maize and potato (Cell and Molecular Genetics Department).

D. Liu (AGC funded). One year study of non-structural proteins of tobacco rattle virus (Virology Department).

Anne McLeod (PMB funded). Two year study to develop immuno-diagnostic methods for erwinias (Mycology and Bacteriology Department).

Elizabeth A. Murant (AGC funded). Three year study of genetic engineering of virus resistance (Virology Department).

T. Reglinski (HGCA funded). Three year study on use of yeast extracts in a new crop protection system (Mycology and Bacteriology Department).

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

G. Simpson (AFRC Plant Molecular Biology) commenced a 1 year study to investigate whether immunological homology existed between yeast and plant UsnRNP proteins (Cell and Molecular Genetics Department).

D. Smith (AFRC Plant Molecular Biology). Three year study on the isolation of endogenous transposable elements in potato (Cell and Molecular Genetics Department).

Anne J. Soutar, further one year from November, working with the Coordinated Variety Trials section. (SASS Edinburgh).

A. D. Turnbull-Ross (IFS). Three year study on genome structure of parsnip yellow fleck virus (Virology Department).

Anne Wallace and Lisa Fyffe (IFS). Three year study of the role of fimbriae in the pathogenicity of erwinias (Mycology and Bacteriology Department).

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

P. Whitty (IFS). Three year study on transposon tagging in potato (Cell and Molecular Genetics Department).

Sandwich Course Students

A. Cassidy (Dundee College of Technology) spent 3 months working on the production of novel starch genotypes (Crop Genetics Department).

A Cassidy (ESF) spent 9 months on isoelectric focusing of barley proteins (Cell and Molecular Genetics Department).

Tamsin S. Corfield (University of Bath) for one year from August, assisting staff at MLURI, Aberdeen (SASS Aberdeen).

D. M. Cormack (ESF) for 9 months on potato protoplast culture (Cell and Molecular Genetics Department).

Alison Eaglesham (Bell College, Hamilton), for 5 months on aphid resistance and virus diseases in raspberry (Virology and Zoology Departments).

L. Gregory (ESF) for 6 months on the isolation of maize U2snRNA genes (Cell and Molecular Genetics Department).

L. D. Hackney (ESF) for 6 months on *Brassica* tissue culture and flowering response (Cell and Molecular Genetics Department).

M. D. Harrington (Polytechnic of East London) completed his studies on the mechanisms of resistance to raspberry aphids (Zoology Department).

V. J. Hodgson (ESF) for 3 months on *Brassica* transformation (Cell and Molecular Genetics Department).

C. Klopp (Ecole Nationale Superieure Agronomique de Rennes) from 24 July-18 August, assisting with the development of a computer system for advising farmers on the choice of cereal varieties (SASS Edinburgh).

Kirsten Knoll (Forschungasanstalt, Geisenheim, Germany) spent 5 months studying the detection and properties of black currant viruses (Virology Department).

T. Orsman (DAFS/LEA) for one year to September 1989, studying aspects of potato genetics research (Crop Genetics Department).

C. Murray (Dundee College of Technology) for 6 months assisting K. Chalmers in an examination of RFLPs in isogenic lines of barley (Cell and Molecular Genetics Department).

Lisa Palmer (Polytechnic of East London) began studies on the use of the nematode fauna to monitor pollution (Zoology Department).

Karen Powell (Robert Gordon's Institute of Technology, Aberdeen) spent 3 weeks assisting in the Library, recataloguing potato literature, and gaining experience of special library work (Information Services).

G. Ross (Dundee Institute of Technology) assisted with field experiments on raspberry cane vigour control (Cellular and Environmental Physiology Department).

J. A. Sibley (Bell College of Technology, Hamilton) worked for 6 weeks on protease production by *Erwinia carotovora* (Mycology and Bacteriology Department).

Hazel Thomson (Dundee College of Technology) assisted with studies on virus-vector and non-vector strains of the fungus *Olpidium brassicae* (Zoology and Virology Departments).

P. Reinhoud (Agricultural University, Wageningen) for 3 months on the development of rapid chemical analysis methods for rape low glucosinolate/erucic acid programme (Crop Genetics Department).

Fiona Walls (Dundee Institute of Technology) for 6 months on the development of regenerating tissue culture systems in *Vicia faba* (Crop Genetics Department).

J. A. Watters (ESF) for 9 months on protein polymorphism in barley (Cell and Molecular Genetics Department).

Visits Abroad

H. Barker visited CIP Peru from February 18-25 to discuss research on potato leafroll virus and future collaboration. He gave a talk on mechanisms of resistance to potato leafroll virus.

J. E. Bradshaw attended the 5th Crucifer Genetics Workshop from 7-9 April at the University of California, Davis, US.

R. Brennan attended the ISHA Symposium on '*In-vitro* culture and horticultural breeding' at Cesena, Italy, from 30 May-3 June.

D. J. F. Brown visited universities and research institutes in The Netherlands, Belgium and West Germany, between 1-19 May to discuss transmission of viruses by nematodes, to attend an EPPO *ad hoc* Committee on the *Xiphinema americanum* group and to give an invited lecture to the Dutch Virology Group. From 26 June-21 July he again visited nematology and virology research centres in West Germany and The Netherlands and spent three weeks studying virus transmission by nematodes at Bari, Italy. During 2-9 August he visited nematology research centres in Pennsylvania and Utah and participated in the Society of Nematologists meeting at Davis, California, USA. From 30 September-7 October he visited and gave lectures at several universities and nematology and virology research centres in Portugal, jointly funded by the Instituto Nacional de Investigacao Cientifica and the British Council. From 17-23 November he returned to The Netherlands to continue collaborative investigations on nematode transmitted viruses with colleagues at the Flowerbulb Research Institute, Lisse and Leiden and Wageningen Universities.

S. T. Buckland visited Sempach, Switzerland, 10-14 April, to attend a Biometric Society EURING meeting on mark-recapture processes in bird ringing.

Stephanie Cooper-Bland visited Wageningen, The Netherlands for the EAPR breeding section and Eucarpia section conference from 11-16 December.

H. V. Davies visited the University of Wageningen, The Netherlands from 22-23 June for discussions on starch synthesis and the development of scientific links. He gave an invited seminar at the Institut für Genobiologische Forschung, West Berlin, 13-15 September, and also visited Brussels, Belgium (EEC HQ), 6 July, for an ECLAIR meeting to discuss an ECSA project.

C. A. Glasbey visited Turin, Italy, 28-29 March, to attend a meeting of an EC sponsored project on solar radiation in microclimates.

B. A. Goodman visited Brussels, Belgium, from 3-4 October, to attend the BCR Workshop on intercomparison of methods for identifying irradiated food organised by the CEC.

S. C. Gordon visited the Laboratoire de Cecidologie, Institut de Botanique, Strasbourgh, France from 11-13 November to discuss research related to gall mite resistance in black currant and to deliver a seminar.

B. S. Griffiths visited the Institute of Population Biology, Copenhagen University, Copenhagen, Denmark from 18 May-9 June. A collaborative experiment on rhizosphere biology was undertaken, two seminars were given and proposals for further joint work were discussed.

D. W. Griffiths attended the International Symposium on Ecological Chemistry and Biochemistry of Plant Terpenoids which was held at Murcia, Spain, 13-15 September.

B. D. Harrison made an invited visit from 8-12 May to lecture at the University of Leuven, Belgium. On 26-30 June he attended by invitation an FAO meeting in Luxembourg on potential applications of biotechnology in crops in developing countries, and chaired the session on diseases and pests. On 9-17 August he gave a series of lectures at Helsinki University to Scandinavian plant virologists. On 9 September he attended a meeting in Montpellier, France to discuss the EEC-funded network project on whitefly-transmitted viruses occurring in West Africa. In mid-October he visited Universities in St Louis and Lexington, USA for discussions on plant viruses and possible collaborations with SCRI.

G. W. Horgan visited the National Institute of Agricultural Research, Madrid, 24-28 April, as part of a collaborative project on analysis of synthetic aperature radar imagery.

N. L. Innes attended Governing Board meetings of CIP in the Dominican Republic and Guatemala from 15-19 May and in Lima, Peru, from 4-8 December. He participated in meetings of the CGIAR in Washington DC, USA from 27-31 November.

A. T. Jones attended the IV International Plant Virus Epidemiology Workshop, Montpellier, France, 2-9 September to present a poster and chair one of the sessions. The visit was partly funded by The British Council.

R. A. Kempton attended the 47th session of the International Statistical Institute in Paris, France, 29 August-3 September and also visited Kenya, from 5-11 November where he led a review team to the Biomathematics Unit, ICIPE.

A. Kumar attended a summer school conference on plant gene expression organised by FASEB, Colorado, USA, 7-11 August. He then visited the USDA Plant Gene Expression Centre, California on 14 August to discuss genetic transformation methods with Drs T. Klein and M. Fromm. He also visited the Department of Vegetable Crops, University of California, on 24 August, to discuss transposon tagging in tomato with Dr J. I. Yoder.

G. D. Lyon 'visited Ciba Geigy, Basle, Switzerland from 26-27 November to discuss phytoalexin elicitors.

G. R. Mackay made an invited visit to the All Union Academy of Agricultural Sciences (VASKHML), USSR from 2-8 July for a seminar and discussions on biotechnological methods in potato breeding.

D. K. L. MacKerron visited Ispra, 18-19 April, to attend a coordination meeting on yield prediction models. He also attended a meeting of the EC joint Faba bean trials (Northern) group in Brussels, Belgium from 23-24 November.

B. Marshall visited the Department of Field Crops and Grassland Science, University of Wageningen, The Netherlands, 12-19 December to complete work on tuber growth in potato.

M. A. Mayo participated in a joint AFRC/INRA meeting held at Versailles from 14-15 February to discuss opportunities for collaborative work between AFRC and INRA scientists in the field of plant virology. He visited the Biochemistry and Plant Pathology Departments of Oklahoma State University, USA, on 20 October and the Plant Pathology Department and the Boyce Thompson Institute at Cornell University, on 25-26 October, when he gave a seminar about the genome structure of potato leafroll virus.

J. W. McNicol visited Brussels, Belgium, on 13 March to attend an EC meeting on near-infrared reflectance analysis.

S. Millam attended an international conference on the Impact of Biotechnology in Agriculture at the University of Picardie, Amiens, France, from 10-12 July.

A. F. Murant visited the ICRISAT/SADCC groundnut rosette project at Chitedze, Malawi, from 30 March-6 April and again from 25-30 November. The second visit was preceded by a visit to ICRISAT, Hyderabad, India from 15-24 November to discuss research on rosette and other diseases of groundnut and to present a seminar.

M. C. M. Pérombelon, D. Hedley and P. Lanham attended a seminar on molecular biology of soft rot erwinias in Brussels, Belgium, from 26-28 January funded by the EC.

D. A. Perry attended the Pathology Section meeting of the EAPR at Baden, Austria, 3-7 July.

W. Powell visited the American Cocoa molecular biology laboratory, Pennsylvania State University, USA, from 19-21 August and discussed RFLP mapping in Cocoa. He gave an invited seminar at the Max-Planck Institute, Cologne, West Germany, on 27 September on genetic manipulation and its role in crop improvement. On the 5-6 October he visited IAEA, Vienna, Austria, and presented a seminar on the application of cellular and molecular techniques in crop improvement. He also spent three weeks in Bangladesh, in October, establishing a tissue culture laboratory at the Bangladesh Institute of Nuclear Agriculture.

W. M. Robertson visited the Institute for Phytopathology, University of Kiel, West Germany from 6-17 February to discuss collaborative work on nematode secretions (NATO funded).

D. J. Robinson attended the 2nd International Symposium on Positive Strand RNA Viruses, from June 26-30 in Vienna, Austria.

Lesley Torrance visited Brussels, Belgium, from 16-17 January to attend a management committee meeting of COST-88. She visited Lisse, The Netherlands, 20-21 April to attend a meeting of the COST-88 database working group and visited Bordeaux, France, 10-13 October to participate in the third COST-88 workshop and attend a management committee meeting.

Helen E. Stewart visited Gilat Regional Experiment Station, Negev, Israel on 7-14 June to view early blight in potato trials.

M. Talbot visited Madrid, Spain, from 17-19 May, to attend a meeting of the UPOV Technical Working Party on computing and automation and subsequently visited Luxembourg, from 25-26 May, to attend a EUROSTAT meeting on the development of statistical expert systems.

W. T. B. Thomas visited Gottingen, West Germany from 27 February-4 March to attend the XII Eucarpia 'Science for Plant Breeding'.

D. L. Trudgill visited INRA, Rennes, France from 27-29 September to attend an EAPR nematology sub-group meeting on potato cyst nematodes and to discuss the formulation of an EEC research proposal. From there he went to Romania from 1-7 October to advise on their newly discovered problems with potato cyst nematodes. On 25-29 November he visited Paris, France to contribute to EPPO *ad hoc* panel on potato cyst nematodes.

R. Waugh visited Dr W. Filipowicz, Basle, Switzerland, in September to discuss pre-mRNA splicing. He also visited the University of Freiburg, West Germany to discuss aspects of plant molecular biology.

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

5-6 January	The Strawberry Conference, Cambridge	
	J. M. Duncan	The Red Core Debate.

5-7 January	Mammal Society, UK Lagomorph Group, East Craigs, Edinburgh	
	B. Boag (W. H. MacFarlane-Smith) (D. W. Griffiths)	Observations on the grazing of two oilseed rape and fodder rape varieties by the wild rabbit *Oryctolagus cuniculus* in Scotland.
10 January	AFRC Soil Science Review, Swindow	
	J. R. Hillman	SCRI research programme on soil-plant dynamics.
12-14 January	1st UK Workshop on Eukaryotic Pre-mRNA Processing, Rydal Hall, England	
	R. Waugh (J. W. S. Brown[1])	Plant UsnRNA genes.
18 January	NFU Scotland, Broughty Ferry, Dundee	
	J. R. Hillman	A toast to agriculture.
13-17 March	Joint FAO/IAEA Division Advisory Group Meeting on Feeding Strategies for Improving Productivity of Ruminant Livestock in Developing Countries, Vienna, Austria	
	I. M. Morrison (R. E. Brice[2]) (S. A. Mousdale[3])	Biodegradation of lignocellulosic materials: present status and future prospects.
20 March	H-GCA Review, London	
	J. R. Hillman	Cereals research at SCRI.
22 March	Scottish Mycology and Plant Pathology Club, Edinburgh	
	P. H. Scott	Use of electrophoresis to identify different *Phytophthora* species from raspberry.
23 March	Association of Applied Biologists and Royal Society of Chemistry joint meeting on Antinutritional Factors in Plants and Plant Products	
	D. W. Griffiths	Polyphenolics and their possible effect on nutritive value.
3-4 April	Society of Experimental Biology, Edinburgh	
	B. D. Harrison (E. A. Murant) (D. C. Baulcombe[4])	Satellite-mediated resistance to cucumoviruses in transgenic plants.

[1]Department of Biological Sciences, University of Dundee
[2]Malaysian Rubber Producers Research Association, Hertfordshire
[3]Hannah Research Institute, Ayr, Scotland
[4]Sainsbury Laboratory, John Innes Institute, Norwich

3-7 April	Society for Experimental Biology Meeting, Edinburgh	
	B. Marshall (J. R. Porter[1])	Concepts of nutritional and environmental interactions determining plant productivity.
	K. J. Oparka (K. M. Wright) (D. A. M. Prior)	Turgor-sensitive sucrose partitioning in potato tubers.
	D. L. Richardson (H. V. Davies) (H. A. Ross) (R. A. Jefferies)	Effects of water stress and temperature on the carbohydrate composition of potato tubers.
	D. Robinson	Strategies for optimising growth in response to nutrient supply.
	A. Stanforth (H. V. Davies) (J. Sprent[2])	Effect of nitrogen source on C/N partitioning in *Vicia faba*.
	R. Viola (H. V. Davies)	Effects of sodium fluoride on glycolysis and starch biosynthesis in potato tubers.
	K. M. Wright (K. J. Oparka)	Sucrose uptake and conversion in source versus sink potato tubers.
	R. Waugh (J. W. S. Brown[2]) (W. Powell)	Cloning of plant U2snRNA genes.
4 April	Society for General Microbiology Workshop, Cambridge	
	M. A. Mayo	Organisation of the coat protein coding region of potato leafroll luteovirus RNA.
	M. A. Mayo	Resistance to plant viruses induced by transformation with interfering nucleotide sequences.
6-7 April	Molecular Biology of Plant Pathogenic Fungi, Birmingham	
	A. M. Campbell	Protoplast production and fusion.
10-13 April	10th AFRC Electron Microscopists Conference, IACR (RES), Harpenden	
	E. W. Milne (J. M. S. Forrest) (W. M. Robertson)	A technique for visualising secretions of cuticular origin from the potato cyst nematode *Globodera rostochiensis*.

[1]IACR, Long Ashton Research Station
[2]Department of Biological Sciences, University of Dundee

	I. M. Roberts (C. Fasseas) (A. F. Murant)	Immunogold labelling of parsnip yellow fleck virus particle antigen in thin sections.
11-12 April	Association of Applied Biologists, Norwich	
	B. D. Harrison	Transgenic virus resistance: approaches, efficacy and durability.
	M. M. Aiton (V. Muniyappa[1]) (I. M. Roberts) (B. D. Harrison)	Recognition and serological relationships of six whitefly-transmitted geminiviruses from India.
	W. P. Mowat (S. Dawson) (G. H. Duncan)	The use of antiserum to a non-structural viral protein to detect narcissus yellow stripe potyvirus.
12-16 April	NATO Advanced Research Workshop, Chichester	
	A. F. Murant	Specificity and recognition events in the transmission of plant viruses by vectors.
	B. D. Harrison (H. Barker) (P. M. Derrick)	Intercellular movement of potato leafroll luteovirus: effects of plant resistance and co-infection.
	B. D. Harrison	Summing up.
14-15 April	5th Annual Meeting Scottish Yeast Group, Dundee	
	A. C. Newton (G. D. Lyon)	Yeast cell walls as phytoalexin elicitors.
18-22 April	EPPO Conference on Phytophthora diseases of citrus and other crops in the Mediterranean area, Palermo, Italy	
	J. M. Duncan	*Phytophthora* spp. attacking strawberry and raspberry.
	J. M. Duncan	Proposal for an international *Phytophthora* diagnostic group.
30 April	Society for Scottish Crop Research Annual Meeting	
	D. A. Perry	The future for crop protection.
2 May	Dutch Virologists Meeting, IPO, Wageningen, The Netherlands	
	D. J. F. Brown	Specificity of transmission of nepoviruses by *Longidorus* and *Xiphinema* vector nematodes.

[1]University of Agricultural Sciences, Hebbal, Bangalore

	A. T. Ploeg (D. J. F. Brown)	Specificity of transmission of Tobraviruses by (*Para*) *Trichodorus* nematodes.
9 May	41st International Crop Protection Symposium, Ghent University, Belgium	
	D. J. F. Brown (A. T. Ploeg) (D. L. Trudgill)	Specificity of transmission of nematode transmitted viruses.
	B. Boag (D. J. F. Brown)	Field sampling for detecting virus transmitting nematodes and their associated viruses.
9 May	International Symposium on Plant Protection, Gent, Belgium	
	B. D. Harrison (M. M. Aiton)	Detection and differentiation of whitefly-transmitted geminiviruses with monoclonal antibodies.
13 May	Scottish Association for Biological Education, Dundee	
	J. R. Hillman	Careers in agricultural research — implications for teaching.
12-14 May	Las Enfermedades de la Papa y su Control, University of La Laguna, Canary Islands	
	D. L. Trudgill	The Scottish Crop Research Institute and the research on potato diseases in Common Market countries.
15-17 May	Suelos Supresivos y Enfermedades de las Plantas su Aplicacion en Lucha Biologica, University of La Laguna, Canary Islands	
	D. L. Trudgill	Los hongos del suelo y el control biologico de nematodes parasitos de plantas.
30 May-3 June	International Society for Horticultural Science Symposium on in-vitro culture and horticultural breeding, Cesena, Italy	
	J. Graham (R. J. McNicol)	Plantlet regeneration and genetic transformation in soft fruit species.
17-21 June	7th International Conference on Plant Pathogenic Bacteria, Budapest, Hungary	
	M. C. M. Pérombelon	Ecology and pathogenicity of soft rot erwinias: an overview.

18-21 June	Rank Prize Funds Symposium, Grasmere	
	B. D. Harrison	Progress in the production of virus-resistant transgenic plants.
19-21 June	21st Colloquium of the International Potash Institute, Louvain-la-Neuve, Belgium	
	K. J. Oparka (K. M. Wright) (D. A. M. Prior)	Osmotic regulation of sucrose partitioning in potato tuber storage tissues.
21-30 June	22nd International Seed Testing, Congress, Edinburgh	
	M. Talbot (A. Soutar) (R. Don)	Monitoring the performance of seed analysis.
	M. Talbot (A. V. Wheelwright) (R. Don)	A sequential procedure for routine tetrazolium testing of cereal seed viability.
	M. Talbot (R. Don) (A. V. Wheelwright)	The relationship between germination and tetrazolium results obtained from barley and wheat samples.
24 June-2 July	5th International Society for Horticultural Science Symposium on Rubus and Ribes, Vancouver, B.C., Canada	
	A. Dale[1] (R. J. McNicol) (P. P. Moore[2] & T. S. Sjulin[3])	Pedigree analysis of red raspberry.
	V. H. Knight[4] (D. L. Jennings & R. J. McNicol)	Progress in the UK raspberry programme.
	H. M. Lawson (J. S. Wiseman)	Alternatives to dinoseb-in-oil for cane desiccation in red raspberry in Scotland.
	R. J. McNicol (J. Graham)	Genetic manipulation in *Rubus* and *Ribes*.
	R. J. McNicol (B. Williamson) (K. Young)	Ethylene production by black currant flowers infected by *Botrytis cinerea*.
	Wendy A. Wallis[5] (R. C. Shattock[1]) (B. Williamson)	Downy mildew (*Peronospora rubi*) on micropropagated *Rubus*.

[1]Horticultural Research Institute of Ontario, Simcoe, Canada
[2]Western Washington Research and Extension Centre, Washington State, USA
[3]Driscoll Strawberry Associates, California, USA
[4]IHR, East Malling, Maidstone, Kent
[5]University College of North Wales, Bangor

25-30 June	8th International Workshop on Plant Membrane Transport, Venice, Italy	
	K. J. Oparka (K. M. Wright) (D. A. M. Prior)	Control of starch synthesis in potato tubers by turgor-sensitive sucrose transport at the plasmalemma.
26 June-1 July	European Association for Potato Research, Physiology Section, Gross Lusewitz, GRD	
	D. K. L. MacKerron (Z.-Y. Peng)	Relations between root and shoot growth: genotypic differences in response to water-stress.
2-7 July	NATO Advanced Research Workshop, York	
	P. M. Derrick	Effects of infection by viruses of different taxonomic groups on plasmodesmatal conductance of fluorescent tracers.
3-4 July	University of Wales Statistics Colloquium, Bangor	
	C. A. Hackett	A mathematical model of plankton in the western Irish Sea.
3-7 July	European Association for Potato Research, Pathology Section, Baden, Austria	
	R. L. Wastie (G. R. Mackay) (P. D. S. Caligari) (Helen E. Stewart)	Progeny testing for gangrene resistance on glasshouse-grown tubers.
	R. L. Wastie	A seedling test for resistance to powdery scab.
11-13 July	British Society for Plant Pathology Workshop, Norwich	
	J. M. Duncan (S. Mohan)	Detection of *Phytophthora* species using ELISA.
	Mary-Jo Farmer (B. D. Harrison)	Detection of potyviruses using monoclonal antibodies to potato virus V.
	Lesley Torrance	Serological techniques for diagnosing plant virus diseases.
16-19 July	EMBO Workshop on Molecular Biology of Plant Virus Pathogenicity, Wye College	
	D. J. Robinson (A. T. Ploeg) (D. J. F. Brown)	Determinants of specificity between tobacco rattle virus isolates and their nematode vectors.

22-26 July	Potato Association of America Conference, Corvallis, Oregon, USA	
	H. V. Davies (D. L. Richardson) (H. A. Ross) (G. R. Mackay)	Invertase and hexose accumulation in stored tubers.
	H. V. Davies (L. S. Talbot)	Studies on the physiological basis for genotype variation in susceptibility of tubers to Internal Rust Spot (IRS) — a calcium related disorder.
	H. V. Davies (D. K. L. MacKerron) (B. Marshall) (A. Baylis[1])	Effects of paclobutrazol — nitrogen interactions on tuber yield and quality.
30 July-3 August	73rd Annual Meeting of the Potato Association of America, Oregon State University, Corvalis, Oregon, USA	
	P. M. Cochrane[2] (C. M. Duffus[2]) (M. J. Allison) (G. R. Mackay)	Amylolytic activity in stored potato tubers.
	J. Brown[3] (G. R. Mackay)	Processing potential of potatoes after storage at low temperatures.
	H. V. Davies (D. L. Richardson) (Heather A. Ross) (G. R. Mackay)	Invertase and hexose accumulation in stored potatoes.
1-2 August	Potato Research Symposium, Warmbaths, RSA	
	D. K. L. MacKerron	Quantified responses of the potato crop to water-stress.
6-11 August	FASEB Summer Research Conference, Colorado, USA	
	A. Kumar (B. Reavy) (M. A. Mayo)	Production of transgenic potato plants containing the coding sequences for coat protein of potato leafroll virus.
13-17 August	Society of Nematologists 28th Annual Meeting, University of California, Davis, USA	
	D. J. F. Brown (A. T. Ploeg) (D. J. Robinson)	Specificity of transmission of tobravirus variants by their vector (*Para*) *Trichodorus* nematodes.

[1]Imperial Chemical Industries plc
[2]Edinburgh School of Agriculture, University of Edinburgh
[3]ESCAGEN Corporation, 830 Bransten Road, San Carlos, California 94070-3305, USA

	D. J. F. Brown (C. E. Taylor) (D. L. Trudgill)	Variation in virus transmission among longidorid vector nematode populations.
	W. M. Robertson (J. M. S. Forrest) (D. Stewart)	Production of antisera to the surface of *Longidorus elongatus* and *L. attenuatus*.
14-18 August	First International Symposium on the Molecular Biology of the Potato, Maine, USA	
	P. M. Cochrane[1] (C. M. Duffus[1]) (M. J. Allison) (G. R. Mackay)	The role of mylolytic enzymes in low-temperature sweetening in potato (*Solanum tuberosum* L.).
	W. Powell (R. Waugh)	Inheritance of RFLP loci in potato.
	W. Powell (M. Coleman) (P. Davie) (R. Waugh)	Genetical analysis of tissue culture response in potato.
21-23 August	Horticultural Biotechnology Symposium, Davis, USA	
	A. Kumar (B. Reavy) (M. A. Mayo)	Production of transgenic potato plants containing the coding sequences for coat protein of potato leafroll virus.
	A. Kumar (R. J. McNicol) (J. Graham)	Development and utilisation of a genetic transformation method in the genus *Rubus*.
21-23 August	Nordic Regional Meeting of Biometric Society, Laugarvatn, Iceland	
	S. T. Buckland	Determining whale abundance.
	C. A. Glasbey	Image analysis in agricultural research.
30 August- 2 September	5th Cell Wall Meeting, Edinburgh	
	G. J. McDougall (S. C. Fry[2])	Xyloglucan oligosaccharides, cellulose and growth.
	I. M. Morrison (S. A. Mousdale[3])	Development of the warty layer — A near death experience of a barley cell wall?
3-8 September	4th International Plant Virus Epidemiology Workshop, Montpellier, France	
	A. F. Murant (I. K. Kumar)	Role of a satellite RNA in green and chlorotic forms of groundnut rosette.

[1]Edinburgh School of Agriculture, University of Edinburgh
[2]Department of Botany, University of Edinburgh
[3]Hannah Research Institute, Ayr

	A. F. Murant (K. R. Bock[1]) (R. Rajeshwari[2])	Resistance of groundnut to components of rosette disease.
	A. T. Jones (A. N. E. Birch) (M. Harrington[3]) (G. W. Robertson)	Characterisation of resistance in raspberry to the virus vector aphid, *Amphorophora idaei.*
	B. D. Harrison (E. A. Murant)	Prospects for satellite-mediated transgenic virus resistance.
	H. Barker	Analysis of polygenically controlled resistance in potato to potato leafroll virus.
4-6 September	IOBC/WPRS/EUCARPIA Working Group on Breeding for Resistance to Insects and Mites, Morges, Switzerland	
	A. N. E. Birch	Resistance to turnip root fly in Brassicas.
	A. N. E. Birch	Resistance to the virus vector aphid *Amphorophora idaei* in raspberries.
4-7 September	9th International Botrytis Symposium, Neustadt an der Weinstrasse, Germany	
	B. Williamson (R. J. McNicol)	Histological studies of latent infection of soft fruit crops by *Botrytis cinerea.*
6-8 September	Plant Cell Signalling and Communication, British Society for Cell Biology, John Innes Institute/ University of East Anglia, Norwich	
	C. J. McDougall	Xyloglucan oligosaccharides and plant growth.
11-13 September	SEB Plant Transport Group Meeting, Rothamsted	
	K. M. Wright (K. J. Oparka)	Sugar transport into potato tuber storage tissue.
	K. J. Oparka (K. M. Wright)	How the devil does Lucifer Yellow enter plant cells?
11-14 September	British Society of Soil Science and Royal Society of Chemistry Agriculture Group, Reading University	
	B. S. Griffiths	Approaches to measuring the contribution of nematodes and protozoa to nitrogen mineralisation in the rhizosphere.

[1]ICRISAT, Chitedze, Malawi
[2]School of Life Sciences, University of Hyderabad, India
[3]North East London Polytechnic, London

11-15 September	Fysiologie Rusta A Dormance Bramber (Conference on Physiology of Growth and Dormancy in the Potato), Jihlava, Czechoslovakia	
	D. K. L. MacKerron (P. A. Gill)	Tuberizace a rust hliz. (Tuberization and growth of tubers).
11-15 September	6th Genstat Conference, Edinburgh	
	C. A. Glasbey	SASS experience of teaching using Genstat.
14 September	Oilseed rape/allergy Press Conference, Forfar	
	W. H. MacFarlane-Smith	The history and recent development of oilseed rape growing in the UK.
18-21 September	2nd Phytophthora International Symposium, Dublin, Ireland	
	J. M. Duncan (D. M. Kennedy) (P. H. Scott)	Relationship between non-papillate soil borne species of *Phytophthora* in root rot of raspberry.
	J. Kinghorne[1] (R. Moon[1]) (A. M. Campbell) (S. Unkles[1]) (J. M. Duncan)	Towards gene-transfer systems and understanding gene structure in *Phytophthora infestans*.
22 September	AFRC Scientific Opportunities Meeting, Bristol	
	J. R. Hillman	Fibres.
25-28 September	Association of Applied Biologists, Roots and the Soil Environment, St Andrews University	
	A. N. E. Birch	Interactions between root flies and brassica roots — clues to alternative control strategies.
	B. Boag	Factors controlling plant-parasitic nematodes.
	B. Boag (D. J. F. Brown) (R. Neilson)	Spatial distribution of plant-parasitic nematodes.
	D. J. F. Brown (D. L. Trudgill)	Evolution of transmission of nepoviruses by longidorid nematodes.
	M. F. B. Dale	Advances in breeding for Tobacco Rattle Virus insensitivity in potatoes.

[1]Plant Molecular Genetics Unit, University of St Andrews

	B. S. Griffiths	The role of bacterial feeding nematodes and protozoa in rhizosphere nutrient cycling.
	N. L. Innes	Breeding for resistance to soil-borne pests and diseases.
	D. J. Linehan	Mobilisation of nutrients in the rhizosphere and their uptake by plants.
	D. K. L. MacKerron (Z.-Y. Peng)	Genotypic comparisons of potato root growth and yield in response to drought.
	E. I. Newman[1] (K. Ritz) (A. P. Jupp[1])	The functioning of roots in the grassland ecosystem.
	D. A. Perry (N. A. Williams)	Anaerobic clostridia in the rhizosphere of crop plants and implications for nitrogen transformtions.
	A. T. Ploeg (D. J. F. Brown)	Factors affecting problems caused by tobacco rattle virus.
	W. M. Robertson (J. M. S. Forrest)	Factors involved in host recognition by plant-parasitic nematodes.
	W. M. Robertson (B. S. Griffiths)	A comparative study of cellular changes in galls induced by *Longidorus elongatus* and *Xiphinema diversicaudatum*.
	D. Robinson	Phenotypic plasticity in roots and root systems: compensations, constraints and compromises.
	I. M. Young (A. G. Bengough)	Mechanical constraints to root growth.
21 September	Scottish Plant Biotechnology Forum, Dundee	
	M. C. M. Pérombelon	Genetic engineering of *Erwinia*.
	B. Reavy (A. Kumar) (M. A. Mayo)	Transformation of potato plants with the potato leafroll virus coat protein gene.
10-11 October	Application of Remote Sensing to Agricultural Statistics, Varese, Italy	
	D. K. L. MacKerron	Agrometeorology of the potato crop.

[1]Department of Botany, University of Bristol

11-13 October	3rd COST-88 Workshop, Detection of Plant Pathogenic Bacteria and Mycoplasma-like Organisms, Bordeaux, France	
	M. C. M. Pérombelon	Detection of potato seed contamination by soft rot erwinias below the threshold level for blackleg development.
16-17 October	Symposium on Viral Genes and Plant Pathogenesis, Lexington, Kentucky, USA	
	B. D. Harrison	Concluding comments and reflections on current trends in plant virology.
24 October	Society for Chemical Industry, Agriculture Group	
	R. P. Ellis	Breeding barley for agriculture with fewer inputs.
26-27 October	AAB Conference, Variability in Plant Monocultures — Physiology, Ecology and Economic Aspects, Wartwick	
	D. A. Elston	Analysis of carrot weights.
	T. D. Heilbronn (D. K. L. MacKerron)	The relative importance of sources of variance in the grade distribution of potato tubers.
4 November	Scottish Organic Gardeners' Conference, Montrose	
	G. D. Lyon	A new approach to control plant diseases.
15 November	Institute of Biology, Scottish Branch Annual Symposium, Roslin, Midlothian, Scotland	
	B. D. Harrison	Genetically engineered plants with resistance to viruses and pests.
	S. Millam (W. Powell)	Genetic engineering in crop plants.
20-23 November	1989 Brighton Crop Protection Conference — Weeds, Brighton	
	H. M. Lawson (J. S. Wiseman) (G. McN. Wright)	Tolerance of seed potato to two new residual herbicide mixtures.
22 November	Society for Scottish Crop Research: Potatoes — getting them right, Dundee	
	D. A. Perry	New methods for testing tuber health.

18-19 December	Association of Applied Biologists meeting on Production and Protection of Oilseed Rape and other Brassica Crops, Churchill College, Cambridge	
	B. Boag (W. H. MacFarlane-Smith) (D. W. Griffiths)	Effects of double low varieties of oilseed rape on mammalian wildlife.
	J. E. Bradshaw (A. N. E. Birch) (D. J. Gemmell) (C. J. Williamson)	Progress at SCRI in breeding swedes (*Brassica napus* L. spp. *rapifera*) with improved disease and pest resistance.
	H. M. Lawson	Prospects for weed control in fodder brassicas.
	S. Millam	*Agrobacterium* mediated transformation of *Brassica* species.
	C. J. Williamson	An assessment of the importance of club-root in oilseed rape.
18-20 December	British Society for Plant Pathology, Nottingham	
	D. M. Kennedy	*Phytophthora* root rot of raspberry.
	D. A. Perry (M. R. Groom)	Cavity spot of carrot.
20 December	Association of Applied Biologists, Imperial College, London	
	B. Boag (R. Neilson) (S. C. Gordon)	Observations on the distribution of insect-parasitic nematodes in Scotland and northern England.
	J. M. S. Forrest (D. Stewart) (W. M. Robertson)	Antibodies to cuticular and other nematode antigens.
	L. A. MacCulloch (W. M. Robertson) (J. M. S. Forrest)	Effect of the lectin concanavalin on the localisation and parasitism of host plant roots by *Meloidogyne javanica* and *Globodra rostochiensis*.
	J. A. Gonzalez (D. L. Trudgill)	Studies of potato cyst nematodes in the Canary Islands.
	A. T. Ploeg (C. J. Asjes) (D. J. F. Brown)	Factors involved in transmission of tobraviruses by trichodorid nematodes, in bulb fields.
	J. M. Robb (J. M. S. Forrest) (W. M. Robertson)	Studies on the nature of the salivary secretions of plant-parasitic nematodes.

Conferences organised

B. Boag organised the Poster Session at the Association of Applied Biologists meeting on Production and Protection of Oilseed Rape and Other Brassica Crops, Cambridge, 18-19 December.

D. J. F. Brown and A. T. Ploeg organised and ran a one day workshop on the taxonomy and identification of British (*Para*) *Trichodorus* virus-vector nematodes for nematology staff at Scientific Services, East Craigs, DAFS, 8 December.

J. W. S. Brown and W. Powell organised a meeting on Potato Biotechnology as part of the Scottish Biotechnology Forum at SCRI, 29 September.

M. F. B. Dale was joint organiser of the AAB Conference, Production and Protection of Oilseed Rape and other Brassica Crops, Cambridge, UK, 18-19 December.

R. J. A. Exley, D. L. Hood and D. K. L. MacKerron jointly organised a conference sponsored by the Scottish Society for Crop Research, entitled 'Potatoes — getting them right', which was held in the Earl Grey Hotel, Dundee, 22 November.

R. A. Kempton organised an AFRC meeting on Statistics in Molecular Biology, 10 May.

A. Kumar was a principal scientific organiser of a course on plant genetic transformation and gene expression held at the University of Leicester, 13-22 December.

B. Marshall, in conjunction with J. Porter, D. Lawlor and I. Rorison, organised the Environmental Physiology Sessions on 'Plant Growth: Interactions with Nutrition and Environment', Society for Experimental Biology, University of Edinburgh, 3-6 April.

M. A. Mayo and D. J. Robinson were co-organisers of an EMBO-sponsored workshop on the Molecular Biology of Plant Virus Pathogenicity held at Wye College from 17 to 19 July.

Jacqueline Muscott was local organiser for the 6th Genstat Conference at Edinburgh from 11-15 September.

M. C. M. Pérombelon organised the plenary session of the International Erwinia (soft rot) Group at the 7th International Conference on Plant Pathogenic Bacteria, Budapest, Hungary, 17-21 June.

D. Robinson, in conjunction with T. J. Hocking (Wolverhampton Polytechnic), organised the Plant Physiology sessions for the Association of Applied Biologists' Presidential meeting held at the University of St Andrews, 25-28 September.

R. L. Wastie organised a meeting of the Scottish Mycology and Plant Pathology Club, Edinburgh School of Agriculture, 22 March.

C. J. Williamson organised a meeting on Priorities in Organic Research and Development, Perth, 30 November.

Courses attended

Elizabeth D. Bowman attended a course on Immunocytochemistry, organised by the RMS, at Lady Margaret Hall, Oxford from 25-29 September.

R. Brennan attended a Protein and Nucleic Acids Workshop at Hatfield Polytechnic, Herts, 11-15 September.

A. Cassidy, S. Cooper-Bland, D. M. Cormack, B. P. Forster and M. Macaulay attended a lecture course on Nuclear Magnetic Resonance held at the Chemistry Department, University of Dundee, September-November.

R. J. Clark attended a one day course in Effective Staff Reporting and Appraisal Interviewing at MLURI, Aberdeen on 2 May.

S. Clark attended a week's course in programming in 'C' at University of Dundee from 11-15 December.

Stephanie Cooper-Bland attended a 3 day course on Techniques in Molecular Biology — Nucleic Acid Workshop at Hatfield Polytechnic, 11-13 September.

J. M. S. Forrest attended a course on monoclonal antibody techniques at the University of London from 20-24 November.

B. P. Forster attended a course on the wheat industry held by Dalgety Agriculture at Cambridge, 20-21 March.

W. I. A. Jack attended a course on Effective Staff Reporting and Appraisal Interviewing at MLURI, Aberdeen, 2-3 May.

C. Anne Jolly attended a course on the 'Application of Molecular Genetics to Plants' held at Bristol University from 24-25 May.

R. Kidger attended a Unix Course on 25-26 October at the Edinburgh University Computing Service.

K. Ritz attended a course on Water and Efficient Analysis and Monitoring organised by V. W. Scientific, York, 1-2 February.

W. M. Robertson and Elizabeth D. Bowman attended an AFRS electron microscopy course at Silsoe from 11-13 April.

M. Talbot attended a course on Quality Systems Management at Napier Polytechnic, Edinburgh, January-April.

K. Taylor attended a course on Malting at Pauls Malts Ltd, Ipswich, 3-7 April.

D. Todd and M. J. Wilkinson attended a course on Forklift Driving at SCRI, 9-11 September.

Courses Organised or Contributed to

B. Boag presented a lecture on soil sampling for nematodes at the Association of Applied Biologists Workshop on Soil Invertebrates held at Homerton College, Cambridge on 22-23 March.

B. Boag, R. Neilson and P. Smith organised a Nematode Computer Identification Course at SCRI on 4-8 December.

Mary C. Coleman lectured to biology students at the University of Dundee on cell and tissue culture methods in crop improvement on 8 March.

Stephanie Cooper-Bland lectured to students at the University of Aberdeen on cellular and molecular techniques in crop improvement.

R. P. Ellis contributed to a course on plant breeding for students of Biology and Pre-clinical Medicine at St Andrews University, 14-15 February. He also lectured on plant breeding to students at West of Scotland College of Agriculture on 27 April.

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

B. D. Harrison lectured to the Department of Genetics and Microbiology, University of Aberdeen on the use of genetic engineering and monoclonal antibodies in plant virology.

A. T. Jones and W. P. Mowat contributed lectures and a practical on plant virology to students on the MSc/Diploma course in Crop Protection. University of Aberdeen.

A. Kumar lectured to students at the University of Dundee on the use of biotechnology in crop improvement.

H. M. Lawson lectured on 'Weed biology and ecology' to Diploma/M.Sc students from The School of Agriculture, Aberdeen, 6 November.

G. R. Mackay organised and contributed to a course of 8 lectures on plant breeding to the Department of Pre-clinical Medicine and Biology, St Andrews University. He also lectured on potato breeding to biology students at the University of Dundee on 8 March.

D. K. L. MacKerron lectured on 'Factors affecting size grades in potato' to honours students in agriculture, University of Aberdeen, 16 March.

R. J. McNicol lectured to students at the Universities of Dundee and Edinburgh on aspects of fruit breeding.

S. Millam lectured to students at the Universities of St Andrews and Edinburgh and Elmwood College on biotechnology and crop improvements, and to the Scottish Horticultural and Agricultural Lecturers Society on plant tissue culture.

K. J. Oparka lectured to the Biological Society, Durham University, 10 October, on endocytosis in higher plant cells. He also lectured on the same subject to the Biological Society, University of Edinburgh, 6 February.

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

K. Ritz lectured at MLURI (Aberdeen) on current perspectives in organic farming research, 18 December.

SASS organised and ran several statistics courses for DAFS scientists.

R. Waugh lectured to students at the University of Dundee on the role of molecular techniques in crop improvement.

Virology Department staff gave lectures and demonstrations in a short course on plant virology for students at the University of Dundee in February.

Editorial Duties

D. J. F. Brown	Editorial Board of *Nematologia Mediterranea*
J. M. Duncan	Associate Editor of *Journal of Horticultural Science*
B. D. Harrison	Editor of *Association of Applied Biologists Descriptions of Plant Viruses* Editorial Board, Proceedings B, Royal Society of Edinburgh
J. R. Hillman	Editor of *Crop Research* Member of the Publication Committee of *Journal of Horticultural Science* Member of Editorial Panel *Agricultural Systems* Member of Editorial Panel Scottish Seed Potato Development Council
N. L. Innes	Editorial Board of *Agbiotech News and Information* Editorial Board of *Crop Research*
H. M. Lawson	Associate Editor of *Journal of Horticultural Science*
G. R. Mackay	Editorial Board of *Heredity*
D. K. L. MacKerron	Associate Editor of *Journal of Horticultural Science*
M. A. Mayo	Editor (plant virology) of *Journal of General Virology*
I. M. Morrison	Editorial Board of *Journal of the Science and Food and Agriculture* Series Editor for *Advances in Plant Cell Biochemistry and Biotechnology*
A. F. Murant	Editor of *Association of Applied Biologists Descriptions of Plant Viruses* Editorial Board of *Interviology* Editorial Board of *Virus Research*
D. A. Perry	Editorial Board of *Crop Research*
W. Powell	Editorial Board of *Heredity* Editorial Board of *Potato Research*
D. Robinson	Associate Editor of *Journal of Horticultural Science*
D. J. Robinson	Editorial Board of *Journal of Virological Methods* Editorial Board of *Journal of General Virology*
D. L. Trudgill	Editorial Board of *Revue de Nematologie* Consulting Editor for *Plant and Soil*
R. L. Wastie	Editorial Boards of *Annals of Applied Biology* Editorial Board of *Potato Research*
B. Williamson	Editorial Board of *Annals of Applied Biology*
J. A. T. Woodford	Editorial Board of *Annals of Applied Biology*

Service on Committees

T. J. W. Alphey	Scottish Food Research Consortium Committee
H. Barker	AAB Virology Group Committee
B. Boag	Nematological and Scottish representative on the European Invertebrate Survey Committee
R. Brennan	NFT Black Currant and Bush Fruit Panel
D. J. F. Brown	Secretary and Treasurer of the European Society of Nematology
S. T. Buckland	Review Group on sampling strategies for integrated population studies, British Trust for Ornithology Scientific Committee of the International Whaling Commission
M. R. Cormack	NFT Scottish Soft Fruit Panel SDA Raspberry Industry Group TRIO Adviser, Fruit Crops SCRI/ASS/COSAC Liaison Committee Soft Fruit Working Group
M. F. B. Dale	Council and Convener AAB Plant Breeding Committee
H. V. Davies	British Society for Plant Growth Regulation — Committee Member International Potato Molecular Biology Conference — Chairman of Organising Committee
J. M. Duncan	Membership Secretary BSPP
R. P. Ellis	SSCR Technical Secretary Cereals Group BSPB Cereal Crop Group Consultative Committee BSPB Representative on Institute of Brewing Scottish Working Party
M. F. Franklin	Biometric Society Committee
B. A. Goodman	Royal Society of Chemistry — Mossbauer Discussion Group MAFF co-operative trial on detection for irradiated foods
S. C. Gordon	AFRC Pesticide Application Discussion Group
B. D. Harrison	Advisory Committee, *Advances in Virus Research* Advisory Committee for NERC Institute of Virology and Environmental Microbiology Royal Society Section 7 Committee
J. R. Hillman	AFRC Plants and Soils Research Committee DAFS Joint Management Board Organising Committee for EAPR Triennial Conference 1990 ECRE Board of Management GIUS, WSC, Technical Committee Horticultural Quartet

	Chairman Kirton EHS Visiting Group
	NFT (Brogdale) Advisory Committee
	Publications Committee, Journal of Horticultural Science
	Royal Society of Edinburgh (Sectional Committee B)
	Chairman SCRI/ASS/COSAC Liaison Group
	SNSA Adviser to Committee
	Strategic Quintet (ADAS/AFRC/SAC/SARI)
	Chairman Crop Production Quartet
	Senate, University of Dundee
	External Examiner in B.Sc. Biological Sciences, University of Lancaster
	Chairman Tayside Biocentre Group
	University of Strathclyde Sub-Board for the Degree of B.Sc. in Horticulture
N. L. Innes	Governing Board CIP, Peru
	Chairman Nominations Committee, CIP
	Secretary Executive Committee, CIP
	External Examiner in MSc Applied Genetics, University of Birmingham
	Horticultural Quartet (ADAS/AFRC/SAC/SARI)
	Royal Society of Edinburgh, Section Committee Biology (I)
	BSPB Technical Adv sory Committee
	SCRI/ASS/COSAC Liaison Group
	University of Dundee Botanic Garden Committee
D. L. Jennings	NFT Raspberry Panel
	NFT Scottish Soft Fruit Panel
	SNSA Adviser to Committee
	Fruit Research Consultative Committee
A. T. Jones	Chairman ISHS Working Group on Virus Diseases of Small Fruits
R. A. Kempton	Royal Statistics Society Council
H. M. Lawson	ADAS/IACR (LARS) Weed Liaison Group
	AFRC Fruit Weed Control Group
	BCPC R&D Sub-committee — Weeds
	SCRI/SAC Weeds Group
G. D. Lyon	SEB Cell Signalling Group
W. H. MacFarlane Smith	BSPB Oilseed and Industrial Crop Group
	NPTC Plant Variety Development Panel
	Chairman SCRI/ASS/SAC Forage Brassica Working Group and member of Liaison Group
	Secretary SCRI/SSCR Forage Group Sub-committee
	Technical Survey Sectoral Quartet on Crop Production

G. R. Mackay	Chairman Eucarpia Potato Section
	Science Committee member EAPR Triennial Conference 1990
	BSPB Potato Crop Group
	DAFS Potato Working Group
	Interdepartmental and Users Committee, DAFS Potato Breeders' Quarantine Unit
S. F. Malecki	Membership Secretary IPMS
U. M. McKean	Tayside Chief Librarians' Local Information Plan Working Party
D. K. L. MacKerron	Chairman Working Group on Water Relations in Potato Production, EAPR Physiology and Agronomy Sections
	Chairman Scientific Committee for 11th EAPR Triennial Conference, 1990
	Secretary SARI/ASS/SAC Potato Working Group
	Secretary SSCR Potato Crop Sub-committee
	SARI/ASS/SAC Liaison Group, Member
L. F. McLaren	Secretary Local Whitley Council (TU Side)
R. J. McNicol	NFT Raspberry Panel
	NFT Strawberry Panel
	NFT Scottish Soft Fruit Panel
	SNSA Adviser to Committee
B. Marshall	SEB Plant Biology Section Committee
M. A. Mayo	International Committee on Taxonomy of Viruses, Executive Committee
S. Millam	SCRI section of IPMS
	"The Grower" Link Panel
I. M. Morrison	AFRC LINK Co-ordinating Group, "Crops for Industrial Use"
W. P. Mowat	Convener SNSA Bulb Technical Committee
A. F. Murant	International Committee on Taxonomy of Viruses, Member of Plant Virus Sub-Committee
J. Muscott	SARI/SAC representative: Edinburgh Computer Users Committee
I. M. Nevison	North-East Scotland Operational Research Group Committee
A. C. Newton	UK Cereal Pathogen Virulence Survey Committee
	BSPP Council Member
M. C. M. Pérombelon	Chairman ISPP International Erwinia (soft rot) Group
	COST-88 Working Group on Detection of Bacteria
D. A. Perry	Treasurer Association for Crop Protection in Northern Britain
	Chairman Scottish Potato Diseases Working Party
G. Ramsay	SARI/SAC Oil and Protein Crop Working Group

K. Ritz	Member SARI/SAC Working Group on Organic Production Systems
	SARI/SAC Soil Liaison Committee
I. M. Roberts	Chairman AFRC Electron Microscope Advisory Group
	Safety Representative, Royal Microscopical Society Education Committee
D. J. Robinson	Society for General Microbiology Virus Group Committee
M. Talbot	DAFS representative: Inter-departmental Statisticians Group for plant variety testing
L. Torrance	Committee for COST project 88 on early detection of plant diseases
W. T. B. Thomas	AAB Plant Breeding Committee
D. L. Trudgill	Chairman and Convenor of the EPPO *ad hoc* panel on potato cyst nematodes
M. J. Wilkinson	Interdepartmental and Users Committee
	DAFS Potato Breeders' Quarantine Unit
C. J. Williamson	Technical Secretary SARI/SAC Working Group on Organic Production Systems
J. A. T. Woodford	Scottish Regional Secretary Royal Entomological Society of London
I. M. Young	SCRI/SAC Soil Compaction Group

Exhibitions and Poster Sessions

10-12 January	*British Growers Look Ahead International 89*, Birmingham
	Novel fruits for the UK
	Alternative fruit crops for the UK
27 February-4 March	*12th Eucarpia Congress*, Göttingen, West Germany
	Sources of resistance to *Plasmodiophora brassicae* used in breeding programmes at SCRI
	Cross prediction of malting quality in spring barley
	Cross prediction studies in forage rape (*Brassica napus* L)
3-7 April	*Society for Experimental Biology*, University of Edinburgh
	Manipulation of the coat protein gene of potato leafroll virus for transformation of potato
	Behaviour of Mul and Ac in transgenic plants
10-13 April	*AFRC Electron Microscopy Meeting*, Harpenden
	Fungal endoparasitism of cereal cyst nematode, *Heterodera avenae*
	Cryo-trimmed, freeze-dried raspberry drupelet infected by *Botrytis cinerea*

11-13 April	*AAB Meeting in Pests, Pathogens and Plant Communities*, University College of North Wales, Bangor The use of plant-parasitic nematodes as indicators of vegetation type
30 May-3 June	*International Society for Horticultural Research Symposium on* in vitro *culture and horticultural breeding*, Cesna, Italy The establishment of an *in vitro Ribes* germplasm collection and preliminary investigations into long-term low temperature germplasm storage The potential use of restriction fragment length polymorphism in *Rubus* breeding
14-15 June	*Cereals '89*, Compton Malting quality and mildew resistance in barley
17-21 June	*7th International Conference on Plant Pathogenic Bacteria*, Budapest, Hungary Activation and inhibition of pectate lyase from *Erwinia carotovora* subsp. *atroseptica* by potato tuber tissue extract
24 June-2 July	5th International Society for Horticultural Research Symposium on Rubus and Ribes, Vancouver, B.C., Canada Black raspberries and purple raspberries should be spinefree and tetraploid.
July 1989-January 1990	*Royal Microscopical Society 150th Anniversary Exhibition*, London Plant Diseases
30 August-2 September	*5th Cell Wall Meeting*, Edinburgh Release of phytoalexin eliciting oligogalacturonides from potato cell walls by polygalacturonic acid lyase
3-8 September	*IVth International Plant Virus Epidemiology Workshop*, Montpellier, France Multivariate analysis of antigenic variation among geminivirus isolates associated with cassava mosaic disease
6-8 September	*British Society for Cell Biology*, Norwich Release of phytoalexin eliciting oligogalacturonides from potato cell walls by polygalacturonic acid lyase

11-14 September	*Microbiology and chemistry of N turnover in soils*, Reading Microbial biomass C, N and respiration under a potato crop receiving N fertilisation with and without C amendments Nitrous oxide production during nitrification and denitrification in soils
18-21 September	*2nd Phytophthora International Symposium*, Dublin Phytophthora root of raspberry Protoplast formation from mycelia, sporangia and encysted zoospores of *Phytophthora infestans* Downy mildew (*Peronospora rubi*) on microporpagated *Rubus* New blight resistant cultivars from SCRI
25-28 September	*Association of Applied Biologists: Roots and the Soil Environment*, St Andrews Phytophthora root rot of raspberry Epidemiology and control of potato blackleg
15-17 October	*International Symposium on Viral Genes and Plant Pathogenesis*, Lexington, Kentucky Sequence comparisons of coat proteins of aphid-transmissible and non-transmissible isolates of potato leafroll virus

Radio and Television

22 January	*BBC TV, Landward*	
	B. D. Harrison	Genetic engineering of virus resistance in plants
	S. Millam	Application of plant tissue culture
	W. Powell	Plant genetic engineering
January	*BBC Radio Scotland, Good Morning Scotland*	
	M. R. Cormack	Sea Buckthorn
	BBC Radio Scotland, Scottish Farming News	
	M. R. Cormack	Novel fruit crops
	BBC Radio 4, Farming Today	
	M. R. Cormack	Novel fruit crops
22 February	*BBC Radio Scotland, Focus*	
	J. M. Duncan	Global warming and plant diseases.
13 and 15 March	*BBC Radio Scotland, Abacus*	
	M. R. Cormack	Sea Buckthorn

21 July	*Grampian Television, North Tonight*	
	M. R. Cormack	The Korvan raspberry harvester
5 September	*Canadian Broadcasting Service, Quirks and Quarks*	
	A. C. Newton G. D. Lyon	Yeast extracts as novel crop protectants
14 September	*BBC Radio Scotland, Farming News*	
	W. H. MacFarlane Smith	Oilseed rape and allergy
3 October	*BBC Radio Scotland, Head-on*	
	W. H. MacFarlane Smith	Oilseed rape and allergy
30 November	*Campus Radio, Radio Tay, The Life Game*	
	G. R. Mackay	How we use plants
8 December	*BBC Radio Scotland, MacGregor's Gathering*	
	D. A. Perry	The Scottish Crop Research Institute

LIST OF ABBREVIATIONS

Organisations

AAB	Association of Applied Biologists
ADAS	Agricultural Development and Advisory Service
AFRC	Agricultural and Food Research Council
AFRS	Agricultural and Food Research Service
AGC	Agricultural Genetics Company
ASS	Agricultural Scientific Services (DAFS)
ATB	Agricultural Training Board
BBC	British Broadcasting Corporation
BCR	Community Bureau of Reference
BPGRG	British Plant Growth Regulator Group
BSPB	British Society of Plant Breeders
BSPP	British Society for Plant Pathology
BTG	British Technology Group
CBCA	Cake, Biscuit and Confectionery Alliance
CEC	Commission of European Communities
CGIAR	Consultative Group on International Agricultural Research
CIP	International Potato Center — Peru
COSAC	Council of Scottish Agricultural Colleges
COST-88	European Co-operation in the field of Scientific and Technical Research
DAFS	Department of Agriculture and Fisheries for Scotland
DANI	Department of Agriculture for Northern Ireland
EAPR	European Association for Potato Research
ECLAIR	European Collaboration Linkage of Agriculture and Industry through Research
ECRE	Edinburgh Centre for Rural Economy
ECSA	European Crisp and Snack Association
EEC	European Economic Community
EHS	Experimental Horticulture Station
EMBO	European Molecular Biology Organisation
EPPO	European Plant Protection Organisation
ESCA	East of Scotland College of Agriculture
ESF	European Social Fund
EUROSTAT	Statistical Office of the European Communities
FASEB	Federation of American Societies for Experimental Biology
GIUS	Glasshouse Investigational Unit for Scotland
HDC	Horticultural Development Council
HGCA	Home Grown Cereals Authority
HRI	Hannah Research Institute
IACR	Institute of Arable Crops Research
IAEA	International Atomic Energy Agency
ICIPE	International Centre for Insect Physiology and Ecology
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IFS	Increased Flexibility Scheme
INRA	Institut National de la Recherche Agronomique
IPMS	Institute of Professionals, Managers and Specialists

ISHS	International Society for Horticultural Science
ISPP	International Society for Plant Pathology
ITE	Institute of Terrestrial Ecology
LARS	Long Ashton Research Station
LEA	Local Education Authority
MLURI	Macaulay Land Use Research Institute
NATO	North Atlantic Treaty Organisation
NIAB	National Institute of Agricultural Botany
NPTC	National Proficiency Test Council
NSCA	North of Scotland College of Agriculture
ODA	Overseas Development Administration
PMB	Potato Marketing Board
RHAS	Royal Highland and Agricultural Society of Scotland
RMS	Royal Microscopical Society
SAC	Scottish Agricultural Colleges
SARI	Scottish Agricultural Research Institutes
SASS	Scottish Agricultural Statistics Service
SCRI	Scottish Crop Research Institute
SDA	Scottish Development Agency
SDD	Scottish Development Department
SEB	Society for Experimental Biology
SERC	Science and Engineering Research Council
SNSA	Scottish Nuclear Stocks Association
SSCR	Scottish Society for Crop Research
TRIO	Tayside Regional Industrial Office
UC	University of California
UK	United Kingdom
USA	United States of America
USDA	United States Department of Agriculture
WSC	The West of Scotland College

Miscellaneous

CASE	Cooperative Awards in Science and Engineering
DM	Dry matter
DUS	Distinctness, uniformity and stability
EHF	Experimental Husbandry Farm
ELISA	Enzyme linked immunosorbent assay
EMAS	Edinburgh Multiple Access System
HPLC	High pressure liquid chromatography
IFS	Increased Flexibility Scheme
NFT	National Fruit Trials
NIR	Near infra-red
NLT	National List Trials
RCCA	Research Council Co-operative Award
SMCO	S-methyl cysteine sulphoxide
u.v.	Ultra violet

AGRICULTURAL AND FOOD RESEARCH SERVICE INSTITUTES

The research programmes of all the agricultural research institutes supported from public funds are co-ordinated by the Agricultural and Food Research Council. The institutes publish annual or periodic reports on their research. Full details can be obtained from the secretaries of the institutes concerned.

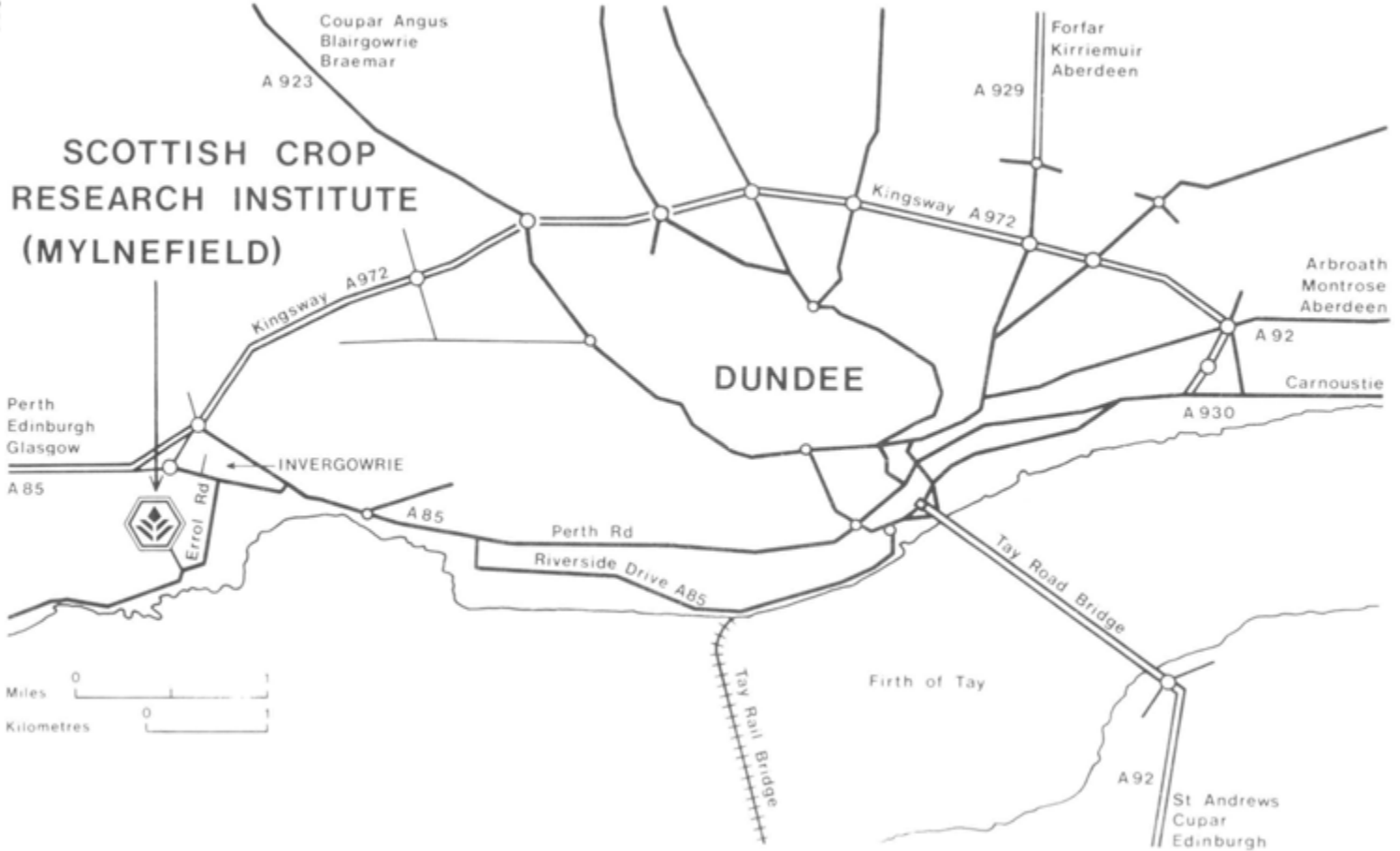
AFRC INSTITUTES

AFRC INSTITUTE FOR ANIMAL HEALTH	Compton, Near Newbury, Berkshire RG16 0NN
Compton Laboratory	Compton, Near Newbury, Berkshire RG16 0NN
Houghton Laboratory	Houghton, Huntingdon, Cambridgeshire PE17 2DA
Pirbright Laboratory	Ash Road, Pirbright, Woking, Surrey GU24 0NF
AFRC & MRC Neuropathogenesis Unit	Ogston Building, West Mains Road Edinburgh EH9 3JF
AFRC INSTITUTE OF ANIMAL PHYSIOLOGY AND GENETICS RESEARCH	Babraham Hall, Babraham, Cambridge CB2 4AT
Cambridge Research Station	Babraham, Cambridge CB2 4AT
Edinburgh Research Station	Roslin, Midlothian EH25 9PS
AFRC INSTITUTE FOR GRASSLAND AND ANIMAL PRODUCTION	
Hurley Research Station	Hurley, Maidenhead, Berkshire SL6 5LR
North Wyke Research Station	Okehampton, Devon EX20 2SB
Roslin Research Station	Roslin, Midlothian EH25 9PS
Shinfield Research Station	Church Lane, Shinfield, Reading Berkshire RG2 9AQ
Welsh Plant Breeding Station	Plas Gogerddan, Aberystwyth, Dyfed SY23 3EB
AFRC INSTITUTE OF ENGINEERING RESEARCH	Wrest Park, Silsoe, Bedford MK45 4HS
AFRC INSTITUTE OF FOOD RESEARCH	Shinfield, Reading RG2 9AT
Bristol Laboratory	Langford, Bristol BS18 7DY
Norwich Laboratory	Colney Lane, Norwich NR4 7UA
Reading Laboratory	Shinfield, Reading RG2 9AT

AFRC INSTITUTE OF ARABLE CROPS RESEARCH	Rothamsted Experimental Station Harpenden, Herts AL5 2JQ
Long Ashton Research Station	Long Ashton, Bristol BS18 9AF
Rothamsted Experimental Station	Harpenden, Herts AL5 2JQ
Unit of Insect Neurophysiology and Pharmacology	Department of Zoology, University of Cambridge, Downing Street Cambridge CB2 3EJ
Broom's Barn Experimental Station	Highham, Bury St. Edmunds, Suffolk IP28 6NP
AFRC INSTITUTE OF HORTICULTURAL RESEARCH	Bradbourne House, East Malling Maidstone, Kent ME19 6BJ
East Malling	East Malling, Maidstone, Kent ME19 6BJ
Littlehampton	Worthing Road, Littlehampton West Sussex BN17 6LP
Wellesbourne	Wellesbourne, Warwick CV35 9EF
Department of Hop Research	Wye College, Wye, Ashford, Kent TN25 5AH
AFRC INSTITUTE OF PLANT SCIENCE RESEARCH	John Innes Institute, Colney Lane Norwich NR4 7UH
Cambridge Laboratory	Maris Lane, Trumpington, Cambridge CB2 2LQ
John Innes Institute	John Innes Institute, Colney Lane Norwich NR4 7UH
Nitrogen Fixation Laboratory	University of Sussex, Brighton, Sussex BN1 9RQ
AFRC COMPUTING CENTRE	West Common, Harpenden, Herts AL5 2HE

SCOTTISH AGRICULTURAL RESEARCH INSTITUTES DEPARTMENT OF AGRICULTURE AND FISHERIES FOR SCOTLAND

HANNAH RESEARCH INSTITUTE	Ayr, Scotland KA6 5HL
MACAULAY LAND USE RESEARCH INSTITUTE	Craigiebuckler, Aberdeen AB9 2QJ
	Bush Estate, Penicuik, Midlothian EH26 0PY
MOREDUN RESEARCH INSTITUTE	408 Gilmerton Road, Edinburgh EH17 7JH
ROWETT RESEARCH INSTITUTE	Greenburn Road, Bucksburn, Aberdeen AB2 9SB
SCOTTISH CROP RESEARCH INSTITUTE	Invergowrie, Dundee DD2 5DA
SCOTTISH AGRICULTURAL STATISTICS SERVICE	University of Edinburgh, James Clerk Maxwell Building, King's Buildings Mayfield Road, Edinburgh EH9 3JZ


SCOTTISH CROP
RESEARCH INSTITUTE
(MYLNEFIELD)
Coupar Angus
Blairgowrie
Braemar
A 923
Forfar
Kirriemuir
Aberdeen
A 929
Kingsway A 972
Kingsway A 972
DUNDEE
Arbroath
Montrose
Aberdeen
A 92
Carnoustie
A 930
Perth
Edinburgh
Glasgow
A 85
INVERGOWRIE
Errol Rd
A 85
Perth Rd
Riverside Drive A85
Tay Road Bridge
Tay Rail Bridge
Firth of Tay
A 92
St Andrews
Cupar
Edinburgh
Miles 0 1
Kilometres 0 1