FOR
REFERENCE ONLY

SCOTTISH CROP RESEARCH INSTITUTE

ANNUAL REPORT 1983

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SCOTTISH CROP RESEARCH INSTITUTE

THIRD ANNUAL REPORT 1983

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* Honorary Lecturer in the University of Dundee.
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◦ Honorary Lecturer in the University of St Andrews.
‡ Visiting Professor in the University of Strathclyde.

GENERAL REPORT

C. E. TAYLOR

The publication in December of the AFRC's Corporate Plan for 1984-88 was of great significance to the AFRS as it is a pointer to changes proposed in the research programme and resources. The Plan reviews the main areas of work being undertaken in the Service and indicates those which should expand or contract, in the light of a declining budget. The Corporate Plan recognises that work on the physiology, agronomy and protection of arable crops is currently oversupported, and recommends certain reductions in research programmes in institutes in England and Wales. The termination of the spring barley breeding programme at WPBS will have consequences for the SCRI programme. The breeding of *Ribes* and of summer fruiting raspberries at EMRS is to cease and SCRI will adopt the UK responsibility for this work. The Institute is, of course, grant-aided by DAFS and therefore does not suffer the immediate consequences of reductions in MAFF and DES funding which are the sources of finance for AFRC institutes. Nevertheless it is anticipated that some financial constraints are likely to be imposed on SCRI during the coming years but that by careful budgeting the Institute's programme will be maintained with only minor adjustments. In any case changes will continue to be made in the light of new scientific ideas and the needs of the industry.

The formulation of the Corporate Plan was facilitated by the development earlier in the year of the new Information System. The old system of projects and packages has been replaced by a new classification. Research programmes are categorised in a matrix structure of research areas (e.g. plant breeding, crop protection) and commodity areas (e.g. cereals, fruit). Each cell of the matrix, that is each combination of research area and commodity area, is designated as a Programme Unit. Programme Units are composed of a number of Research Objectives which are the more specific targets to be achieved. The Institute's Programme Units are listed elsewhere in this Report. The new classification will enable greater precision of financial control especially when allied to the administrative computer network. SCRI will not join this network until the proposed extension of the Administration building is completed and suitable facilities for the terminal are then available.

At its meeting on 14 June the AFRC received a report on the work of the Institute when the programme and development of the Institute was discussed. An AFRC Visiting Group is due to examine the work of the

Institute in greater depth during 1984. Visiting Groups were last at Mylnefield in 1973 and at Pentlandfield in 1975.

The glasshouse/headerhouse complex for the Zoology Department was commissioned. It extends to 1183m^2 and cost £533,000. The facilities provided are excellent and they include specially designed features for extracting nematodes from soil and plant samples, insect rearing rooms, controlled temperature facilities and computerised control of glasshouse ventilation; they should greatly facilitate the programme of that Department. A crop handling building of 872m^2 was opened for the Forage Brassica Breeding Department. It provides all the handling, treatment and storage needs for this group of crops. A 500m^2 extension to the Brassica glasshouse was also opened although phytotoxicity of the glazing strips proved an initial problem limiting its use. Work began on site clearing for new propagation glasshouses, and a central services project commenced. The latter will provide a ring main of power and water around the site so that later building developments can tap them easily. Accomplishing this at an early stage should allow the later developments to be completed much more expeditiously.

The building developments, and the temporary re-housing of some other staff, enabled the transfer of four scientists and their supporting posts from Pentlandfield to Mylnefield. The remaining staff of the Forage Brassica Breeding Department will move early in 1984. At the end of the year Professor N. L. Innes, Deputy Director of NVRS, was appointed as Head of the Plant Breeding Division. He will take up his appointment in July 1984 at which time the Institute's divisional structure will become operative and provide the basis from which an integrated and forward looking research programme can be developed.

Distinguished visitors to the Institute included Dr K. Dexter, the Director General of ADAS, who gave the thirteenth lecture of the Scottish Society for Crop Research on 'A View of the Way Ahead for Agricultural Research and Development'; Lord Selborne, Chairman of the AFRC; M. R. De Craene, Agricultural Attaché at the Belguim Embassy; The Chairman and Board of Directors of Solanex Limited; Mr J. Gibson, Under Secretary at DAFS. Many other individuals and groups visited the Institute and expressed an interest in its work. It was a pleasure to receive them. An innovation was the release of the Annual Report for 1982 at a Press Day which was attended by journalists from newspapers, trade journals and radio. Other individuals or groups have specific links with departments of the Institute, often collaborating in programmes or providing practical help. The Institute is most grateful to all of these.

Governing Body

In April the following members of the Governing Body retired: Mr W. Andrew Biggar, Mr T. Martin Clucas, Professor G. R. Dickson,

Professor D. L. Lee, Mr A. Gordon Porter, Mr J. R. Robertson and Mr R. J. Smith. They are thanked for their service to the Institute. Professor N. F. Robertson became Chairman and several new members are welcomed.

The Institute learned with regret of the death of Dr James Philp on 24 August. He was a member of the Governing Body of SHRI for six years.

Appointments

L. S. Ainsworth	ASO	Zoology Department
H. Bain	HSO	Chemistry Department
M. Brownlie	ASO	Forage Brassica Breeding Department
C. R. Dalrymple	EW	Estates Division
J. Dinsmore	ASO	Forage Brassica Breeding Department
L. Doig	CA	Administration Division
R. L. Fyall	CA	Administration Division
I. Hamilton	ASO	Physiology and Crop Production Department
S. M. S. Howie	ASO	Virology Department
D. Hutcheson	Craftsman/ Engineer	Engineering and Maintenance Division
R. Johnston	Craftsman	Engineering and Maintenance Division
E. M. Millar	ASO	Mycology and Bacteriology Department
K. J. Oparka	SSO	Physiology and Crop Production Department
I. J. Potts	CO	Information Services Division
D. A. M. Prior	ASO	Physiology and Crop Production Department
S. P. Rawlings	ASO	Zoology Department
G. A. Ritchie	ASO	Virology Department
L. Scobie	ASO	Physiology and Crop Production Department
J. A. Shepherd	EO	Administration Division
P. J. Stewart	ASO	Zoology Department
M. A. Tunnock	Agricultural Worker	Estates Division
J. D. Watson	ASO	Data Processing Department
A. M. Young	ASO	Physiology and Crop Production Department
Y. White	CA	Administration Division

Promotions

I. M. Chapman	SSO	Estates Division
M. S. Phillips	SSO	Potato Breeding Department
H. Taylor	SSO	Physiology and Crop Production Department

Awards

V. M. Anthony	Ph.D., University College of North Wales
D. J. F. Brown	Ph.D., Open University
I. E. Burdge	ATB Certificate of Craftsmanship
	Scottish Association of Young Farmers' Clubs Certificate of Proficiency: Soft Fruit (Merit)
M. J. De, Maine	M.Phil., University of Edinburgh
S. M. Dodd	Ph.D., University of Dundee
F. J. Dunn	SCOTEC Ordinary Certificate in Biological Sciences
P. E. Dyce	Higher National Diploma in Biology
L. A. Farrer	Member of the Institute of Biology
K. Forbes	Ph.D., University of Edinburgh
A. E. Grant	Scottish Association of Young Farmers' Clubs Certificate of Proficiency: Soft Fruit
K. Hamilton	SCOTEC Ordinary Certificate in Biological Sciences
I. Hamilton	Higher National Diploma in Biology
R. Keith	Scottish Association of Young Farmers' Clubs Certificate of Proficiency: Soft Fruit
E. W. Milne	SCOTEC Ordinary Certificate in Biological Sciences
S. Mudie	Higher National Certificate in Biology
G. Ritchie	Higher National Diploma in Biology
J. Ross	Higher National Certificate in Biology
H. M. A. Wahdan	Ph.D., University of Dundee

Resignations

R. T. Blyth	Agricultural	Estates Division
R. Borzucki	HSO	Chemistry Department
J. E. Brinklow	SO	Physiology and Crop Production Department
F. M. Bruce	SO	Chemistry Department
R. J. Giles	HSO	Cereal Breeding Department
I. Geoghegan	SO	Zoology Department
D. H. Goodall	Tractorman	Estates Division
D. L. Harris	ASO	Potato Breeding Department
A. M. Hayter	PSO	Cereal Breeding Department
D. Hobbs	ASO	Zoology Department
J. G. McCluskey	ASO	Chemistry Department
T. Nelson	ASO	Cereal Breeding Department

G. Peaston	ASO	Forage Brassica Breeding Department
J. Penman	SO	Cereal Breeding Department
A. M. Young	ASO	Physiology and Crop Production Department
C. I. Young	Craftsman	Engineering and Maintenance Division

Retirements

W. R. S. Batchelor, P&TO IV in the Farm Workshop retired on 18 October after 29 years service.

I. G. Montgomerie, PSO, retired on 26 April after serving the Institute for over 29 years, initially with the West of Scotland Strawberry Breeding Unit and for the last 20 years in the Mycology & Bacteriology Department at Mylnefield.

J. B. P. Stevenson, Specialist Typist, retired on 11 August after 12 years in the Administration Division.

B. M. M. Tulloch, HSO in the Soft Fruit Breeding Department, retired on 31 January 1983 after 28 years service.

J. Turner, EW V, retired from the Estates Division on 29 April after 8 years service.

G. R. White, Farm Manager, Estates Division, Pentlandfield, retired on 31 October after 28 years service. His career with SPBS began as a cereal breeder.

W. J. Warburton, Craftsman/Electrician, retired from the Engineering and Maintenance Division on 13 May after 10 years service.

Visiting Workers

M. Lopez (Centro Regional de Investigacion y Desarrollo Agrario Division 7 (Lavante), Valencia, Spain) spent 4 days in October to become familiar with methods used in ecological studies of soft rot erwinias (Mycology and Bacteriology Department).

A. G. Navas Sanchez (Instituto Español de Entomologia, Madrid), visited for 3 months to study the geographical distribution of British plant parasitic nematodes (Data Processing Department).

H. S. Pepin (Agriculture Canada, Vancouver, British Columbia), completed a study of variation in pathogenicity of isolates of *Didymella applanata* on raspberry cultivars from Britain and N. America (Mycology and Bacteriology Department).

D. V. R. Reddy (ICRISAT, Hyderabad, India), arrived in November to spend 6 months studying aphid-borne and soil-borne viruses of groundnut (Virology Department).

A. Remah (Institut Agronomique et Vétérinaire, Agadir, Morocco), spent 4 months working on a lucerne virus as part of his training in Britain (Virology Department).

L. Sujkowski (Potato Research Institute, Mlochów, Poland), worked with H. E. Stewart and R. L. Wastie for 6 weeks on *Phytophthora infestans* (Potato Breeding Department).

Research Assistants

R. A. Bain (PMB Research Assistant), commenced a 2 year study of infection by soft rot erwinias on 1 November (Mycology and Bacteriology Department).

T. D. Heilbronn (PMB Research Assistant), commenced a 2 year project, studying the gap between farm yields and potential yields of potato (Physiology and Crop Production Department).

Research Students

Madiha Al-Hashimi (Government of Iraq, Baghdad), continued studies on the ecology and epidemiology of *Fusarium nivale* on barley (Mycology and Bacteriology Department).

V. M. Anthony (SERC-RCCA post-graduate student, jointly with the University College of North Wales), completed research on the infection of raspberry by rust *Phragmidium rubi-idaei* (Mycology and Bacteriology Department).

S. M. Dodd (AFRC post-graduate student), completed her studies on genome nucleic acids of nepoviruses (Virology Department).

J. G. Elphinstone (AFRC post-graduate student), continued studies on contamination of potato stocks by *Erwinia carotovora* (Mycology and Bacteriology Department).

M. R. Groom (MAFF research assistant, jointly with University of Dundee), continued studies on the causes of cavity spot of carrots (Mycology and Bacteriology Department).

J. Hinton (SERC-RCCA post-graduate student, jointly with the Department of Biological Sciences, University of Warwick), continued his studies on the genetics of *Erwinia carotovora* (Mycology and Bacteriology Department).

W. W. Kirk (AFRC post-graduate student), continued studies on leaf growth of the potato (Physiology and Crop Production Department).

L. Leach (SERC-RCCA post-graduate student, jointly with Queen Elizabeth College, University of London), started studies on the control of development and moulting in nematodes (Zoology Department).

V. M. Lumb (PMB post-graduate student), continued studies on the effects of climate in Scotland and Israel on the epidemiology of blackleg of potato (Mycology and Bacteriology Department).

L. A. Perryman (AFRC post-graduate studentship, St Andrews University, Department of Botany) continued studies irradiated pollen as a means of gene transfer in plant breeding (Potato Breeding Department).

N. Ross (SERC-RCCA post-graduate student, jointly with the Queen's University, Belfast), studied the biology of *Erwinia carotovora* in the potato phylloplane until his sudden death on 18 August (Mycology and Bacteriology Department).

Z. A. Stephan (Iraq post-graduate student), completed his studies on the biology of *Meloidogyne ardenensis* and *M. hapla* (Zoology Department).

G. White (SERC-RCCA post-graduate student, jointly with the University of Durham), commenced studies on pod setting and development in new genotypes of *Vicia faba* L (Physiology and Crop Production Department).

Sandwich Course Students

C. M. Brotherton (Coventry Polytechnic), worked on late blight and soft rot of potatoes (Potato Breeding Department).

R. M. P. Dyker (West of Scotland Agricultural College), investigated the pathogenicity of *Fusarium nivale* at low temperature (Mycology and Bacteriology Department).

S. A. Gardner (Napier College), studied genetics of resistance to powdery mildew in *Hordeum spontaneum* (Cereal Breeding Department).

A. Grimason (Hamilton College of Technology), studied the use of polyacrylamide electrophoresis as an aid in determining gene transfer in irradiated pollen crosses (Chemistry Department).

G. Macdonald (North East London Polytechnic), work experience (Potato Breeding Department).

C. A. Manhood (North East London Polytechnic), work experience (Potato Breeding Department).

N. Smoktunowicz (Sunderland Polytechnic), worked on weed seed banks of arable soils and on aspects of fruit quality in raspberry (Physiology and Crop Production Department).

J. P. Wheeler (Dundee College of Technology), studied the effect of nematicides and fungicides on the behaviour of plant parasitic nematodes (Zoology Department).

N. Youle (Sheffield City Polytechnic), worked on the development of computer data base management systems for the processing of plant parasitic nematode survey data (Zoology Department).

Visits Abroad

T. J. W. Alphey visited Sorrento, Italy, 24-28 October, to attend the Fourth Meeting of the Scientific Steering Committee of the European Plant Parasitic Nematode Survey and the joint meeting of the Societa' Italiana di Nematologia and the Societa' Italiana di Fitoatria.

J. Brown visited Burgos (N. Spain), 16-20 October, to harvest and assess trials of SCRI potato clones.

P. D. S. Caligari visited Israel, 28 June-8 July, to assess SCRI potato clones grown in trials for commercial assessment and *Verticillium/Alternaria* screening. He visited Burgos (N. Spain), 16-20 October, to harvest and assess trials of SCRI potato clones.

M. F. B. Dale visited Majorca and Valencia (Spain), 9-14 May, to harvest and assess trials of SCRI potato clones.

R. P. Ellis visited the University of Colorado, University of California, Washington State University, University of Saskatchewan, Canada Agriculture Winnipeg, Ciba Geigy Seeds, University of Guelph from 19 June-8 July to see barley research and breeding programmes in North America.

R. A. Fox attended a Council Meeting of the EAPR, 9-12 May, at Lucerne and at Interlaken, Switzerland, concerned *inter alia*, with arrangements for the 1984 EAPR 9th Triennial Conference. He attended a meeting of the EAPR Disease Assessment Committee at Århus, Denmark, on 6 June and an EAPR Editors' Meeting in Wageningen, Netherlands, 6-7 September. He visited pathologists at the BBA and the German-Dutch Potato Gene Bank at Braunschweig, Federal Republic of Germany, 25-29 September for discussions, mainly on potato diseases.

D. R. Glendinning visited Israel from 1-7 December, to discuss collaborative work in progress and to gain knowledge regarding their autumn potato crop and its problems. While there he gave a seminar at the University of Tel Aviv on potato history and the work of the Strategic Section of the Potato Department.

B. D. Harrison spent 17 February-1 March giving a series of lectures on plant virology at Ain Shams University, Cairo, Egypt, and visiting nearby centres of research on plant virus diseases. In September, Harrison and A. F. Murant spent about 10 days in Canberra as Visiting Fellows of the Australian National University and took part in discussions with A. J. Gibbs (Research School of Biological Sciences) and colleagues about the Virus Identification Data Exchange project.

A. T. Jones visited the Soviet Union from 26 July to 5 August, under the terms of the Cultural Agreement. He visited some centres of plant virus research and exchanged information on viruses and virus diseases of berry fruit crops.

V. M. Lumb worked at the Volcani Center, Bet Dagan, Israel, between March-June and November-December, carrying out field experiments in relation to the joint project on potato blackleg between SCRI and the Volcani Center. The visits were supported by the PMB and the Volcani Center.

G. R. Mackay visited Algeria and Spain (Valencia), 9-13 May, to harvest potato trials. He went to Århus, Denmark, 6-10 June, to attend the EAPR Conference and EEC Workshop on conservation of old potato

varieties. He visited Braunschweig, Germany, 14 September, to discuss co-ordination of CPC and Dutch/German Gene Bank with the Dutch/German Programme Committee. He visited Rome, Italy, 28 November-1 December, to attend meeting of EEC Workshop on potatoes with IBPGR, to discuss Descriptors and Descriptor States.

A. F. Murant attended the Workshop on Plant Virus Epidemiology held at Corowa, N.S.W., Australia, from 25-27 August.

M. C. M. Pérombelon visited Valencia, Spain, 11-15 April, to investigate the feasibility of a joint project between SCRI and Luis Matutano S.A. and INIA-CRIDA 7 to study blanking problems in crops grown from imported Scottish seed potatoes. The visit was supported in part by 'Luis Matutano S.A.'

C. E. Taylor attended the Societa Italiano Nematologia meeting in Sorrento, Italy, from 24-26 October. He also attended three meetings as a member of the Scientific Council di Istituto di Nematologia Agraria di CNR, Bari, Italy, from 14-16 April, 15-17 June and 19-21 December. He visited a number of research institutes of the Victoria Department of Agriculture, Australia, during August.

W. T. B. Thomas visited Gore, New Zealand, from 10 January-1 April, to select and harvest material from SCRI barley nursery.

R. Thompson attended a planning meeting of the EEC Plant Protein Group in Brussels on 9 February.

P. B. Topham paid an invited visit to the Instituto Español de Entomologia and the Instituto de Edafologia y Biologia Vegetal (CSIC) Madrid, for a week at the end of November to give a Colloquium entitled 'Kilometric distance and faunistic distance: dimensions in the faunistic analysis of the longidorids revealed by the European Plant Parasitic Nematode Survey.'

D. L. Trudgill visited the Swiss Federal Research Station at Wädenswil, between 27 June and 1 July to discuss and advise on a problem in cherry trees caused by a nematode-transmitted virus.

Conferences at which papers were given

6 January	Society for General Microbiology Virus Group, Newcastle	
	H. Barker	Effects of actinomycin D on the infection of tobacco protoplasts
2-3 February	National Agricultural Centre, Stoneleigh, conference on Yield of Potato, Peterborough	
	D. L. Trudgill (J. A. T. Woodford)	Nematode and aphid pests of potato

25 March	13th Meeting of the AFRC Modeller's Group, London	
	D. K. L. MacKerron	A simple model of potato growth
6 – 8 April	Discussion meeting on blackleg and soft rot of potatoes, held under aegis of British Society for Plant Pathology, Leeds	
	R. L. Wastie	Bacterial soft rot and blackleg at SCRI
8 April	Society for Experimental Biology, Environmental Physiology Group, Hull	
	D. K. L. MacKerron (P. D. Waister)	Wind and plant physiology – a review
18-20 April	ADAS Carrot Conference, Norwich	
	D. A. Perry	Cavity spot – causes and treatments
28 April	NSCA PYO and Direct Sales Conference, Craibstone	
	H. M. Lawson	Weed control strategy for pick-your-own crops
6-10 June	Breeding and Varietal Assessment Section EAPR Potato Section of Eucarpia Meeting (jointly with Pathology Section), Århus, Denmark	
	J. Brown	The use of computers in plant breeding
	R. L. Wastie (P. D. S. Caligari) (H. E. Stewart) (G. R. Mackay)	Comparison of seedling and whole plant tests for estimating resistance to foliage blight
	R. L. Wastie	Factors affecting tests for resistance to soft rot and blackleg
7-10 June	Joint Meeting of the EAPR Pathology and Breeding Sections and the Potato Section of Eucarpia, Århus, Denmark	
	R. A. Fox	Epidemiological cycles of *Erwinia* spp. in potato; the potential for disruption by copper sprays
17-24 June	International Seed Testing Congress, Ottawa, Canada	
	D. A. Perry	Report of the Vigour Test Committee
25-31 July	EAPR, Physiology Section, Helsinki, Finland	
	P. D. Waister (P. A. Gill) (H. A. Ross)	Inter-stem and inter-plant competition in the potato crop

17-24 August	Fourth International Congress of Plant Pathology, Melbourne, Australia	
	B. D. Harrison	The impact of new cropping practices on soil-borne viruses
	B. D. Harrison (M. A. Mayo)	The use of protoplasts in plant virology
	A. F. Murant	Helper-dependence among persistent and semi-persistent viruses
	A. F. Murant (M. A. Mayo)	Diversity of plant virus satellites
	C. E. Taylor	Nematode transmission of plant viruses
25-27 August	Workshop on Plant Virus Epidemiology, Corowa, N.S.W., Australia	
	B. D. Harrison (J. A. T. Woodford) (C. S. Aveyard) (S. C. Gordon)	Insecticidal control of potato leafroll virus in potato crops in Scotland
29 August	Hannaford Memorial Workshop on Effects of Virus Diseases on Crop Plants and Approaches to their Control, Adelaide, S. Australia	
	B. D. Harrison	Approaches to the control of virus diseases of plants
5-9 September	EAPR, Virology Section Meeting, Braunschweig, West Germany	
	R. M. Solomon	Testing a tuber sap treatment for detecting PLRV by ELISA in tubers of a diverse range of potato clones
16 September	HEA Meeting 'Exploiting the Ericaceae', SCRI	
	M. R. Cormack	Blueberries and cranberries
20-22 September	AAB Multidisciplinary Meeting 'Plant Breeding – an Integrated Discipline', Selwyn College, Cambridge	
	H. Barker	Studies on mechanisms of resistance in potato to potato Y and potato leafroll viruses
	M. R. Cormack	Requirements for mechanical harvesting of raspberries
	M. F. B. Dale (M. S. Phillips)	Resistance to *Globodera pallida* within *Solanum tuberosum*
	B. D. Harrison (T. Tamada) (I. M. Roberts)	Studies on strains of potato leafroll virus

	A. T. Jones (M. A. Mayo)	Satellite-like nature of small circular RNA molecules associated with some Australian viruses
	A. F. Murant	Nature of the dependence of the TBRV satellite RNA on its helper virus
	M. S. Phillips (D. L. Trudgill) (J. M. S. Forrest)	Comparison of the development of some populations of *Globodera pallida* on clones with quantitative resistance to this nematode
	R. M. Solomon (G. R. Mackay)	Current progress in breeding for resistance to potato virus Y
	D. L. Trudgill	Use of polar co-ordinates for assessing cultivar tolerance to potato cyst-nematodes and estimating yield losses
28 October	Computers and Glasshouse Control (organised by AFRC CC)	
	J. W. McNicol	A Description of the SCRI Zoology Glasshouse Control System
12 November	Society for General Microbiology, Scottish Branch Meeting, Edinburgh	
	A. F. Murant	Role of virus coat proteins in the transmission of plant viruses by vectors
12 November	Society for General Microbiology – Scottish Branch Meeting, Edinburgh	
	M. C. M. Pérombelon (K. Forbes)	Mapping of the chromosomes of *Erwinia carotovora*
17 November	Linnean Society Meeting 'Co-evolution, Resistance and Nematodes', London	
	W. M. Robertson (B. S. Griffiths)	Histochemical changes induced in plant cells by virus-vector nematodes
21-25 November	10th International Congress of Plant Protection, Brighton	
	R. A. Fox	Potatoes; problems, progress and future research
12-13 December	AFRC 'Genetic Manipulation of Crop Plants: Five Years On,' Churchill College, Cambridge	
	P. D. S. Caligari	Limited gene transfer

Conferences Organised

J. W. McNicol (on behalf of M. Talbot, ARCUS) one-day meeting for the Scottish Agricultural Colleges on 'Computer Direct Entry Recording'.

B. Marshall (with F. I. Woodward) organised the SEB Environmental Physiology Group meeting on 'Instrumentation for Environmental Physiology', held at Hull University from 6-8 April.

A. F. Murant organised the Meeting of the AAB Virology Group at the AAB Multidisciplinary Meeting at Selwyn College, Cambridge, on 22 September.

M. C. M. Pérombelon convened session 2.5 'Interactions among plant pathogenic and other bacteria in, and around, plants' at the 4th International Congress of Plant Pathology, Melbourne, 17-24 August, and a satellite meeting of the International Erwinia (Soft Rot) Group.

P. D. Waister organised a 2-day meeting on co-ordination of R&D in potato physiology in the UK, at SCRI from 21-22 April.

P. D. Waister and M. R. Cormack with A. Horgan[1], organised a meeting of the Scottish Branch of the HEA on 'Exploiting the Ericaceae', held at SCRI on 16 September.

R. L. Wastie organised a Blight Resistance Workshop at SCRI on 8-9 September, attended by 25 potato pathologists from several European countries. He organised a meeting of the Edinburgh Mycology and Plant Pathology Club entitled 'Variation in phytopathogenic fungi' at SCRI on 16 September.

Courses Organised or Contributed to

R. P. Ellis gave a course on 'Plant Breeding' to 4th year Honours students of Botany Department, University of Edinburgh, during March.

S. C. Gordon and J. A. T. Woodford contributed lectures and practicals on soft fruit pests, potato aphids and the control of aphid transmitted viruses for the Pest Module of the BASIS Training Course on Crop Protection at WSAC, Auchincruive, on 27 January.

B. D. Harrison, A. F. Murant and D. J. Robinson of the Virology Department gave a short course of lectures to botany students from St Andrews University and three students were given guidance in projects dealing with plant viruses.

D. K. L. MacKerron lectured to students at ESCA on environmental physiology of potatoes on 31 October.

D. K. L. MacKerron, B. Marshall, R. Thompson and P. D. Waister led a discussion on modelling potato growth, at ESCA on 2 March, and gave lectures on crop physiology to B.Sc. and M.I.Biol. students at WSAC, Auchincruive, on 19 April.

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[1]Crop Division, ESCA.

D. L. Trudgill contributed to an ESCA course demonstrating crop sampling for potato cyst nematode at Dundee, on 10 August.

The 3-week course of lectures at Dundee University on crop physiology, weeds, fungal pathogens and plant viruses was repeated in 1983.

Courses Attended

L. S. Ainsworth, S. Rawlings and P. J. Stewart attended an EMAS Data Processing Training Course, at Edinburgh Regional Computing Centre, between 19 October and 8 December.

B. Boag attended an SRC/ARC Middle Management Course II at Stroud, 21-25 March and at Abington, 25-29 April.

E. M. Borrino attended an AFRC Reporting Officer's Course.

R. J. Clark attended 'An Introduction to Data Base Management Systems' at the Civil Service College, London, from 6-8 December.

T. G. Geoghegan and G. Cruickshank attended a seminar on the new 'Agfachrome Speed' material and process at Edinburgh, on 11 October.

C. E. Henry attended a course on specialised transmission electron microscopy by the Royal Microscopical Society at the University of Leeds, 11-15 April.

W. M. Robertson attended a Quantimet 900 Image Analyser Training course at Cambridge, 22-26 August.

P. Smith attended a Quantimet 900 training course from 20-26 August.

P. Smith attended a course in the Edinburgh University Department of Statistics entitled 'Categorical Data Analysis', during January and March.

K. Taylor attended an ERCC Pascal Programming Course, 13-17 June.

R. Thompson attended a SERC selection and promotion interviewing course, 7-10 November.

J. Watson attended a 6-day EMAS Course at ERCC, November-December.

N. A. Williams attended a course on gas chromatography, 18-22 April, at Loughborough University of Technology.

Twelve members of staff attended a six-session course on Biometrics given by J. Bryan-Jones of ARCUS, at SCRI, during March-April.

Invited Lectures

P. D. S. Caligari gave a lecture on the measurement of competitive ability, Population Genetics Group of Edinburgh University on 1 June. He gave a lecture on the use of irradiated pollen for gene transfer in plant breeding in Department of Genetics, University of Edinburgh, on 6 December.

I. A. Cowe gave a lecture on near infra-red reflectance analysis at ESCA on 8 June. Also he gave a lecture 'Factors affecting the complexity of near infra-red reflectance calibrations' on the 22 March at a Royal Institute of Chemistry Seminar: NIR Analysis – how near infra-red reflects composition, held at NSCA, Aberdeen.

J. M. Duncan gave a paper detection and identification of *Phytophthora fragariae* at the European Plant Protection Organisation Meeting on strawberry red core, Harpenden, 1-2 February.

B. D. Harrison and A. F. Murant, respectively, gave lectures on geminivirology and cassava and satellitism and dependence among plant viruses on 1 and 5 September, in the Research School of Biological Sciences, Australian National University, Canberra.

D. L. Jennings gave a lecture on fruit breeding to students at the Royal Botanic Gardens, Edinburgh, on 14 June.

J. F. Malcolmson gave a lecture on the application of scanning electron microscopy to increased understanding of host/parasite relationships, at the Edinburgh School of Agriculture, on 15 November.

M. C. M. Pérombelon gave a talk on potato blackleg to the Scottish Early Potato Growers' Association, in Ayr, on 24 August.

C. E. Taylor gave a talk on the science and politics of crop research, to the COSAC Agricultural Advisers, at St Andrews, on 31 October.

P. B. Topham gave a seminar on the work of a statistician in an agricultural research institute at the Dundee College of Technology, on 3 November.

D. L. Trudgill gave a lecture on the biology and control of potato cyst nematode in seed potato land, to a meeting of farmers organised by ESCA, on 27 January.

Editorial Duties

P. D. S. Caligari	Member of Editorial Board of *Heredity*
R. A. Fox	Executive Editor *Potato Research*
B. D. Harrison	Editor of *Commonwealth Mycological Institute/ Association of Applied Biologists, Descriptions of Plant Viruses*
	Member of the Editorial Board of *Journal of General Virology*
	Member of Editorial Board of *Intervirology*
A. T. Jones	Member of Editorial Board of *Annals of Applied Biology*
H. M. Lawson	Member of Editorial Board of *Annals of Applied Biology*
I. H. McNaughton	Joint Editor of *Cruciferae Newsletter*
M. A. Mayo	Joint Editor, *Journal of General Virology*

A. F. Murant	Editor of *Commonwealth Mycological Institute/ Association of Applied Biologists Descriptions of Plant Viruses*
D. A. Perry	Member of Editorial Board of *Crop Research*
D. J. Robinson	Member of Editorial Board of *Journal of Virological Methods*
C. E. Taylor	Joint Editor of *Nematologia Mediterranea* Associate Editor of *Journal of Horticultural Science* Member of Editoral Board of *Crop Research*
P. B. Topham	Editor *Crop Research* Assistant Editor *The Lichenologist*
D. L. Trudgill	Consulting Editor of *Plant and Soil*
P. D. Waister	Associate Editor of *Journal of Horticultural Science* Associate Editor of *Crop Research*
A. B. Wills	Member of Editorial Board of *Crop Research* Joint Editor *Eucarpia Cruciferae Newsletter*

Service on Committees

T. J. W. Alphey	Co-ordinator and UK representative of the European Plant Parasitic Nematode Survey
M. M. Anderson	NFT Black Currant Panel
M. J. C. Asher	UK Cereal Pathogen Virulence Survey Committee
B. Boag	Member of the Ecology Committee of the Society of Nematologists Nematology representative on the European Invertebrate Survey Committee
D. J. F. Brown	Secretary and Treasurer to the European Society of Nematologists
M. R. Cormack	NFT Scottish Soft Fruit Panel
M. F. B. Dale	AAB, Member of Plant Breeding Group Committee
R. P. Ellis	Institute representative BAPB Cereal Crop Group BAPB representative on COSAC Recommended List Consultative Committee
F. J. W. England	BAPB, Member of Cereal Crop Group BAPB, Co-ordinator spring barley trials
R. A. Fox	EAPR, Council Member; Vice-Chairman, Pathology Section; Vice-Chairman, Disease Assessment Committee Association for Crop Protection in Northern Britain – Secretary/Treasurer of Standing Committee; Organising Committee Member, Conference on Crop Protection in Northern Britain, 1984

S. C. Gordon	AFRC Pesticide Research Discussion Group Member of the Pesticide Application Group Committee of the AAB
W. I. A. Jack	NFT Scottish Soft Fruit Panel
D. L. Jennings	NFT Raspberry Panel NFT Scottish Soft Fruit Panel SNSA Adviser to Committee
R. J. Killick	Institute of Biology, Scottish Branch Council
B. D. Harrison	Institute of Virology, Oxford, Advisory Committee Fourth International Congress of Plant Pathology, Virology Programme Committee Sixth International Congress of Virology, Programme Committee
H. M. Lawson	ADAS/WRO Liaison Group AFRC Fruit Weed Control Group ISHS Working Group on Weed Control in Vegetables SAC Weeds Group
W. H. Macfarlane Smith	BAPB, Oilseed and Industrial Crop Group Field Experimentation, Variety Development and Multiplication Panel of the National Proficiency Test Council
G. R. Mackay	BAPB, Member of Main Committee and Convener Potato Crop Group EEC, Member of Workshop on Old Potato Varieties
I. H. McNaughton	Member of the Co-ordinating Committee for EC Research Programme 0890 'The Collection of land-races of Cruciferous crops in EC countries'
J. W. McNicol	ERCC, member of Research Councils' Users' Committee
R. J. McNicol	NFT Strawberry Panel NFT Scottish Soft Fruit Panel
J. F. Malcolmson	SCOTEC, Member of Scottish Joint Committee for National Certificates and Diplomas in Biology
B. Marshall	SEB Environmental Physiology Group Committee
M. A. Mayo	Society for General Microbiology, Virus Group Committee XIVth International Congress of Microbiology, Member of Virology Programme Sub-Committee of the Scientific Programme Committee
W. P. Mowat	Convener of SNSA Bulb Technical Committee

A. F. Murant	ISHS, Chairman of Working Group on Small Fruit Viruses
	International Committee on Taxonomy of Viruses, Member of Executive Committee and Plant Virus Sub-Committee
	AAB, Convener of Virology Group
M. C. M. Pérombelon	ISPP, Member, Bacteriology Section Committee
	Chairman, International *Erwinia* (Soft Rot) Group
D. A. Perry	ISTA Vigour Test Committee, Chairman
I. M. Roberts	Chairman, AFRC Electron Microscope Advisory Group
C. E. Taylor	ACAS Scientific Advisory Committee
	AFRC Plants & Soils Research Committee
	AFRC Research and Policy Advisory Committee
	Chairman, European Plant Parasitic Nematode Survey (European Science Foundation)
	Chairman, SCRI/ASS/COSAC Liaison Group
	ECRE Board of Management
	NFT (Brogdale) Advisory Committee
	PMB Research and Development Committee
	President, European Society of Nematologists
	Programme Organising Committee of the First International Congress of Nematology
	Publications Committee, *Journal of Horticultural Science*
	SNSA (Flower Bulbs) Adviser to Committee
	University of Strathclyde Sub-Board for the Degree of B.Sc. in Horticulture
	WSAC Glasshouse Technical Committee
R. D. Taylor	ATB Horticultural Training South of Scotland Committee
	Scottish Association of Young Farmers' Clubs Proficiency Tests, Council for Agriculture: Horticulture Panel
R. Thompson	SCRI/Colleges Liaison Group
P. B. Topham	ERCC – member of Research Councils' Users' Committee
P. D. Waister	Tayside and Fife Branch Committee of BA
	Chairman HEA Scottish Branch
	NFT Scottish Soft Fruit Panel
	Dundee University Botanic Garden Committee
	Elmwood Agricultural and Technical College Horticultural Advisory Committee

A. B. Wills	BAPB Vegetable Crop Group AAB, Member of Plant Breeding Group Committee
J. A. T. Woodford	AAB, Member of Entomology Group Committee

Exhibitions and Poster Sessions

6 January	*Society for General Microbiology Virus Group Workshop on Plant Viruses*, Newcastle 'Sequences at the 3′ ends of tomato black ring virus genome RNA species'
26 January	*Farm Fair '83*, organised by ESCA, Forfar, 'Water – effect on tuber size and numbers'
22 April	Meeting on co-ordination of R&D in potato physiology, SCRI 'Potato physiology and crop production at SCRI'
14-16 June	*Physics at Work Exhibition*, Dundee College of Technology 'The effects of temperature on the growth of plants'
19-24 June	*10th Eucarpia Congress*, Wageningen, Netherlands 'Irradiated pollen in barley breeding'
20-24 June	*DAFS/SARI Exhibition*: RHAS Ingliston A co-ordinated display of the work of SARI's
2 August	*Press Day: SCRI Annual Report Presentation Information was displayed for relevant research reports*
9-10 August	*Asmer Seeds Ltd, 21st Anniversary Open Days* AFRS and Private Sector Co-operative Cabbage Breeding 'Sib identification in F_1 hybrids'
17-24 August	*Fourth International Congress on Plant Pathology, Melbourne* 'Dependence of heracleum latent virus on a fellow closterovirus for transmission by aphids'
19-20 August	*Perth Horticultural Show* A selection of topics concerning black currant, potato and raspberry
16 September	*HEA meeting, Exploiting the Ericaceae, SCRI* 'Blueberries and cranberries'
13-15 September	*International Seed Trade Association Meeting on 'Biochemical Tests for Cultivar Identification'* held at NIAB. 'The use of SDS polyacrylamide gel electrophoresis in varietal identification'

20-22 September	AAB Multidisciplinary Meeting 'Plant breeding – an integrated discipline', Selwyn College, Cambridge 'Screening for resistance to PCN in a potato breeding programme'
20-25 November	*10th International Congress of Plant Protection, Brighton* DAFS Exhibit: 'Plant Protection in Scotland' 'Breeding for Plant Health: Potato' 'Breeding for Plant Health: Raspberry' 'Certification for Plant Health: Narcissus Certification Scheme' 'Certification Scheme: Raspberry Certification Scheme' 'Plant Health in Practice: Biology of pathogens in relation to the control of excessive cane vigour' 'Plant Health in Practice: Interaction in pest control and crop management' 'Research for Plant Health: Behaviour of potato leafroll virus (PLRV) in vector aphids' 'Research for Plant Health: Dependence of carrot mottle virus(CMotV) on helper virus for transmission by aphids' 'Research for Plant Health: Detection of defective (NM) isolates of tobacco rattle virus (TRV) using complementary DNA' 'The propagation of virus-tested raspberries'
12-13 December	*AFRC Genetic Manipulation Group: 5 Years On, Churchill College, Cambridge* 'Induction and growth of microspore-derived embryos of *Brassica napus* ssp. *oleifera*

Radio and Television

F. J. W. England, 11 August, 'Plant Breeding' (BBC, Radio Scotland).

D. L. Jennings, 4 August, 'The Tummelberry' (BBC Radio).

D. A. Perry, 22 November 'Snow rot of winter barley' (Radio Tay).

P. D. Waister and D. K. L. MacKerron, 9 August, 'Research on growth and development of the potato crop' (Radio Tay).

INDEX TO RESEARCH PROGRAMME

CEREAL BREEDING

R. P. ELLIS

The cv. Tweed performed well in the 1983 Scottish Agricultural Colleges' Recommended List Trials and on the 1984 List is the highest yielding cultivar given a 'Good' rating for malting quality. The spring barley breeding programme still takes the major part of the department's effort but work on winter barley has increased.

The gene which controls the erect habit in cv. Golden Promise has been located on chromosome 7 between loci which determine rachilla hair length and reaction to DDT. A study of oat lines, derived from a composite cross, has shown for the first time in an economically important crop that the environment used for selection can affect the subsequent environmental sensitivity of the selected lines.

PU 2(a) Breed improved malting and feeding cultivars of spring barley

The new spring barley cv. Tweed (Ann. Rep. 1982, 49) performed well in its second year in the Scottish Agricultural Colleges' Recommended List Trials. In 1983 its yield was the best of all the semi-dwarf varieties in the trial series. As a result Tweed will receive a general recommendation for growing in Scotland in 1984 and it will have a 'Good' rating for malting quality. It has been confirmed that its mildew resistance combines BMR groups 2 and 8 and this represents a new diversification group (DG8). A crop of Tweed has been grown at The Murrays farm so that commercial scale malting tests can be made. Cv. Leith was placed on the National List but yielded rather poorly in 1983 Scottish trials and proved to be too susceptible to *Rhynchosporium secalis*. Overall its yield was less than that of the mean of the controls and it will not be entered in 1984 College trials.

Cultivars Beauly (SCRI 184/14/7), Cromarty (SCRI 212/15/1), Heriot (SCRI 300/6/9/11) and Nairn (SCRI 300/6/14/5) all satisfactorly completed DUS and VCU tests in 1983 and were placed on the National List. Cv. Elliot (SCRI 295/14/5) could not be distinguished from Beauly and it was therefore withdrawn. Heriot and Nairn will be included in the Scottish Colleges' recommended list Trials in 1984. These Cultivars are both derived from the cross Trumpf × HB855/467/8 but are quite distinct from each other. Heriot is a late heading cultivar but matures quickly. It possesses good disease resistance and has yielded very well in Scottish trials. Nairn is an early heading cultivar, although it is not, relatively,

early maturing. It too has good resistance to mildew, yellow rust and *R. secalis* but is susceptible to brown rust. Both Heriot and Nairn have very good malting quality, approaching that of Triumph but without the latter's dormancy problem.

The resubmitted stock of cv. Donan satisfactorily completed its first year of DUS testing and will proceed to the second year of tests in 1984. All three new submissions to first year National List Trials in 1983 were disappointing in their performance. Cv. Thurso (SCRI 42/3/5) failed DUS tests and cultivars Findhorn (SCRI 58/30/10) and Kerry (SCRI 130/73/2) did not yield very well.

Four new submissions for NLT1 in 1984 have been made. All are of the erectoid type, two from the cross ((Akka × Midas) × Aramir) × Ingot and two from the cross (Goldmarker × Athos) × (Goldmarker × Magnum). The 1983 SCRI breeders trials were badly affected by adverse growing conditions and there was a 6-week difference in the sowing of the first and last trial sites.

Some 200 stocks have been selected from F_4 and intermediate trials for primary trial and multiplication in 1984. As in 1983, the majority of these stocks will be selections from the SCRI spring barley nursery at DSIR/CRD Gore, New Zealand. This allows an extra generation of selfing before the derivation of a pure stock and therefore should present fewer problems in multiplication. Exchange of F_4 lines between the ARS barley breeding stations continued in 1983. SCRI received approximately 2000 lines and although poor establishment prevented full assessment of these lines, 27 were selected for trial, with selections from the SCRI F_3 nursery, in 1984.

Sixty-eight crosses were multiplied in New Zealand in 1982/3 and on return were grown in both an F_2 bulk trial and as spaced plant populations. Multiplication in New Zealand has the advantage of giving a high return of grain from very few F_1 seeds. This not only reduces the amount of time and space devoted to producing F_1 seed but also releases a substantial amount of glasshouse space in the winter. Although a large number of spaced plants were sown in 1983, the F_2 populations were written off due to exceptionally poor establishment. However, selected crosses from the F_2 bulk trial are being grown under single seed descent conditions in the glasshouse during the winter for sowing as short F_4 rows in 1984.

Climatic conditions were very unfavourable during the spring and early summer of 1983, resulting in a protracted sowing. Cold and wet weather after emergence encouraged a heavy infection of *R. secalis* in all the trials and nurseries. Powdery mildew developed on the later-sown trials and nurseries and selection against susceptibility was possible but there was no appreciable infection in earlier sown material. Yellow rust developed in the disease nursery and in the F_3 nursery where the disease had been

introduced and selection was possible in both cases. A heavy infection of brown rust developed during the hot weather of July but most of the material was too far advanced for any worthwhile selection.

An Epson HX-20 micro-computer was purchased and evaluated for use as a data-logging device. It has been used to score field trials using either machine prompted codes or manually entered codes. The data were stored on micro-cassette tapes for subsequent transfer to the main frame computer via the Apple II micro-computer. The Epson also proved very useful for the recording of data in the laboratory and can be used to log weights from a balance.

(R. R. Ellis, W. T. B. Thomas, J. S. Swanston, D. Farrar, A. Young)

PU 2(b) Breed improved malting cultivars of winter barley.

The 1983 crossing programme was carried out on detached tillers obtained from field grown plants. Embryo culture was used to recover F_1 hybrid embryos and these were grown on suitable media and vernalised in sterile tubes. This procedure proved to be most satisfactory given the lack of vernalisation facilities available at Pentlandfield.

The winter barley breeding material was sown in mid-September 1983. Selections made from the PBI F_4 exchange material were sown in replicated F_5 yield trials. A further 1500 F_4 lines were received from the PBI and they will be examined in the Scottish environment. The most advanced material generated at SCRI consists of 5200 F_3 hill plots from thirty crosses. Random F_3 lines will be used for cross prediction purposes.

(W. Powell)

PU 2(d) Study genetics and biochemistry of cereals and develop breeding methods.

Studies continued on the use of random F_3 lines for cross prediction (Ann. Rep. 1982, 43). Approximately 50 randomly selected F_4 lines were derived by single seed descent, multiplied at the F_5 generation in New Zealand in 1982/3 and assessed in a yield trial using a generalised lattice design at the F_6 generation in 1983. Extreme weather conditions in New Zealand resulted in very low yields for three of the six crosses and these trials could not be replicated due to the shortage of seed. Seventy-eight crosses from the 1982 crossing programme were assessed by the F_3 cross prediction technique but were sown late owing to the unfavourable spring of 1983.

Random F_2 plants from a large sample of the 1983 crossing programme were derived from glasshouse F_1 plants by the use of embryo culture for F_3 cross prediction in 1984. This technique considerably reduced the generation time so that F_2 plants were at the four leaf stage

before the F_1 plants were ripe. By applying this technique to the F_1 seed, it is possible to derive random F_3 lines for cross prediction in the field from the previous summer's crossing programme.

Analysis continued of the results from the collaborative study on cross prediction with J. L. Jinks[1]. The work has been extended to investigate the use of doubled haploid lines in cross prediction. As doubled haploids represent an F∞ population they are a powerful tool for studies in breeding methodology.

The 'haploid initiator' stocks obtained from A. Hagberg of Svalov were crossed reciprocally with the cv. Golden Promise so that the frequency of haploid production could be examined. The F_2 progeny from these crosses were sown in 1983 and the number of haploid plants produced was very low (<0.5 per cent) and it would therefore not appear to be applicable to barley breeding programmes. However, the embryological basis of haploid embryo formation is an intriguing question which merits further investigation.

Studies continued on the use of irradiated pollen in barley breeding (Ann. Rep. 1982, 44). Observations on quantitative characters in the M_2 population of the cross Golden Promise × Magnum (♂) showed a greater resemblance to the maternal parent than the F_2. Furthermore, differences between the F_2 and M_2 mean were very similar to those between the F_2 and Golden Promise mean. This is indirect evidence that the similarity between the M_2 generation and the maternal parent is not due to directional mutation induced in the paternal genome. These data, coupled with cytological information, indicate that the paternal genome is present in the M_1 plants, although this may be in a damaged form. However, during transmission from the M_1 to the M_2 generation the paternal genome is preferentially eliminated resulting in a predominance of the maternal phenotype.

During 1983 M_3 single plant progenies were grown in the field and scored for mildew reaction and the presence of the erectoides dwarfing gene. Selections from this population were sent to New Zealand for multiplication and will be returned in 1984 for preliminary yield trials.

Immature embryos have been found to be good explants for callus induction and plant regeneration in barley. Golden Promise lines regenerated from embryo-derived callus were examined, with J. M. Dunwell[2], to determine the range of variation induced in agronomically useful characters. This will complement earlier work on microspore derived lines.

Studies continued on the value of selection on yield components amongst random inbred lines derived by single seed descent (Ann. Rep. 1982, 45). Approximately 500 random F_4 lines from each of six crosses

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[1]Genetics Department, Birmingham University.
[2]JII

from the breeding programme were derived by single seed descent. From each cross 50 lines were selected for high thousand grain weight and also for grain number above a minimum standard. These lines, together with 50 randomly selected lines from each cross (see above), were multiplied in New Zealand in 1982/3 and assessed in generalised lattice yield trials in 1983. Single plants were recovered from each plot and are being scored for height and the components of yield.

Studies continued on the chromosomal location of the *erectoides* dwarfing gene present in spring barley varieties (SPBS Ann. Rep., 1979-80, 57). Doubled haploid populations derived from the F_1 hybrid between Golden Promise × Mazurka were found to complement the data previously obtained from F_2 populations (SPBS Ann. Rep. 1979-80, 57). Both sets of data indicated that the dwarfing gene is located on chromosome 7, between the rachilla hair length and DDT reaction loci. Furthermore a cross between Golden Promise and a translocation stock indicated that the gene was on the short arm of chromosome 7. Data from single seed descent lines showed that an extra round of recombination was sufficient to break the linkage between the dwarfing gene and the rachilla hair length loci.

Although the spring oat breeding programme at SRCI has been terminated (SPBS Ann. Rep. 1980-81, 13) the oat composites which had been used in the breeding programme, provided ideal populations for investigations into genotype-environment interactions and the role of natural selection in oat improvement. Results from these studies provide the first evidence, in an economically important crop, that the environment in which selection for mean performance is made determines in part the environmental sensitivity of resulting selections. Hence both mean performance and environmental sensitivity are amenable to manipulation by the oat breeder.

Investigation started on the probable location of a number of genes determining malting quality components (SPBS Ann. Rep. 1980-81, 74). Four cultivars were each crossed to two multiple genetic marker stocks, enabling factors on five chromosomes to be located. F_2 plants, from all eight crosses, were examined to determine homozygous recessive types. The following year, heterozygotes and dominant homozygotes were identified by studying plants from F_3 rows. Malting quality components were also assessed on grain from these rows. Initial work concentrated on locating firstly, the gene determining beta-amylase electrophoretic pattern, which is associated with diastatic power and, secondly, genes contributing to grain hardness, as measured by the milling energy test, and therefore affecting malting quality.

(R. P. Ellis, W. T. B. Thomas, J. S. Swanston, W. Powell)

PU 2(e) Improve, and use on cereal breeding material, screening methods for fungal disease resistance

Twenty-eight lines of the wild barley *Hordeum spontaneum*, from a large population collected in Israel, were selected as immune to UK races of powdery mildew in a screening programme carried out in the field in 1979 and 1980 and subsequently in glasshouse tests with known isolates. These lines have since been used in recurrent backcrosses designed to incorporate the resistance into more adapted agronomic backgrounds for use as parents in the barley breeding programme. F_2 populations (50-200 plants) from crosses between each line and the susceptible cv. Golden Promise were grown as spaced plants in the field and scored for resistance/susceptibility to powdery mildew at the three- to four-leaf stage. At the same time 100 selfed B_3 (third backcross to Golden Promise) plants of each line were assessed in the glasshouse following artificial inoculation with spores of a widely virulent race suspended in FC43 liquid. Segregation ratios indicated that a single dominant gene was conditioning the resistance in 24 of the lines. In two of the lines there was evidence for two independent recessive genes and in one case a single recessive gene appeared to be operating. Incomplete dominance was detected on one cross. In only one instance did results from the rwo generations fail to concur. Crosses with varieties carrying identified resistance genes and between the *H. spontaneum* lines are planned to examine allelic relationships.

The possibility of accelerating the selective incorporation of resistance genes derived from exotic germplasm into adapted backgrounds, using pollen irradiation techniques, is being explored. Pollen derived from 12 selected mildew resistant *H. spontaneum* lines was used after whole ears had been exposed to 10 grays of gamma radiation from a Cobalt-60 source. Crosses were made to cv. Golden Promise, and the M_1 generation selfed to provide the segregating M_2. Equivalent F_2 generations were derived by conventional crossing techniques. Up to 300 M_2 and F_2 plants of each cross were assessed for mildew resistance and for some simply-inherited morphological characters in the glasshouse over-winter, following inoculation with conidia suspended in FC43 electronic liquid. Preliminary results suggest that, in some lines, segregation ratios have been significantly distorted as a result of the irradiation. In these cases there appears to be an increase in the frequency of the maternal phenotype in the M_2, as compared with the non-irradiated F_2 generation. Seed of mildew-resistant selections has been harvested with a view to comparing the performance, for breeding purposes, of M_3, F_3 and selfed B_3 generations in a replicated field trial in 1984.

The expression of major resistance genes in haploid barley tissue was examined. Segments of the primary leaf of haploid F_2 plants, derived

using the *H. bulbosum* technique, were inoculated in a settling tower in the laboratory. Mildew isolates of known virulence were used to detect the presence or absence of resistance genes identified in the parents of each cross. Plants were then treated with colchicine to produce fertile diploid seed. Seedlings derived from this were used to provide diploid primary leaf segments for tests to confirm the haploid reaction. Screening at the haploid stage was found to be successful in allowing the identification and selection of resistant segregants, prior to chromosome doubling to produce homozygous diploid lines, for further evaluation in a breeding programme.

(M. J. C. Asher, W. Powell)

NEW SPRING BARLEY CULTIVARS

TWEED

National List and Plant Breeders Rights 1981.

Origin Tweed was selected from the cross (Akka × Maris Mink) × Maris Mink.

Straw length 9 cm shorter than Triumph.

Straw strength Similar to Triumph.

Maturity Similar to Triumph.

Disease resistances

	Tweed	Triumph
Mildew	8	8
Yellow rust	9	7
Rhynchosporium	4	7
Brown rust	7	7

Malting Quality Post harvest dormancy – short.
Hot water extract – superior to Golden Promise.
Diastic power – lower than Golden Promise, similar to Ark Royal.

Yield Potential

	Tweed	Triumph
National List Trials 1980-81 – England and Wales	100%	111%
National List Trials 1980-81 – Scottish sites	113%	105%

LEITH

National List and Plant Variety Rights 1982.

Origin Leith was selected from the cross (Akka × Maris Mink) × Maris Mink.

Straw length 4 cm shorter than Triumph.

Straw strength Similar to Triumph.

Maturity Similar to Triumph.

		Leith	Triumph
Disease resistances	Mildew	8	8
	Yellow rust	6	7
	Rhynchosporium	(6) 3	7
	Brown rust	6	8

Malting quality Post harvest dormancy – short.
Hot water extract – superior to Golden Promise.
Diastatic power – superior to all control varieties.

		Leith	Triumph
Yield potential	1981/82 National List Trials – All sites	104%	109%
	1981/82 National List Trials – Scottish sites	108%	108%

BEAULY

National List and Plant Variety Rights 1983.

Origin Beauly was selected from the cross Georgie × Trumpf.

Straw length Slightly shorter than Triumph.

Straw strength Similar to Triumph.

Maturity Earlier than Triumph.

		Beauly	Triumph
Disease resistance	Mildew	7	7
	Yellow rust	7	7
	Rhynchosporium	7	6
	Brown rust	3	8

Malting quality Post harvest dormancy – short.
Hot water extract – higher than Golden Promise, lower than Triumph.

		Beauly	Triumph
Yield potential	1982/83 National List Trials – England and Wales	105%	104%
	1982/83 National List Trials – Scottish sites	98%	100%

CROMARTY

National List and Plant Variety Rights 1983.

Origin Cromarty was selected from the cross Trumpf × Aramir.

Straw length 6 cm shorter than Triumph.

Straw strength Similar to Triumph.

Maturity Similar to Triumph.

		Cromarty	Triumph
Disease resistances			
	Mildew	8	7
	Yellow rust	9	7
	Rhynchosporium	6	6
	Brown rust	5	8
Malting quality	Post harvest dormancy – short.		
	Hot water extract – similar to Golden Promise.		
Yield potential		Cromarty	Triumph
	1982/83 National List Trials – England and Wales	105%	104%
	1982/83 National List Trials – Scottish sites	98%	100%

HERIOT

National List and Plant Breeders Rights 1983.

		Heriot	Triumph
Origin	Selection from the cross Triumph × HB855/467/8.		
Straw length	6 cm shorter than Triumph.		
Straw strength	Slightly stronger than Triumph.		
Maturity	3 days later than Triumph.		
Disease resistances		Heriot	Triumph
	Mildew	7	7
	Yellow rust	9	7
	Rhynchosporium	7	6
	Brown rust	7	8
Malting quality	Post harvest dormancy – short.		
	Hot water extract – slightly lower than Triumph.		
Yield potential		Heriot	Triumph
	1982/83 National List Trials – England and Wales	105%	104%
	1982/83 National List Trials – Scottish sites	102%	100%

NAIRN

National List and Plant Breeders Rights 1983.

Origin	Selection from the cross Trumpf × HB855/467/8.
Straw length	7 cm shorter than Triumph.
Straw strength	Similar to Triumph.
Maturity	Similar to Triumph.

Disease resistances

	Nairn	Triumph
Mildew	7	7
Yellow rust	9	7
Rhynchosporium	6	6
Brown rust	2	8

Malting quality

Post harvest dormancy – short.

Hot water extract – slightly higher than Golden Promise.

Yield potential

	Nairn	Triumph
1982/83 National List Trials – England and Wales	110%	104%
1982/83 National List Trials – Scottish sites	98%	100%

FORAGE BRASSICA BREEDING

A. B. WILLS

The year was dominated by planning for and carrying out the transfer of breeding work and staff from Pentlandfield. This was completed with the exception of the pure stocks unit which will move early in 1984 and then become part of a new stocks and trials unit within the Department. Inevitably, work was disrupted by the transfer but an almost full programme of breeders' trials was carried out at Mylnefield.

The second major event was the handing over of the new seed and crop handling building which became available for use during the harvest period, thus making it possible to process most of the trials samples required for dry weight determination and chemical analysis. The building provides facilities for crop sample weighing, oven and freeze drying, milling and sample storage, and for seed drying, threshing, cleaning, grading, packeting, weighing and storage. It also has ample storage space for bulky items of equipment. Having all these facilities under one roof is a major improvement over the previous situation.

The year was also notable for the inception of the MAFF-funded arrangement for pre-National List trials, indicated in last year's Annual Report, whereby promising selections are trialled at a number of NIAB sites. Three lines each of swede and rape were entered in the pre-National List trials, together with three kale selections funded under alternative arrangements. Differences in the performance of swede lines in these trials compared with local trials, recorded below, are worthy of note. A 2 year collaborative project with FRI on the glucosinolate content of forage brassicas has been completed. From the results of analyses carried out at FRI it was concluded that, in order to reduce goitrogenicity, selection for lower levels of glucobrassicin (which releases SCN^-) in kales and cabbages should continue, whereas it is more important to select rapes, swedes and turnips for lower levels of progoitrin (which releases goitrin).

The new swede cultivar, Redford (D29), was added to the National List in December, 1983.

Some breeding work on horticultural brassicas was continued in order to conclude longer-term experiments and to produce seed for distribution. These items are reported under the project headings used in previous Annual Reports. Research on incompatibility and genetics, which was not exclusively relevant to horticultural brassicas, is reported under the appropriate forage brassica research objectives.

PU 5(a) Breed improved swede cultivars and investigate breeding methods

Inbreeding within cultivars

Selections derived from nine cultivars were grown in trial for further evaluation. The highest yielding lines from the cultivars Acme, Magnificent, Seefelder and Vogesa gave dry weight yields ranging from 10.6 – 21.6% more than their respective parent cultivars. A re-selection from cv. Bangholm Wilby had 14.8% dry matter content in comparison to 14.2% for cv. Dryden (SG430) but had lower dry weight yield than Dryden. A selection from cv. Ruta Øtofte gave 13.8% dry matter, but again dry weight yield was lower than the controls. The highest yielding lines from cv. Criffel in the 1982 trial were sown again and two of them were selected for future inclusion in pre-cultivar trials.

F_1 hybrid breeding

A trial was grown to assess 42 hybrids produced by hand-pollination from crosses between lines selected from commercial cultivars. The trial suffered from erratic establishment, leading to a very high coefficient of variation (22%). The highest yielding hybrid produced 18% more dry weight yield than the mean of the control cultivars, but this was not significantly different from cv. Melfort, the highest yielding control.

Seed from an experiment to examine methods of hybrid production (Ann. Rep. 1982, 60) was sown in a yield trial and in observation plots to enable the proportion of outcrossing to be determined. There were no differences in yield between plots grown from seed produced in insect-proof cages or in isolation plots, nor between single-, three-way-, and double-cross hybrids. Interactions between S-alleles were studied in a diallel set of crosses using nine S-allele lines, three of which had the same S-allele but in different genetic backgrounds. Several reciprocal differences were observed, including a male sterility factor in an artificial *B. napus* line which appeared to be paternally inherited. In three lines with the same S-allele, the variations in self-incompatibility appeared to be due to variation in the style only, with the reaction in the pollen being active in all three cases. All types of dominance relationships appeared to be present, including reversal of dominance between stigma and style leading to self-compatible plants.

Three partially inbred lines of swede were crossed with ten S-allele lines to test their interactions, and six crosses with a fourth swede line were also made. Even though the S-allele lines were highly inbred, and the swede lines had been selfed for three generations, there were still inconsistent results from within crosses. However, at least two S-alleles had high activity with each of the swede lines tested.

Pedigree breeding

F_2 seed was produced overwinter in controlled environment cabinets and sown in May. In some cases only little seed was produced, but there was sufficient to obtain more than 5000 F_2 plants for selection. Although this technique saves a year in the breeding cycle, it has been discontinued because seed production under artificial conditions is difficult and not completely reliable.

At the F_3 stage, 204 lines were grown in trial for evaluation and selection. The lines were sown as three sets of α-designs, using the same four control cultivars throughout to provide comparability between sets. Eleven lines, including six derived from a cross between cv. Bangholm Magres and Criffel, produced dry weight yields more than 10% greater than the mean of the controls. The highest dry matter content of 14.3% was given by two lines from a cross between cultivars Melfort and Marian; these lines also had good dry weight yields with 96 and 105% of the control mean. Yields of over 10% higher than the mean of the controls were also obtained in the F_4 trial, from six lines out of 46 entries. Selections will be made from these and five other lines with yields of over 5% higher than the controls. Three F_5 lines gave dry weight yields of 10% higher than the mean of the control cultivars, and these will be multiplied for pre-cultivar trials.

Pre-cultivar trials

Mass-multiplications of the best F_4 families were tested in pre-cultivar trials to provide data for National List submissions, whilst F_5 lines from these families were selected further for yield and uniformity. This procedure could save two years in the breeding programme, but it necessitates multiplying lines which will not be submitted. The highest yielding F_4 multiplication was a family from the cross between cultivars Pentland Harvester × Doon Major, and the two F_5 lines from this family yielded 100 and 114% of the control mean, the latter being the highest yielding F_5 line. A multiplication from this line will be made for pre-National List trials.

Also in trial for the first time were four other lines from the pedigree programme and a selection from cv. Bangholm Dima (BDgdb) with good clubroot and mildew resistance. BDgdb and one of the pedigree lines gave higher yields than the mean of the controls and will be assessed further.

Three selections (Da 502, Da 671 and BRdf) were tested for a second year in pre-cultivar trials and also entered in pre-National List trials with NIAB. Dry weight yields were 94, 103 and 98% of the controls, respectively, in the SCRI trials and 116, 101 and 95% in the NIAB trials. As BRdf was the highest yielding line in 1982, further trials are necessary before submissions are made to NLT.

Turnip root fly resistance

The cultivars Angus and Melfort have high dry matter contents and good turnip root fly resistance. These characters may not be correlated (SPBS Ann. Rep. 1980-81, 64) although trials to investigate this (with NSCA) are still in progress. An investigation of other possible resistance mechanisms was started jointly with the Chemistry Department and NSCA. A trial was grown in the north of Scotland (by NSCA) and a similar one at The Murrays farm (by SCRI), with Angus, Melfort and four other cultivars having medium to low DM contents. Leaf and bulb samples were taken on three occasions from each site for chemical analysis but the results are not yet available.

A low proportion of swede bulbs from breeding trials at Mylnefield had internal mines which were attributed to turnip root fly attack. Where possible the frequency of infestation was scored but such records are unlikely to provide a reliable basis for selection unless much more serious attacks occur.

(S. Gowers, I. K. Munro, D. J. Gemmell)

Cultivar collection

A replicated trial of 87 cultivars from the swede cultivar collection was grown at The Murrays farm. All were scored for leaf, bulb and flesh colours and the trial harvested to give fresh and dry weight yields and dry matter contents. Data are now being analysed.

Of these 87 cultivars, several are represented by only small quantities of seed and will require to be multiplied again before being put into long term storage. Where sufficient seed was available 100 g has been sent to the Vegetable Seed Bank at NVRS to be included with other forage brassicas in the EEC collection.

(I. K. Munro)

PU 5(b) Breed improved kale cultivars and investigate breeding methods

Work continued on the kale polycross improvement programme started in 1971. The fifth generation was produced in 1983 for assessment at Mylnefield in 1984. In addition, four fourth generation families were mass-multiplied for future assessment as potential cultivars. Four third generation families were in pre-National List trials at four sites in the south of Scotland and north of England for a second year, and three of them were in trials at NIAB sites in England and Wales.

Work also continued on the new marrow-stem kale population constructed in 1981 from 105 plants which had shown some resistance to clubroot in seedling tests in 1980. Seed was harvested in 1983 from 152 resistant plants from the 1982 test. The next stage is family selection for lower contents of S-methyl cysteine sulphoxide (the haemolytic factor),

the indolylmethylglucosinolates (which release the goitrogenic thiocyanate ion on hydrolysis), and for improved clubroot resistance, higher dry yield and digestibility.

Three recurrent selection schemes suitable for kale, involving half-sib (HS), full-sib (FS) and selfed (S) families, were compared by computer simulation. When only the initial response to selection was considered the S Scheme was superior to the FS scheme which in turn was superior to the HS scheme and selecting 6 out of 240 families, the highest selection intensity assessed, was best. However, for selection programmes continuing beyond five generations the loss of desired alleles is also an important consideration. If the breeder wishes to include as many as 20 cultivars in his initial population, then some loss of desired alleles is likely to occur, but can be kept to a minimum by careful choice of selection scheme. The HS scheme was superior in this respect to both the FS and S schemes and selecting fewer than 24 families, out of 240 assessed, would seem undesirable. When as few as five cultivars were included in the initial population there were only slight losses when 6, 12 and 24 families were selected in the HS, FS and S schemes respectively. For 120 families assessed the respective average relative responses were 2.11, 2.54 and 2.41, and for 240 families assessed they were 2.45, 2.93 and 3.11. Thus there was little to choose between the FS and S schemes, although practical considerations favour the FS scheme because of the incompatibility system in kale.

The work undertaken in collaboration with FRI on the glucosinolate content of cruciferous fodder crops was extended in 1982 with a survey of cultivars of kale and cabbage (*Brassica oleracea* L.), turnips and stubble turnips (*B. campestris* L.), and swedes and fodder rape (*B. napus* L.). As fodder brassica breeders wish to reduce the goitrogenicity of these crops, the concentrations of 2-hydroxy-3-butenyl glucosinolate (5-vinyloxazolidine-2-thione is the goitrogenic hydrolysis product) and 3-indolylmethyl glucosinolate (the thiocyanate ion is the goitrogenic hydrolysis product) were of particular interest. High concentrations (mmol/kg dry matter) of 2-hydroxy-3-butenyl glucosinolate were found in stubble turnip leaf (8.12) and bulb (9.20), turnip bulb (9.97), swede bulb (5.66), and rape leaf (8.99) and stem (21.81), but not in kale or cabbage. In contrast the concentration of 3-indolylmethyl glucosinolate was relatively high in cabbage head (6.39) and kale leaf (3.25) but not in the other crops.

(J. E. Bradshaw)

PU 5(c) Breed improved fodder cabbage cultivars and investigate breeding methods

The fodder cabbage breeding programme was started in 1978. The aim is to improve head dry matter yield and content by improvement of a

foundation population which consisted of suitable autumn and winter culinary cabbages (eg round autumn, flat drumhead, winter white and January King types). 1983 was the seed production year for the second selected generation and 120 families will be assessed in 1984.

Three important agronomic questions needed to be answered in relation to the assessment of breeding material. These were: how late can the crop be sown without adversely affecting yield and heading ability? What is the optimal seed spacing in a crop to be left unsingled? Is a heavy top dressing of nitrogen fertiliser necessary? The conclusions from two large experiments done in 1979 and 1983 are that in south east Scotland the crop should be sown before the end of May and preferably at the beginning of the month; 25 cm seed spacing in rows 50 cm apart is a satisfactory compromise between a large proportion of head, the possibility of gaps resulting from poor establishment, and total dry matter yield; and that applying 150, 75 and 75 kg/ha of N, P_2O_5 and K_2O respectively in the seed bed is adequate as a further 150 kg/ha of N as a top dressing resulted in only a modest increase in yield.

(J. E. Bradshaw)

PU 5(d) Breed improved turnip cultivars and investigate breeding methods

Turnip cultivars for the Scottish uplands

Selections made in 1981 (Ann. Rep. 1982, 66) were sown in trials to assess yields at an upland site (Couston Henderson farm) in comparison to a lower lying site (Mylnefield). As sufficient seed was not available to sow all lines at both sites the main trial was sown upland at Couston Henderson. Four lines in each trial outyielded the control cultivars, and selections for a polycross were made from these. The mean dry weight at Couston Henderson was higher and the plants showed no infection by mildew.

The backcrossing series to transfer clubroot resistance from stubble turnip ECD04 into cultivars of traditional turnips was continued (Ann. Rep. 1982, 66). Fourth backcrosses were made using cv. Foll as a recurrent parent, and fifth backcrosses using cv. Green Top Scotch. Lines from the backcrossing series from (ECD04 × Green Top Scotch) have been selfed to isolate lines homozygous for clubroot resistance. Selfed lines from (ECD04 × cv. Hvit Mainepe), homozygous for clubroot resistance, were multiplied but seed set was poor.

Multiplications made from each backcross in 1982 were sown in trial. The absence of parental types among these third backcross progenies showed that further backcrosses are necessary to produce lines close to the cultivar type and with the desired clubroot resistance.

(S. Gowers, D. J. Gemmell)

PU 5(e) Breed improved rape cultivars and investigate breeding methods

In conjunction with the three Scottish Colleges of Agriculture, a survey was carried out into the growing of forage rape in Scotland. Information was sought on sowing techniques, date and rate of sowing, methods and levels of fertiliser application and weed control, methods of utilisation and recommendations for improvement of the crop. The data, when complete, should help in the formulation of breeding plans.

The main forage rape trials were located at Mylnefield in 1983 though some advanced material was grown at the Murrays farm for continuity. The very dry conditions which prevailed at sowing and through most of the growing season were a major problem. At both sites establishment was reasonably good but subsequent growth and yields were poor. The average dry matter (DM) yield for the cultivars Barsica, Emerald, Lair and Winifred at Mylnefield was equivalent to only 3.89 t/ha and at the Murrays farm was only 2.64 t/ha compared with 5.19 and 5.98 t/ha at Ayr and Newcastle respectively.

A trial was grown of F_1 hybrid lines produced through self-incompatibility. The parents included re-synthesised *Brassica napus* and cultivars of swede, oil seed rape and forage rape including the high yielding Emerald and Hobson. Most of the hybrid lines were very short and non-uniform, and much breaking of the stems and petioles occurred. The highest yielding hybrid, BD50, equalled the control mean (3.53 t/ha DM yield) and most entries gave little more than half that. Hybrid vigour was not demonstrated in this trial, in comparison with work elsewhere which showed significant heterosis for DM yield.

Fifty-one F_2 populations from a range of parents including cultivars, re-synthesised *B. napus* and lines treated with ethyl methane sulphonate (EMS), were examined and 227 selections made for height, leafiness, non-flowering, absence of stem and petiole breaking, and mildew resistance.

F_3 lines were allocated to either a two or four replicate randomised complete block trial depending on seed availability. In the former there were 40 entries with the control cultivars Emerald, Barsica, Crack and Nevin and in the latter ten entries with the controls Emerald and Barsica. Several lines had higher fresh weight yields than the mean of the controls but none had significantly greater dry matter yield. Eleven lines were retained for further testing on the basis of good mildew resistance and potential resistance to clubroot. The best yielding of these lines were also among the tallest. Some shorter, lower yielding lines also were retained to provide a range of types for different farming requirements.

The four replicate randomised complete block F_4 trial contained ten entries including the oil seed rape cultivar Gulliver which flowered very early and therefore was treated as missing plots. The controls were Emerald, Nevin and Crack. None of the entries outyielded the highest

yielding control, Crack, and although three lines were retained for further testing on the basis of mildew resistance, their development to cultivar status is unlikely.

There were five entries and three controls, Emerald, Nevin and Crack, in the four replicate randomised complete block F_5 trial. All of the entries were from re-synthesised *B. napus* crossed with the low thiocyanate cv. Samo. One line, B17, had a higher fresh weight and similar dry matter yield to the best control, Crack, and was retained for further testing along with two other lines which had better than average mildew resistance.

The seed size trial was continued for a third year, again using the line SCRI 57 and the same seed grades: 1.50-1.75 mm, 2.00-2.25 mm and 2.75-4.00 mm. The controls were the cultivars Emerald and Barsica. Overall the yields were slightly less than in 1982 (mean DM yield of trial equivalent to 3.42 t/ha cf. 3.65 t/ha in 1982), and the trial was badly affected by the extremely dry conditions. As in 1982, variations in seed size had no significant effect on yield and other characters (Ann. Rep. 1982, 64-65). However, as moisture was limiting in both years, differences due to variation in seed size were unlikely to be expressed.

The plant spacing trial with cv. Lair and SCRI 57 was also continued for a third year, though in an attempt to obtain yield differences, spacings were changed to 5.1, 12.7, 20.3 and 25.4 cm (cf. 5.1, 6.4, 10.2 and 12.7 cm in previous years). Inter-row spacing (0.5 m) and seed size (2.00 to 2.25 mm) remained unchanged. The mean dry matter yield of the trial was lower than in 1982 (4.11 cf. 4.25 t/ha). With Lair, the highest fresh weight and dry matter yields were obtained at 12.7 cm spacing whereas SCRI 57 gave best yields at 20.3 cm. For both, a spacing of 12.7 cm gave the tallest plants. However, the differences in yield and height were small and probably limited due to the lack of moisture.

(W. H. Macfarlane Smith)

PU 5(g) Multiply and stabilise breeders' selections; and trial selections in collaboration with other organisations

In 1983, 61 polythene tunnels and over 30 insect cages were used for multiplications, together with several small tunnels and cages for purely experimental work. Although fewer tunnels were used than in 1982, several were larger and the work load was at least as great. Four isolation sites in East Lothian were also planted.

The hot, dry summer had very adverse effects on the plants in cages and isolation plots resulting in stunted growth, late flowering and reduced, or later, seed set. Plants in most tunnels set reasonably good seed where pollination had taken place early and the seed ripened early in the hot weather, but where pollination was later, seed sets were much poorer.

(I. K. Munro)

PU 5(h) Investigate novel combinations of genomes to produce breeding material

A trial was grown to compare four lines of radicole (*Raphanobrassica*) which had given the best performance in trial in 1982 (Ann. Rep. 1982, 58-59) with the forage rape cultivars Lair, Emerald, Barsica and Nevin. Premature flowering occurred in three of the four lines of radicole probably due to the combination of early sowing (22 June) and drought stress. Only RB 35/5/BL had an acceptably low level of flowering. To simplify comparisons, yield was measured as total plot weight when plants were cut at ground level. On this basis the radicole lines yielded exceptionally well, with the best of them, RB 35/Medst/B, having fresh weight and dry matter yields equivalent to 54.07 and 7.21 t/ha respectively, compared with 34.69 and 5.78 for Lair, the best control cultivar.

(W. H. Macfarlane Smith, I. H. McNaughton[1])

PU 5(i) Study S-allele incompatibility in brassicas

Nature of the incompatibility reaction

The pollen germination inhibitors, detected in self-pollinated stigmas 2 h after pollination using a TLC bioassay procedure (Ann. Rep. 1982, 54-55), may be important in self-incompatibility in *Brassica oleracea* and were investigated further. In one experiment self- and cross-pollinated stigmas from glasshouse-grown plants homozygous for the incompatibility allele S_{23} were collected 0.25, 0.5, 1.0, 2.0, 4.0, 8.0 or 24.0 h after pollination and stored at −40°C, until 300 stigmas of each treatment had been collected. The ethyl acetate soluble fractions were chromatographed on silica TLC plates which were then sprayed with *Petunia* pollen (Ann. Rep. 1981, 67). Stigma number proved to be an unsatisfactory criterion for ensuring equality between treatments. Random check weighings indicated that the final weights of tissue in the different treatments differed by up to 80% and this apparently masked differences in inhibition of pollen germination between treatments. Nonetheless it was possible to show that self-pollinated stigmas collected 1-2 h following pollination contained the greatest amounts and largest numbers of inhibitors.

Temperature was found to be important for the optimum expression of the inhibitors. Above 20°C inhibition of *Petunia* pollen by ethyl acetate extracts of S_{23} stigma tissue was considerably reduced for all but one of the chromatograph zones detected, while between 14°C and 17°C all the expected zones were clearly visible. This may result from a loss of activity of the inhibitors or reflect some aspect of the increased growth rate of the pollen at higher temperatures.

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[1]Tissue Culture and Cytology Unit

Satisfactory germination of *B. oleracea* pollen on TLC plates has been obtained by soaking clean plates in 20 mM TAPS buffered to pH8 for 0.5 h, thus giving the TLC plates a high background pH. When such plates were used to detect inhibitors of *B. oleracea* pollen germination in ethyl acetate stigma extracts both the number of inhibitory zones and their Rf values differed markedly from those obtained using *Petunia* pollen, possibly due to the difference in the pH used for the two bioassays. Using the self- and cross-pollinated S_{23} stigma extracts referred to above, it was found that all extracts gave two major inhibitory zones (Rf 0.09, 8 mm diam and Rf 0.32 12 mm diam) and a zone of partial inhibition of varying diameter (Rf 0.72). In addition, stigmas collected 1 – 4 h after pollination contained an inhibitory zone at Rf 0.54, 4 mm diameter but no consistent differences between self- and cross-pollinated stigmas were detected.

Preliminary studies have been conducted with W. M. Robertson[1] to investigate the availability of binding sites on the surface of *B. oleracea* stigma and pollen. Avidin-rhodamine stained the outermost layers of fresh pollen and unpollinated stigmas but staining of both stigma surface and adhering pollen grains was reduced after self-pollination for 1 h.

(T. Hodgkin, G. D. Lyon[2])

PU 5(j) Study genetics of brassicas and formulate improved breeding methods

Self-pollinated progenies from accessions of *Brassica campestris* with annual habit were grown to confirm the inheritance of phenotypic variants noted in 1982 and to detect additional ones. Genetically controlled variation was found for over 20 seedling and plant characters and crosses made to determine their mode of inheritance. A number of progenies was also screened to detect variation in the Acp-1 and Acp-3 loci and to investigate esterase isoenzyme variation. Crosses were made to study the genetics of the esterase isoenzymes and to attempt to clarify the status of Acp-1 allozymes with very similar mobilities (Ann. Rep. 1982, 56).

To assist in the identification of phenotypic variants in *B. campestris* a character list has been drawn up which describes variable characters observed here and those reported in the literature. This is regularly updated and serves as a valuable guide in assessing any variation observed in new accessions.

Major differences were found in the numbers of Acp-1 and Acp-3 allozymes detected in the accessions of *B. campestris* screened in 1982

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

(Ann. Rep. 1982, 56). Although only one or two allozymes were found for each locus in some accessions, others possessed as many as six. If variation in allele numbers were correlated with variation for other characters it would provide valuable preliminary guidance on the appropriate number of seedlings to grow of any new accession. To investigate this possibility, 250 seeds of each of 10 accessions which possessed differing numbers of Acp-1 and Acp-3 allozymes were sown. Scores were recorded for anthocyanin pigmentation and hairiness of different plant parts, as these characters commonly show considerable variation. Following transplantation a large number of the seedlings were damaged or destroyed by birds and it was not possible to complete the record of phenotypic variation.

Phenotypic variation in self-incompatibility and in some polymorphic enzymes appears to be controlled by corresponding genes in *B. campestris* and *B. oleracea*. Variation found in these characters in *B. napus*, the amphidiploid hybrid between *B. campestris* and *B. oleracea*, may result from independent expression of genes from each genome or from inter-genomic interactions. As little is known of the expression in *B. napus* of genes from each of the parent species an attempt was made to re-synthesise *B. napus* using two Chinese cabbage (*B. campestris*) lines known to be homozygous for eight genes and a Chinese kale (*B. oleracea*) line homozygous for the eight corresponding genes but with different character expressions. No embryos for culture were obtained from pollinations made in October and November and the experiment will be repeated.

Emphasis was placed on investigations to find more isoenzyme loci for use in genetic studies of the three *Brassica* species. For this electrophoretic work, polyacrylamide is preferred to other media and much effort went into determining the optimum procedures for separation on polyacrylamide gels of enzymes described in the literature from starch gel separations. Phosphoglucomutase (PGM) (e.c.2.7.5.1) variation was analysed on 7.5% polyacrylamide vertical slab gels following preliminary work with a horizontal starch gel system. Clear separations were obtained only from centrifuged extracts (4°C, 30 min) in a supplemented tris-citrate buffer. As described elsewhere (Arus *et al., Euphytica* **31**, 417, 1982), two loci appeared to be involved, each with two active alleles, but it is suspected that null alleles also occur at each locus. The family of bands in the fastest migrating zone was more clearly separated on polyacrylamide than on starch gels. Enzyme activity was depressed or absent in extracts from field-grown plants made immediately after frosts had occurred. A number of families segregating at various marker loci were screened to determine PGM phenotypes, preparatory to linkage studies. Preliminary evidence suggests that the PGM loci are inherited independently and that neither is linked to Acp-2 (acid phosphatase), rd

(reduced development), A (anthocyanin), Hr (hairy leaf margin) or gl-3 (glossy leaf).

Analyses were undertaken with D. A. Perry[1] to determine the pectolytic enzyme complement of anaerobic pectolytic *Clostridium* spp. Crude cell-free extracts of cultures grown on calcium polypectate medium were run on 10% polyacrylamide gels containing 0.1% pectin, incubated in a series of buffers from pH 4.0 – 8.0 and stained with ruthenium red. Preliminary assessments of the clearing and banding pattern indicated that there were quantitative differences between pectin methylesterase, pectin lyase and polygalacturonase.

(T. Hodgkin, E. Wiseman, A. B. Wills, I. H. McNaughton[2])

03011 Brussels sprout: breeding hybrid cultivars

Two field experiments included material from each of three generations bred using a cyclic single cross selection system (SHRI Ann. Rep. 1979, 59).

The first experiment comprised the best hybrids selected from the third cycle which was first grown in 1981, their half-sib inbreds, the parents of those hybrids and their half-sib inbreds. Because of poor emergence the grandparental generation of inbreds and hybrids were not fully represented. The second experiment was composed of hybrids only, randomly taken from the last two cycles of inbreeding. Poor growth due to pigeon damage followed by drought in July and August caused plants to be shorter than usual but favourable autumn conditions gave medium yields of good quality buttons.

Three harvests were made from October to late December, when stem and button measurements were recorded directly onto a microcomputer. The data had not been analysed fully at the end of the year.

(A. J. Redfern)

03012 Cabbage: breeding hybrid cultivars

The near-isogenic inbred parent sublines of hybrid cv. Monega were crossed using blowflies to increase parent line seed stocks. Similarly, one parent of Kelpie (C9112), a winter hardy savoy currently in NLT (Ann. Rep. 1982, 55) was multiplied in this way. Parent lines of cv. Celtic and of other selections now in breeders' trials were selfed. Hybrid seed of cv. Monega and four other winter hardy savoy and Celtic-type selections was produced in small cubicles.

Advanced selections of hybrid winter hardy savoy cabbages including Lundie (C9392) and Kelpie were sown at three dates (13th April, 26th April and 27th May) and grown in trial to assess yield and holding

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

ability. Several Celtic-type selections were grown with cultivars Celtic and Corsair in another trial for selection of a possible NLT entrant.

A winter hardy savoy hybrid, Lussa (C9361), was entered for NLT while C9783 and C9161 were entered into NIAB breeders' trials.

Plots of 12 plants each of potential parent inbreds, separated from one another by one plot width and length, were grown to observe seed bearing ability and lodging. Extreme differences in these characteristics were due respectively to poor pollination conditions when the latest flowering inbreds were in bloom and to the exposed position of the site.

(A. J. Redfern, A. B. Wills)

03019 Broccoli: breed calabrese cultivars adapted to north Europe conditions

Ninety test progenies produced by crossing plants selected from a randomly mated population (Ann. Rep. 1981, 71) to the tester cultivars Bravo and Corvet were sown in cold frames in April and transplanted into four randomised blocks. Primary spears were harvested at peak condition in a manner similar to that described (Ann. Rep. 1982, 58) but severe pigeon damage soon after transplanting followed by serious drought caused lower than expected yields. Data were recorded directly onto mark sense cards and principal components analysis was applied as before.

Half-sib inbreds of the best 30% of progenies selected in 1982 (Ann. Rep. 1982, 58) were polycrossed by blowflies in isolation, in order to produce a population combining high yield and good head quality with increased potential for machine harvesting.

As this work is being terminated selected stocks will be made available through the recognised channels for further use by interested breeders.

(A. J. Redfern, A. B. Wills)

NEW SWEDE CULTIVAR

REDFORD

Origin	A line selected from Bangholm Dima.
Root shape	Globe.
Skin colour	Light-purple.
Flesh colour	Yellow.
Dry matter content	Medium-high.
Keeping quality	Good.
Clubroot resistance	Average.
Mildew resistance	Good.

Redford is a main crop cultivar, generally intermediate in most characters between Marian and Ruta Øtofte, but without any tendency to neckiness and bolting. In the UK National List trials at nine centres over two years, Redford gave average dry matter yields of nearly 5% higher than the mean of the control cultivars. Some susceptibility to internal browning has been observed, however, particularly at the N.E. England trial site.

POTATO BREEDING

G. R. MACKAY

The late cold wet spring and the summer drought in 1983 seriously affected the ware trials at The Murrays farm and yields were markedly lower than in previous years. Yield was also reduced at Blythbank but the quality of the seed was high and most requirements for 1984 have been met.

The potato cyst nematode resistance clones 11305a2 and 11233ab22 and the first early clone 10337de40 completed first year National List Trials (NLT) and the interim reports are awaited. All three have been resubmitted for second year statutory trial and seed has been supplied to contract growers by arrangement with NSDO. In autumn 1983, five clones were submitted for first year NLT in 1984. One, 11396ab12, has been eliciting considerable interest amongst our collaborators in the Potato Processors' Association. The clone produces a high yield of tubers in the ideal size range for the manufacture of potato crisps. Its apparent ability to accumulate sugars very slowly during prolonged storage, allied to a wide spectrum of resistance to viral and fungal pathogens, seems to compensate for it having a somewhat lower dry matter percentage than expected of a processing cultivar. Of the other four clones submitted, one is a first early and three are early maincrops; one of the latter clones, 11704ae26, is the first Neo-tuberosum hybrid to be submitted for NLT as a potential cultivar.

The new maincrop cv. Kirsty continues to elicit a good response from growers to whom NSDO have supplied seed and this augurs well for its future. Cultivars Provost and Baillie are now in the hands of the industry and we are informed that whereas most seed stocks were committed to maximising multiplication in 1983, some seed should be reaching the ware growers in 1984.

Cultivars Ailsa (10442 8), Rhona (10333ab18) and Moira (9869a9) completed NLT in 1983; the final reports and a decision from the statutory authorities are awaited. Unfortunately demand for seed for overseas trials, allied to the summer drought, resulted in rather lower than usual quantities of seed being available for distribution to our collaborators in the industry than usual.

The collaborative work with ADAS in testing advanced clones prior to submission to NLT continued throughout 1983. The data from the PCN tolerance trials were particularly useful in confirming the merits of

current National List candidates, 11305a2 and 11233ab22, and identifying the best of less advanced material.

Arrangements for the trialling of advanced clones to assess their export potential is now becoming routine. Seed has been supplied for the first trial in Cyprus and material which has demonstrated potential in Spain and Israel has been supplied for trial in Algeria, Egypt and Tunisia by arrangement with Solanex Limited.

Studies on the efficiency of early generation selection are continuing to provide data on which to base the future programme. There is increasing emphasis on the development and use of progeny testing as a means of identifying superior genotypes. A number of clones identified as duplex at major gene resistance loci were intercrossed and/or selfed to produce triplex or quadruplex clones, as future breeding material.

In addition to the routine quality tests, all clones reaching their 4th clonal generation (M_2) were subjected to an additional crisping test after storage at 5°C. Several produced acceptable (pale coloured) crisps, superior to those from cv. Record. This is of major interest to the processing industry and we have been encouraged to put more effort into this area by the Potato Processors Association Technical Committee.

The routine screening of clones was continued for their resistance or susceptibility to many of the diseases to which potatoes are prone. The use of the CHIP program is particularly useful in this respect, enabling the breeders to access and use the data from their pathologist colleagues much more quickly and hence efficiently than hitherto. The development of improved or novel resistance screening methods, for example to potato leafroll virus and bacterial soft rot, should also greatly aid the breeding effort in the future.

Integration of the work of the Novel Germ Plasm breeders with that of the main programme have continued and in 1983 a number of crosses involving Neo-tuberosum, diploid and dihaploid derivatives were included in the commercial pollination programme for the first time since 1974. It has been agreed that clones from the former strategic breeding department should now move into the main progrmme at the third clonal year stage (M_1), to permit their assessment against contemporary material from other programmes. Once a backlog of material has been assessed this will become a routine feature of the programme.

PU 6(a) Breed cultivars of potato improved for agronomic characters as demonstrated in the field trials in the UK

Clones in National List Trials (NLT) or post NLT

The early maincrop cv. Kirsty which was entered on the National List in 1982 continues to elicit favourable responses from growers. NSDO plans to launch it commercially in 1985. The two early maincrop cultivars

Rhona (10333ab18) and Ailsa (10442(8)) and the first early cv. Moira (9869a9) completed NLT in 1983; the decision on whether they will be entered on the National List is awaited from the authorities. The early maincrop clones 11305a2 and 11233ab22, which are resistant and tolerant to both *Globodera pallida* and *G. rostochiensis* and the first early clone 10337de40 completed first year NLT. They have been resubmitted for their second and final statutory trials in 1984.

Advanced potato selections

1983 was the second year in which all the early maincrop material reaching the sixth clonal generation as well as more advanced clones were raised in replicated trials at the ADAS farms of Arthur Rickwood EHF, Gleadthorpe EHF, Stockbridge House EHS and Terrington EHF and at The Murrays farm. The trials contained 55 clones and five control cultivars grown in two 10-tuber plots at each site. The planting, husbandry and harvesting of the trials was carried out by the ADAS staff while SCRI staff weighed, graded and scored the produce. The data from these trials and those of 1982 provided the major basis for deciding our submissions to NLT and which less advanced but promising clones would be retrialled in 1984.

Six clones and six controls were grown in first early trials at Trefloyne and Penrice, south Wales, Cairnside, Wigtownshire and The Murrays farm. Of the six clones one was submitted for NLT in 1984 and one other was identified as a possible candidate for the following year.

The five submissions for first year NLT are:

11396ab12 a high yielding early maincrop with a broad spectrum of disease resistance. It has shown potential as a crisper particularly as it seems to accumulate reducing sugars less rapidly in storage at low temperature than does cv. Record.

11566ac7 an early maincrop producing yields at least as good as those of cv. King Edward. Its tubers are parti-coloured and resemble those of King Edward but differ from it in being wart resistant.

11328ab18 an early maincrop clone producing parti-coloured tubers of good shape and size. It produced an attractive ware sample which keeps very well in store.

11704ae26 a high yielding early maincrop producing red eyed tubers. It has a broad spectrum of disease resistance and has performed well in several overseas trials.

11291 3 a high yielding first early clone which possesses the H_1 gene conferring resistance to *G. rostochiensis*.

A number of advanced clones were supplied, by arrangement with NSDO, to external collaborators. The data so far obtained have usefully supplemented those of SCRI.

Breeding for resistance and tolerance to potato cyst nematodes

During 1983 the field trialling of advanced PCN resistant clones from SCRI, DANI and PBI for PCN tolerance prior to NLT submission continued with the co-operation of ADAS. Three sites infested with *G. pallida* were provided by ADAS: at Ramsey near Cambridge, at Nocton near Derby and at Hemsworth in South Yorkshire. SCRI clones were also trialled at a site near Dundee infested with G. rostochiensis.

All sites suffered from the drought conditions of 1983 to varying degrees and the yields at the Dundee site were so depressed that no significant differences were detected between clones or treatments. At the three *G. pallida* sites differences in tolerance between clones were observed, these being most marked at the South Yorkshire site which had the highest initial PCN population. In general the rankings of the clones for tolerance, expressed as yield loss in the untreated (no nematicide) plots, were consistent across the three sites. The two most advanced PCN resistant clones, currently in NLT, 11305a2 and 11233ab22, performed satisfactorily as in previous years. Of the nine advanced clones trialled in 1983 five were selected for further testing in 1984, having performed well in these and other trials. As in previous years, there was no correlation between PCN resistance and tolerance and yield losses between treated and untreated ranged from 0 – 60%, thus emphasising the importance of these collaborative trials with ADAS.

Pot tolerance trials

The field PCN tolerance trials provide the breeding programme with valuable information on the advanced PCN resistant material but only a limited number of clones can be included. In an attempt to develop a glasshouse screening method which can handle large numbers, the same clones that were included in the ADAS trials were also grown in large pots of sterile and deliberately PCN infested compost in the glasshouse. The tubers were harvested and weighed, at maturity. The results of the glasshouse trial were encouraging, with differences being observed between the infested and non-infested soils. Some anomalies were evident, however, when comparing these results with those from the field trials. These differences may eventually be accounted for by differences in maturities of the clones which included both earlies and maincrops, and will be investigated in further studies in 1984.

Seed maintenance and multiplication

(a) *Blythbank*

The planting at Blythbank was delayed until the end of May by the cold wet weather. However, all the clones grew well, benefitting from the hot summer weather, and despite the lack of rain were well up to size by the usual defoliation date at the beginning of August. However, the average

number of tubers per plot was reduced by as much as 50%. This caused problems particularly with some of the more advanced clones for which there is a heavy demand for overseas as well as UK trials.

(b) *Seed spacing experiment*
The plot size at Blythbank is determined by the need to remove diseased plants completely without damaging their neighbours and the need for an average multiplication factor of ten. This has led to fairly wide spacing in the past. However, with more experiments being planned and more clones being planted it has become necessary to find the minimum spacing to permit roguing and a reasonable multiplication rate. To investigate this a plot spacing experiment has been grown for the last 2 years. Preliminary analyses of the results suggest that although the present spacing is near optimum for our requirements, reducing the inter-tuber distance by a few inches may be possible.

PU 6(b) Breed potatoes for export potential and select suitable cultivars by overseas trialling

As in 1982, trials were carried out at two sites in Spain, one in the north (Burgos) and one in the south (Valencia), by arrangement with Matutano S.A.. At Valencia the trial consisted of two blocks with 102 plots in each. Amongst the material trialling were 10 control cultivars and 10 clones being retrialled after selection on the basis of the 1982 results. The remainder, all the clones reaching the sixth clonal generation in 1982, were being trialled for the first time. The trial at Burgos was similar to that at Valencia but five clones were resubmissions. Eleven clones showed promise in Valencia and 10 at Burgos and have been selected for retrial in 1984.

For the first time every clone reaching the sixth clonal generation and one or two reselections from 1982 were also sent for trial at Gilat Experimental Station, Israel. This material comprised 60 clones which were grown in two trials. One trial was a straightforward commercial assessment of the clones as in 1982; the other included a large number of other clones and although also assessed for commercial characters, its primary purpose was the evaluation of susceptibility/resistance and tolerance/intolerance to *Verticillium dahliae* and *Alternaria solani* (see p.67). On the basis of the commercial assessment of the two trials 12 clones have been resubmitted in 1984.

Trials of 25 advanced clones were carried out in Algeria, at three sites, by arrangement with Institute de Dévéloppement des Cultures Maraichères, Staoueli. Six clones were selected as having commercial potential by an SCRI breeder and our collaborators at IDCM. These included cv. Provost and 10333ab18 (Rhona) and 10337de40 which have been in UK NLT. They will now proceed to more extensive commercial

evaluation by Solanex/NSDO whilst the remaining less advanced clones have been resubmitted along with a second sample of advanced material for breeders' trials in 1984.

In Autumn 1983 seed of all clones reaching the sixth clonal year was despatched to the two sites in Spain, to Israel and for the first time to Cyprus for trials in 1984. It is now intended that these sites will provide the initial screen of breeding material for its suitability in overseas conditions. The best clones at these sites will be retrialled there and, depending on their particular characteristics such as skin and flesh colour in relation to local market preferences, trialled in other countries such as Algeria, Tunisia and Egypt for a fuller evaluation of their potential in these markets. Ten clones so identified in 1983 have been despatched for trials in all these countries.

Verticillium *and* Alternaria *field trial*

This trial was carried out at the Gilat Experimental Station in collaboration with A. Nachmias[1]. More than 300 clones from the museum collection, the Neo-Tuberosum programme, the diploid breeding programme, the blight resistant collection and the commercial programme were grown. The trial consisted of three treatments, one (the control) was kept as disease free as possible, one was planted in *Verticillium* infested soil where *Alternaria* was controlled and in the third *Verticillium* was controlled but *Alternaria* was allowed to develop. Disease assessments were made by our Israeli collaborators on the foliage of all the clones in each of the three treatments to estimate the apparent resistance/susceptibility. At harvest, yields and other characteristics such as tuber size and internal condition were recorded by an SCRI breeder. Tolerance was measured as the difference in yield between the control (disease free) and diseased blocks. The relationship between resistance as expressed in the growing plant (foliar symptoms) and tolerance was not clear cut. Clones expressing various combinations of reactions (i.e. resistant and tolerant, susceptible and tolerant, resistant and intolerant, and susceptible and intolerant) were identified within each of the diseases as well as combinations between diseases. Samples of these have been resupplied for similar trials in 1984. It is encouraging that amongst this first batch of material several clones, putatively resistant and tolerant to both diseases, were identified and some speculative crosses with them have been attempted to produce progenies for further work.

PU 6(c) Study the genetics of potatoes and improve breeding and trialling methods

Computer housed information package

Although most of the Computer Housed Information Package (CHIP)

[1]Volcani Institute, Israel

has now been loaded and run on the Apple II micro computers at Pentlandfield, the usefulness of such machines with a package the size of CHIP is now in doubt because there is insufficient core storage available for even the smallest data bases required by the breeders. The package is therefore still used entirely on the main frame computers at the Bush Estate. Attempts to adapt the package for use on micros has virtually stopped and is unlikely to restart until faster micros with larger core storage are available.

Use of the package increased and additional routines were added. Areas developed were: the analysis of data from more than one year or location; new routines to allow selection of a subset of genotypes depending on specified criteria; additional data tabulation facilities and faster transfer of data from one data base to another.

Discussions have taken place with various people outwith the Institute as to how the package can be made more widely available, but the means to support external uses have not been identified.

Early generation selection

Research has been initiated to examine the efficiency of the breeding scheme which has evolved in the Department, particularly its effectiveness in the early clonal generations and at the seedling stage.

Representative progenies from several crosses were grown from true seed in the glasshouse, then as a single plant at one or two sites in the first clonal generation (depending on the number of tubers produced from each seedling), and at two sites in the second clonal year. After harvest at each stage, all the clones were assessed independently by four potato breeders in the Department according to visual preference. Tuber numbers and weights and several tuber characteristics and defects were recorded. Several characters were also recorded during the growing season in the first and second clonal generations.

Under the traditional breeding scheme, after each assessment (i.e. seedlings and first clonal year) a certain proportion of the clones would be discarded depending on their performance. All the clones in this experiment were retained and planted the following year, irrespective of how the breeders assessed them.

To date, 1600 clones, from eight crosses, have been assessed as seedlings grown in the glasshouse and in the field in consecutive years as single- and three-tuber plots, at two sites with replication at each site. A further 1400 clones from 14 crosses have also completed the first two years of the experiment and will be planted in 1984 as three tuber plots in the field.

Analyses of the data are incomplete but show that the four breeders were in good agreement as to which clones looked the most attractive in each environment. However, there appears to be little agreement between the breeders' assessment of the seedlings and their assessment of the same

clones grown from tubers in the first clonal year. In the first clonal year (single plants), there was poor repeatability of selection between the two sites. The size of the tuber planted in the first clonal year greatly influenced the yield of the first clonal year plants, but some clones which produced only small tubers as seedlings, produced large yields in the first clonal year.

The results from these experiments have already led to modification in the routine production and selection of clones in the commercial programme. For example, in 1984 no selection will be practised on glasshouse grown seedlings. Tubers of all seedlings will be retained to permit evaluation of the 'commercial merits' on a progeny basis. At the same time sub-samples of the same progenies will be screened for foliage blight resistance, using the seedling screen developed in the Department.

Irradiated pollen as a means of limited gene transfer

Investigations into the use of irradiated pollen as a means of achieving limited gene transfer in potatoes progressed to the production of the second generation from irradiated crosses. Some such progenies are presently being assessed and show that the radiation has had an effect but further progenies are needed to assess fully the possibilities. Seeds from irradiated pollen crosses of other *Solanum* species with *S. tuberosum* have been obtained.

Production of true-breeding material

Work to examine the possibilities of producing true-breeding clones from tetraploid potatoes started. Inbreeding, by selfing, has reached the second generation but problems of infertility and the difficulty of getting plants grown from true-seed to flower makes progress slow. Therefore, other methods of producing such material are being examined.

(G. R. Mackay, P. D. S. Caligari, J. Brown, M. F. B. Dale, C. J. W. Torrance, G. E. L. Swann, J. Spence)

PU 6(d) Develop new potato breeding material from primitive and novel germplasm

Neo-Tuberosum

Selection 11704ae26, submitted for National List Trials as a potential cultivar, has one of its parents a Neo-Tuberosum clone which was taken from the population in 1981: the cross was made in 1974.

In 1983 nine Neo-Tuberosum parents were included in commercial crossing programmes, two for resistance to virus Y, two in potato cyst nematode breeding, two for their crisping qualities, two for blight resistance, and one for *Verticillium* resistance.

Intercrossing of Neo-Tuberosum clones is in progress with the aim of obtaining improved parents for use in commercial breeding. Objectives, in separate programmes, are enhancement of crisping quality, of potato

leafroll virus (PLRV) resistance, of virus Y resistance, of *Verticillium* resistance, of potato cyst nematode resistance, of blight resistance, of scab resistance, of earliness of maturity, and the combining of resistance to PLRV and to virus Y. Attention is given to agronomic and culinary qualities in all cases. While each cross made has a specific objective, many of the parents used have more than one of the desired properties.

The apparent immunity of G1.77M/72 to *Verticillium dahliae* mentioned last year unfortunately was not confirmed in a repeat test in Israel, though it still appeared resistant.

Diploid potatoes

In the programme based on primitive diploid cultivars the current emphasis is on obtaining tetraploid hybrids in direct crossing with commercial-type tetraploids, using diploid parents which produce a proportion of unreduced 'diplandroid' pollen. Some diploid clones which have been found resistant to virus Y in the Cambridge field exposure trials give anomalous results in glasshouse inoculation tests and their resistance may be of a potentially valuable polygenic nature. To determine how well it is expressed in hybrids with commercial-type parents, two of them were crossed with cv. Cara. One, DB152(13) which has c. 1½% diplandroids in its pollen, gave 62 seeds from 142 pollinations but the other, 42P11 which has very few diplandroids, gave only four seeds from 56 pollinations. These two diploids are also resistant to potato leafroll virus. Two other Y-resistant diploids were crossed with two Y-susceptible tetraploid breeding lines. In this case the genotype of the tetraploid (seed) parent appeared to influence the results, 379 seeds being obtained from 183 pollinations with G6783(2) but only five from 96 pollinations with 3683(2). As diplandroid pollen is produced by a process analagous to first division restitution, it is expected that virtually all the tetraploid hybrids obtained will have the resistance genes of the diploid parents.

To determine whether the vigour in initial tetraploid hybrids from diploid-tetraploid crossing can be maintained through further generations of crossing, in 1979 a hybrid obtained by crossing a superior diploid, 13T48, with cv. Pentland Dell was back-crossed to Pentland Dell. Some very attractive clones were obtained from the progeny. Three of these were crossed again with Pentland Dell and a reasonable amount of seed of the second backcross generation was obtained. In similar programmes first backcross progenies have been obtained from cultivars Maris Piper and Pentland Squire but, in spite of intensive efforts, not from cultivars Desiree, Pentland Crown, Stormont Enterprise or Ulster Concord. However, tetraploid hybrids obtained by crossing Ulster Concord and Arran Consul with diploids have been crossed successfully with Pentland Squire and a number of promising clones have been identified in these progenies which, although not true first backcrosses in the sense of

having the same cultivar as both parent and grandparent, are broadly equivalent.

Dihaploids

Tetraploids obtained by crossing foliage blight resistant dihaploids with PCN resistant tetraploids, and having resistance to both, are being used as sources of further dihaploids. Of 27 such dihaploids 16 were found to be highly resistent to blight, and five out of six of the latter which were screened for PCN resistance had less than 20% of the cyst numbers found on cv. Pentland Crown controls. Two dihaploids with combined foliage blight and PCN resistance have now been crossed with tetraploids, 102 seeds being obtained from 1027 pollinations.

The dihaploid PDH135 is resistant to foliage blight and to gangrene and three out of four tetraploid offspring of a cross between it and a PCN resistant tetraploid have been found resistant to both, two of them also being resistant to PCN. In crosses with a range of tetraploids this dihaploid has given tetraploid offspring with good yields and tuber sizes, and from a small batch assessed alongside seedlings of the cultivar breeding programme three were chosen for further examination next year, as also were two derived from the Pentland Crown dihaploid PDH40.

In field trials, tetraploids obtained by doubling the chromosome number of a dihaploid using colchicine did not differ from the dihaploid in tuber yield, in the rate of photosynthesis per unit leaf area, or in the amount of shoot material produced; this suggests that the actions of the genes concerned are unaffected by the ploidy level. The parent from which the dihaploid was obtained, Pentland Crown, had a significantly higher tuber yield and rate of photosynthesis than the dihaploid and its chromosome-doubled derivatives.

(D. R. Glendinning, C. P. Carroll, M. J. De, Maine)

PU 6(e) Improve potato breeding material and methods for cooking and processing requirements

Cooking quality assessment

The routine cooking quality assessment continued as in previous years and approximately 3,000 clones were tested. Possibly as a result of the hot dry summer the texture of the cultivars tended to be more floury than usual but there was less sloughing and after cooking blackening. This made it more difficult to identify clones of inferior quality.

Low temperature storage for crisping varieties

The normal temperature for storing crisping potatoes is 10°C, which during the winter represents a considerable cost for the processors. A clone that could be stored at a cooler temperature but still crisp well

without reconditioning treatment out of store would cost less to keep through the winter. The clone 11396ab12 (see p.64) would appear to be an example. To identify other such clones a sample from all the clones in the fourth clonal year of the breeding programme was stored at both 10°C, as usual, and at 5°C. Initial results have shown that amongst the clones a few crisped well (pale colour) direct from storage at 5°C. It is proposed to introduce this as a routine screen at this stage to identify clones with this characteristic.

(G. R. Mackay, P. D. S. Caligari, J. Brown, M. F. B. Dale, C. J. W. Torrance, G. E. L. Swan, J. Spence)

PU 6(f) Improve and use screening methods for resistance and tolerance to pests and diseases of potatoes

Potato cyst nematode

Four hundred and eighty clones were screened for resistance to both *Globodera rostochiensis* (Ro1) and *G. pallida* (Pa3, Lindley) and 56 to *G. pallida* (Pa1). In addition 40 Neo-Tuberosum clones were tested for resistance to Ro1, Pa1, Pa3 (Lindley) and Pa3 (Cadishead). Among these clones resistance to Ro1 was found to correlate poorly with that to the three *G. pallida* populations. Four hundred 'proto-clones' derived from individual protoplasts of cv. Désirée at RES were assessed for resistance to *G. pallida* (Pa3). The mean numbers of cysts observed on cv. Pentland Crown and Désirée were 261 and 373 respectively, and on the 'proto-clones' ranged from 129 to 469. All tests were carried out in closed containers.

Forty-eight progenies from crosses made in 1982 were screened for resistance to *G. pallida* by a bulk seedling test which has now become part of the routine screening procedure.

In order to identify, as early as possible, clones with quantitative resistance to *G. pallida*, attempts have also been made to screen individual plants grown from true seed. As such tests tend to over-estimate the numbers of clones that are resistant, the effect of inoculating seedling plants at different times was studied to see if the reliabilty of such a test could be improved. Individual plants from three progenies derived from *S. tuberosum* ssp. *andigena* CPC2802 were inoculated as they were pricked out, either with cysts pre-soaked in potato root diffusate (to induce a rapid hatch) or with cysts pre-soaked in tap water. A third group of plants was inoculated with cysts pre-soaked in tap water, four weeks after pricked out. The results of this test were compared with assessments, in closed containers, of the resistance of plants grown from tubers taken from the plants used for the seedling test. In every case the seedling test over-estimated the number of individual plants identified as resistant. However, the mean resistance of the three progenies estimated over all plants showed good agreement

between the seedling and tuber-grown plant tests. These results indicate that seedlings are more appropriately used to assess the resistance of progenies rather than of individual clones.

(L. A. Farrer, M. S. Phillips)

Major gene resistance to PVY and PVX

Fifteen thousand seedlings representing 94 progenies were spray-inoculated with potato virus Y (PVY), potato virus X (PVX) or both, for progeny tests or selection for virus resistance. These included progenies of crosses between, and selfs of, parents duplex for PVY resistance genes; resistant survivors of these progenies were kept for test crossing to identify triplex individuals. Resistant seedlings of other progenies of duplex parents were also retained, for assessment as potential cultivars. These progenies showed higher survival rates than those screened in previous years, when most parents used were simplex. In other progeny tests two putative duplex PVX resistant parents and a putative duplex PVY resistant parent were identified.

Four hundred clones, including the cultivars Rhona, Moira and Ailsa, were screened for resistance to various strains of PVX and PVY by sap or graft inoculation. Rhona was confirmed resistant to the common and B strains of PVX and probably to the A strain of PVY, but susceptible to the common (Y°) and C strains; Ailsa was confirmed resistant to A, C and probably B, but susceptible to the common strain of PVX and probably PVY°, to which it has shown varied responses previously. Moira was found resistant to C and Y° and susceptible to PVX common strain, but showed varied responses to A and B. The cv. Baillie was confirmed susceptible to A.

Leafroll and PVY trial

Three hundred clones which had been exposed to potato leafroll virus (PLRV) and PVY in a trial at PBI, Cambridge, in 1982 were grown on and scored in 1983. The trial was well infected: in plots of the resistant control cv. Pentland Crown 46% of the plants became infected with PLRV and 4% with PVY.

Most of the clones bred for virus resistance showed good resistance to PVY, many clones showing no infection. Many showed good leafroll resistance; 15 showed significantly less infection than Pentland Crown, including seven which showed no infection. Some clones showed good resistance to both viruses. Two Neo-Tuberosum and one Group Phureja clone showed no leafroll infection and some showed resistance to PVY.

Moira was confirmed resistant to PVY, with no plants infected, but was susceptible to PLRV. Ailsa and Rhona both appeared at least moderately susceptible to PLRV and susceptible to PVY.

PLRV progeny testing

Six SCRI progenies were used to assess a method devised at CIP, Peru,

for progeny testing for PLRV resistance, by exposing true seedlings to viruliferous aphids in a glasshouse and observing primary symptoms. The seedlings so far reflect the known resistance levels of the parents, in that the progenies from the most resistant parents rank more resistant than those from susceptible parents.

ELISA tuber tests

In an experiment to test a tuber sap treatment developed by D. N. Miller-Jones[1], for enhancing ELISA test results on tuber samples (Ann. Rep. 1982, 77), PLRV-infected tubers were readily distinguished from healthy ones in 12 or 13 genetically diverse clones when the sap extraction buffer contained diethyl dithiocarbamate (DIECA).

Potato mop-top virus

Two clones were found to be susceptible to primary spraing symptoms of potato mop-top virus (PMTV) in a field trial planted at Braco, Perthshire, in 1982. The incidence of spraing overall in the trial was too low to draw conclusions about the other clones, although Rhona showed spraing symptoms in a few tubers.

Tobacco rattle virus

A field trial for resistance to tobacco rattle virus (TRV) spraing symptoms was planted in infested ground at Tayport, Fife, in 1982. The tubers harvested were scored for the presence of spraing. The material was well infected, so resistant clones could be identified with confidence. Moira proved resistant (with only one tuber affected out of 12 plots); Rhona and Ailsa were susceptible. Baillie again showed intermediate susceptibility to spraing but suffered from internal rust spot, which may have been due to TRV. Four other clones (11728ab2, 11704ae26, 10341ab8 and 11233ab22) proved resistant, and eight others susceptible or intermediate.

Twenty-three clones were included in the trial in order to compare their resistance to spraing with their response to sap inoculation of detached leaflets with TRV (PRN isolate). Previous work (SPBS Ann. Rep. 1980-81, 96) with cultivars and *S. tuberosum* clones suggested that spraing-resistant clones usually developed distinct necrotic lesions on inoculated leaflets, whilst susceptible ones usually developed either diffuse lesions or none. It was therefore hoped that sap inoculation might be useful as a preliminary screening for TRV spraing resistance. New data on Neo-Tuberosum and hybrid Tuberosum-Phureja clones, however, suggest that the correlation does not hold for these categories of material.

(R. M. Solomon)

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[1]DAFS, Agricultural Scientific Services, East Craigs

The routine assessment of resistance/susceptibility of clones to tobacco rattle virus (TRV) is at present dependent on field trials at infested sites. The results are somewhat variable from year to year depending on a number of environmental factors such as rainfall and initial nematode infestation levels. In 1983 further work was initiated to investigate and develop methods of improving the screening of clones. With the co-operation of ADAS access to a TRV infested site was obtained. Soil samples from this site and the routine TRV screening site at Tayport were brought back to Pentlandfield for use in pot tests in the glasshouse. Cultivars with known susceptibility/resistance to TRV were then planted at both sites and also in the same soil in pots in the glasshouse. The soils were tested to check that they carried TRV infective nematodes; the results indicated that the Tayport soil had good levels of infestation while the Leeds site had relatively poor levels of infestation.

When the daughter tubes were harvested and scored for presence and severity of TRV spraing few symptoms were found in either the glasshouse grown tubers or in those from the two trial sites. The disappointing results may be attributed in part to the extreme soil temperatures and soil moisture deficits experienced during the summer and also in part to low infestation levels in the field trials.

Further investigations are planned for 1984 with the objective of developing a screening method which will allow large numbers of clones to be assessed reliably.

(R. M. Solomon, M. F. B. Dale)

Bacterial soft rot

Screening tests were performed *in vitro* on tubers of 34 clones. Anaerobiosis was achieved by maintaining a film of water on tubers inoculated by jet injection. The level of rotting was assessed after 10 days incubation at 20°C. The tests confirmed that cultivars Ailsa and Rhona have an appreciable level of resistance to tuber soft rot.

Potted plants were tested for resistance to blackleg by direct stem injection of *Erwinia carotovora* subsp. *atroseptica* and incubation in a growth room for eight days at 20°C. Maris Bard was the most susceptible and Pentland Squire the most resistant of 22 cultivars examined. Twenty-four advanced clones were tested similarly: cv. Ailsa exhibited a similar level of resistance to Pentland Squire.

Skin spot

One hundred and twenty-three clones were tested for resistance to skin spot (*Polyscytalum pustulans*) in 1982-83. Forty-nine of these scored 7 or more on the 9 point scale of increasing resistance. Eighty-four clones (out of 95 tested) received a score within two points of that recorded the previous year. The 1983-84 test was unsatisfactory in that very low levels of infection were observed.

Dry rot

Forty-four clones were tested for resistance to *Fusarium solani* var. *coeruleum* in winter 1982-83. Eleven of 14 clones of potential interest for crisping scored five or more on the 1-9 scale of increasing resistance.

Late blight

Six hundred and eight clones were assessed for foliage resistance in the glasshouse. Of commercial selections bred for blight resistance, 32 of 52 fifth year, and 17 of 27 sixth year clones scored six or more on the 1-9 scale of increasing resistance, as did 31 of 128 fifth year and 27 of 86 sixth year clones from other crosses. Eighty-six of 264 strategic breeding clones also showed this level of resistance. In the field trial of advanced clones at Yonderton Farm, Ayrshire, 12 of 21 early clones and 8 of 53 maincrop clones were at least as resistant as the resistant control cultivars Maris Peer (early) and Stormont Enterprise (maincrop). Agreement with previous glasshouse results was fairly good ($r = 0.842$, $p<0.001$).

Resistance to tuber blight was assessed in laboratory tests on clones from the sixth year onwards of the commercial programme. Eighteen of 44 early clones and 54 of 127 maincrop clones were rated seven or more on a 1, 3, 5, 7, 9 scale of increasing resistance. One hundred and sixty-two of the clones had been tested the previous year, and 122 received the same or adjacent rating in both years.

In an attempt to reduce discrepancies between years in glasshouse test results, the effect was investigated of physiological age of the seed tuber at planting. From early March tubers of five early cultivars were stored at 4, 10 and 20°C for 4, 11 and 17 weeks before planting. Plants from the different storage regimes showed no difference in susceptibility except for cv. Wilja where storage for 17 weeks at 20°C led to significantly higher susceptibility than storage at 4°C for the same period.

The effect of the method of raising seedlings on the number surviving the seed pan test (SPBS Ann. Rep. 1979-80, 79) was also examined. Application of nitrogenous fertiliser (1.2% Solinure 7) to seedlings watered from above increased survival, but watering from below and feeding once per week gave the highest number of seedlings surviving inoculation.

Survivors from the experiment to investigate the effect on susceptibility of seedling age at inoculation (Ann. Rep. 1982, 80) were planted in the blight trial at Ayr. Resistance was confirmed for all but one progeny which had been identified as susceptible by the seed pan test.

Gangrene

Routine cornmeal sand tests done in the winter of 1982-83 on 254 fifth year commercial selections identified 75 clones as highly susceptible. In tests of sixth year and more advanced selections 123 of 202 clones scored

seven or more on the 1-9 scale of increasing resistance, as did 109 of 236 strategic breeding clones. Of clones also tested the previous winter, 149 of 194 commercial clones and 127 of 137 strategic breeding clones received scores within two points on the scale in both years.

Common scab

Fifth year commercial selections and strategic breeding clones were screened for resistance at Archerfield, East Lothian, in 1982, but the level of scab was too low for reliable assessment. Two hundred and two more advanced selections were tested at Scoughall Farm, Whitekirk, East Lothian, and 51 clones scored seven on the 1-9 scale of increasing resistance. Sixty of the most advanced selections were also tested at Gleadthorpe EHF, Nottinghamshire; the two tests agreed well, 49 clones receiving scores within two points on the scale at both sites. This level of agreement was also shown by 63 of 74 clones tested at Scoughall in both 1981 and 1982.

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

As in 1982 an experiment was carried out in the glasshouse using cultivars, with known susceptibility/resistance to common scab, grown in 10 cm pots containing naturally infected soil from the scab trial site at Archerfield. Additionally, this year, the plants were grown in sterile sand artificially inoculated with the causal organism *Streptomyces scabies*. The results are currently being analysed but have already shown that in general the reactions in the glasshouse correspond well with the known performance of these cultivars in the field.

(R. L. Wastie, P. D. S. Caligari)

PU 9(l) Study the components of virulence in potato cyst nematodes and resistance in the host

Host-parasite relationships

Juvenile nematodes were placed in contact with the roots of 1-week-old plants grown from eye sprouts for a period of 3 days. The number of juveniles present in the roots of susceptible and resistant cultivars did not differ significantly. However, over the next 3 weeks many more nematodes left the resistant cultivars. This was true both for *Globodera rostochiensis* Ro1 and Maris Piper (H_1 resistance), and for *G. pallida* and the resistant *ex-vernei* clone 12380abc(2). Contact between the nematode and its host during these 3 weeks determines whether it will settle and develop or leave the roots.

Recognition between the nematode and the plant may involve the interaction of a saccharide-containing macromolecule and a lectin-like component. Binding assays with seven different fluoresceinated lectins did not detect any carbohydrate residues on invasive juveniles. However,

N acetyl-D-glucosamine and D-mannose or ∝-D-methyl mannoside were present on the surface of third stage juveniles of *G. rostochiensis* developing on susceptible potatoes. The binding of *Ricinus communis* agglutinin 1 to the nematode surface appeared to be non-specific as it could not be blocked by D-galactose. The binding sites are being further studied by transmission electronmicroscopy of sections labelled externally with lectin-ferritin conjugates. So far the presence of N acetyl-D-glucosamine has been confirmed by this technique.

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

Virulence of populations of Globodera pallida

Studies of the variation in virulence between populations of *Globodera pallida* (Ann. Rep. 1982, 76) were continued by examining their hatching ability, success in invasion and fecundity. *In vitro* studies of hatching were conducted using root diffusates from the non-resistant cv. Pentland Crown, two partially resistant clones derived from *Solanum vernei* and one derived from *S. tuberosum* ssp. *andigena* CPC2802. Diffusates were added sequentially (Ann. Rep. 1981, 176) to batches of cysts from four populations for 6 weeks. The two most virulent populations produced higher hatches in response to all diffusates but the differences in total hatch between populations was small. The invasion rate of two of these populations, the most and the least virulent, were compared on Pentland Crown and two *S. vernei* hybrids by inoculating week-old sprouts with 1500 juveniles/plant. After 2 days the roots were stained and the number of juveniles within them counted. Whether examined as the number of juveniles/plant or juveniles/g root, the number of juveniles of the most virulent population was three times that recorded for the least virulent.

Estimates of the egg content of cysts from six populations grown on eleven *S. vernei* hybrids and five CPC2802 hybrids showed that those populations with the highest multiplication rates also had the largest cyst contents. These findings, together with those on invasion rates, suggest that some of the differences between populations can be attributed to differences in fitness.

Relationship between initial population density and nematode reproduction rates on partially resistant clones

The reproductive rates of two populations of *G. pallida* over a range of initial population densities (Pi) were compared on cv. Pentland Crown and two *S. vernei* hybrids. The final numbers of eggs/g dry soil (Pf) increased over the range of densities, whilst the reproductive rate (Pf/Pi) decreased. The response curve to increasing Pi by the partially resistant clones was similar in form to that observed for the non-resistant clone, but the response rates and maximum final densities were lower. The

[1]Zoology Department

experiment demonstrated the wide range of Pf/Pi values (0.7 to 6.8 for clone 11305 a2 with the Friskney population) that can be obtained in pots from partially resistant clones, depending on environmental factors. This highlights the limitation of using particular multiplication rates as criteria for assessing resistance. At all inoculation levels the ranking of the clones remained the same, so that if resistant clones as well as non-resistant are included the resistant controls could be used to delineate resistance categories.

(M. S. Phillips, L. A. Farrer)

SOFT FRUIT BREEDING

D. L. JENNINGS

Progress is reported in all aspects of the Department's programme, although some important aspects of black currant work were handicapped by the recent loss of two staff members. It is gratifying that in black currants we are now reporting upon selections which combine an advance in frost tolerance with improvements in juice quality, and that in raspberries we report disease resistance from amongst high yielding selections. The good performance reported for several selections of black currants, raspberries and strawberries in regional or national trials makes them future candidates for release as new cultivars.

A new blackberry × raspberry hybrid 'Tummelberry' is announced. The Tummelberry resembles Tayberry, from which it is derived, but differs from it in flavour and ripening season. It is therefore expected to have a useful complementary role to that of Tayberry, especially for pick-your-own marketing.

PU 13(a) Provide improved cultivars of raspberry and study relevant characters

Four advanced selections which have yielded well in the current first stage National Fruit Trials (NFT) were recommended for inclusion in regional trials in England and Scotland and in commercial appraisal trials on growers' holdings. Of the selections, 7515C5 is mid-season and has given excellent results in processing tests; 7518E6 and 7331/7 are early, large-fruited and considered very suitable for pick-your-own marketing; and 7133R40 is late. A further five selections are being propagated for inclusion in new stage 1 trials at Brogdale and SCRI.

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

Hardiness

Portions of dormant canes with buds were cooled slowly to a range of sub-zero temperatures and then thawed gradually. The survival of the buds was then determined by their ability to grow at room temperature. The most hardy of 19 genotypes tested was a selection of wild *R. strigosus* from British Columbia; buds of this genotype survived −27°C in January. Cv. Glen Moy was the least hardy. Assessments of freezing injury were also attempted by using conductivity determinations to compare the amount of electrolyte leakage which occurred from frosted

and non-frosted material. There was no relationship between the assessments based upon conductivity and those based upon bud survival, but the conductivity results tended to be inconsistent. Refinements in techniques are therefore being studied.

(R. J. McNicol)

PU 13(b) Provide improved cultivars of black currant and study relevant characters

Under the aegis of ADAS, 2500 1-year-old plants of each of two late maturing potential juice processing cultivars – SCRI P8/12/7 (cv. Ben More × cv. Ben Lomond) and P9/8/7 (a complex Ben Lomond hybrid) – were distributed for machine harvesting and further regional growers' trials (Ann. Rep. 1982, 91).

Regional trials and commercial assessments

Ben Lomond and cv. Baldwin gave their highest mean yields on record at Brogdale EHS (equivalent to 27 and 26 t/ha), probably because there were no spring frosts or cold weather at flowering. They outyielded all other cultivars and selections in the trials. The lower yield of Ben More (17 t/ha) as not associated with low minimum temperatures during its later flowering period.

The three late flowering SCRI selections distributed for growers' trials in winter 1982/83 (Ann. Rep. 1982, 91) gave very high yields (23-26 t/ha) for the fourth year in succession; for the years 1980-83, P8/12/7 has now out-yielded Baldwin by 34%, In a trial planted in 1979/80, cv. Ben Sarek, SCRI F6/3/39 (an early maturing Ben Lomond × (*R. nigrum* × *R. dikuscha* hybrid)) and SCRI 243/7 (cv. Seabrook's Black × cv. Janslunda) × (cv. Anger von Oeffelt × cv. Sztahanovka) gave their first commercial crop, and their juice processing qualities are being assessed by Beecham Products, Coleford.

At Luddington EHS, cv. Luddington I (a form or hybrid of Baldwin), Ben Sarek, Ben Lomond and Ben More yielded 7, 13, 14 nd 16 t/ha respectively and two late flowering SCRI selections averaged 20 t/ha. These results support the belief that Ben More is better adapted to the conditions of Luddington than Brogdale, and underline the need for wider regional trialling of potential new cultivars.

Frost tolerance screening tests

Cut shots of 50 selections derived from the cultivars Sunderbyn II, Matkakoski, Ben Lomond or Ben More were frosted in a controlled frost chamber at −4.5°C for 4 hours at three stages of flower development, grape, first open flower and full flower. Cut shoots of Ben Lomond, Ben More and Baldwin were used as standards for comparison.

None of the Baldwin flowers survived the frost at first open flower stage. All the selections survived the frost at grape stage better than

Baldwin. Flower survival in 20 of them was at least equal to that of Ben Lomond, and in 10 of them 40% or more of the flowers survived at full flower stage. Ben Lomond flowers survived better at first open flower stage than those of Ben More, but none survived at full flower. Flower survival at full flower stage in the three late flowering selections distributed for trialling ranged from 38 to 73%.

Two of the frost hardy selections were submitted for trialling at Brogdale EHS: SCRI P9/1/3 (cv. Goliath × cv. Ojebyn) op × Ben Lomond – an early maturing, large berried type – and SCRI AB3/7 (243/7 × Sunderbyn II), the first of the SCRI 243/7 derivatives which combine superior juice quality with the flower hardiness and the characteristic form of strong mildew resistance present in Sunderbyn II. This particular combination of attributes was also found in less productive or more spreading selections from Sunderbyn II crosses with Baldwin, cv. Merveille de la Gironde or P10/8/2 (SCRI 243/7 × cv. Westra). The first notable frost hardy selections were made from the crosses P10/8/2 × Matkakoski and M48/2 (Baldwin × (Goliath × Ojebyn)) × 238/32 (Goliath × Ojebyn), where the maternal parents were chosen for their excellent juice quality.

(J. Thomson, M. M. Anderson)

Plant habit and branch strength

Four 2-year-old plants were selected from a progeny of SCRI 243/7 × (Baldwin × *R. sanguineum*), and six from a progeny of SCRI 243/7 × BB115/5 (a *R. nigrum* × *R. sanguineum* F_3 hybrid). They will be observed for their branch strength, plant habit, vegetative and reproductive vigour and mildew resistance.

Two small replicated black currant trials were planted in April to provide plants of contrasting habit for studies on aspects of the black currant growth cycle and on branch strength and flexibility.

Resistance to reversion virus

R. dikuscha, R. ussuriense, R. nigrum sibiricum, R. grossularia and *R. divaricatum* cultivars and hybrids free from visual symptoms of reversion virus and whose reversion resistance status is either unknown or uncertain were graft inoculated in 1981 or 1982 with reversion virus. Typical flower-bud symptoms were produced in 1983 by SCRI 243/7, the cultivars Baldwin, Smena, Szahanovka Altaja, Pamjat Michurina, two derivatives each of the cultivars Primorski Champion and Golubka and two of *R. grossularia*, but no symptoms were produced by *R. ussuriense* or several *R. dikuscha* and *R. nigrum sibiricum* derivatives. These plants will be re-examined for symptoms in 1984.

New progenies

Nine thousand seedlings were planted in nursery rows to undergo primary selection for plant form and disease resistance. Selection thereafter will

be for improved juice quality in progenies of frost-hardy derivatives of Ben More and its sister seedlings 238/36/12 and Ben Sarek and Ben Lomond; for frost hardiness combined with good juice quality in progenies of SCRI 243/7 derivatives, notably AB3/7 (SCRI 243/7 × Sunderbyn II); and for frost hardiness in progenies of gall mite and reversion resistant selections. The first group included seedlings of P8/12/7 (Ben More × Ben Lomond) and P10/18/121 (Ben Sarek × Ben Lomond) which are derived from reciprocal crosses between BB115/5 (*R. nigrum* × *R. sanguineum* F_3), and C2/1/62 (*R. nigrum* × (*R. nigrum* × red currant F_3)), two selections notable for their upright habit and strong branches (SHRI Ann. Rep. 1979, 55; Ann. Rep. 1982, 93).

The crosses Ben More × Ben Lomond and Ben Lomond × Ben Sarek were repeated reciprocally, SCRI P8/12/7 was backcrossed to both parents, and both Ben Sarek and Ben Lomond were crossed with AB3/7 (243/7 × Sunderbyn II) to transfer the non-sporulating form of mildew resistance from Sunderbyn II, and with a Golubka × Brödtorp hybrid to transfer resistance to reversion virus. Other crosses were made with *R. ussuriense* and its derivatives to investigate possible sources of the colour augmentation and remarkable colour stability of the juice of Ben Lomond and its hybrids. Finally, crosses were made between the tetraploid cultivars Jostaberry (*R. nigrum* × *R. divericatum*), Kroma (*R. nigrum* × *R. divericatum*) × (*R. nigrum* × *R. niveum*) and naturally occurring tetraploid forms of Ben More and P9/8/7 (Ben Lomond complex hybrid). These crosses were also made using normal diploid black currant as the seed parent. Seeds were obtained from all the crosses attempted except for those of *R. ussuriense*.

(M. M. Anderson)

Juice quality

The juices of 400 fruit samples were analysed for quality to complete the survey of the breeding material begun in 1977 to identify sources of juice quality components.

At the outset of this investigation, two pre-eminent and contrasting sources of juice quality were identified – Ben Lomond (cv. Brödtorp × Janslunda) × (cv. Consort × cv. Magnus) and SCRI 243/7, a hybrid derived from European, Scandinavian and a complex (*R. nigrum* × *R. dikuscha*) hybrid from the USSR. Subsequent analyses of 1027 juice samples have confirmed their value as donor parents for improved juice processing qualities. The intense juice colour and colour stability attributes of Ben Lomond are thought to have been derived from the Canadian cv. Consort (cv. Kerry × *R. ussuriense*), and the unusual combination of intense juice colour and high ascorbic acid content of SCRI 243/7 partly from Seabrook's Black and partly from Sztahanovka (a *R. nigrim* × *R. dikuscha* derivative from the USSR).

Over the four years from 1979 to 1982, F_1 hybrids of SCRI 243/7 have been rated highly for intense juice colour (E515 at pH 1.0), ascorbic acid content adjusted to standard specific gravity (AAsg), and high juice pH; they usually had small berries and relatively low yield of juice adjusted to standard specific gravity (JYsg). In contrast, F_1 hybrids of Ben Lomond have been rated somewhat less highly for juice colour and AAsg but very highly for large berry size and a high JYsg; they usually had a low juice pH and a low °Brix/TA ratio. Both groups of hybrids received favourable scores for flavour from an experienced taste panel at Beecham Products.

The colour quality of the juice samples is measured by three spectral indices: copigmentation index (E515 at pH 3.0/E515 at pH 1.0), which gives a measure of colour augmentation and stability at juice pH 3.0; blue index (E580 at pH 1.0/E515 at pH 1.0), which gives an indication of the perceived darkness of a juice sample; and brown index (E515 at pH 1.0/430 at pH 1.0), which is indicative of the proportion of degraded anthocyanins present.

In 1982 samples, E515 at pH 1.0 was positively correlated with copigmentation index ($r = 0.38$ for 276 d.f.) and blue index ($r = 0.60$), and negatively correlated with brown index ($r = -0.53$).

Nearly a third of juice samples obtained from Ben Lomond derivatives occurred in the best group for copigmentation index and a similar proportion of Westra (Baldwin) samples occurred in the worst group. A high blue index was a common feature of SCRI 243/7 derivatives: juice samples from a third of them were classified into the best group and only 9% into the lowest. High brown indices occurred most frequently in juice samples of Westra derivatives.

Thus, two major improvements in juice colour quality have been obtained from selections derived from two asiatic black currant species closely related to *R. nigrum, R. ussuriense* and *R. dikuscha*.

(J. Thomson, M. M. Anderson)

PU 13(c) Provide improved cultivars of blackberries and other *Rubus* fruit

An advanced tetraploid spine-free blackberry selection, 74126RA8, has now given very high yields for 3 years in the NFT. The hybrid is notable for its vigour and large fruit size but it is late ripening and not satisfactory for some aspects of fruit quality. The NFT committee recognised its deficiencies but considered that it should be released to meet certain needs. A decision has not yet been made. A similar selection, 78102E10 was superior to it at SCRI and is being propagated for early submission to NFT.

Observations were made on six spine-free progenies obtained by backcrossing two hybrids from the cross between hexaploid Tayberry and a non-adapted spine-free septaploid blackberry to the Tayberry and two of its close relatives. The progenies contained a high proportion of plants bearing only 'blind' laterals, because of failure to initiate flower buds, while many others had low fertility or poor fruit quality. Three selections were chosen for a further backcross to Tayberry. The dominant gene for spinelessness present in this material has also been bred into a tetraploid blackberry × raspberry hybrid. A backcross of this hybrid to tetraploid raspberries was made in an attempt to transfer the gene to these raspberries and then produce new Tayberry-like blackberry × raspberry hybrids.

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

PU 13(d) Devise and use on fruit breeding material screening methods for fungal disease resistance

A wide range of material was used to compare resistance to *Didymella applanata* and *Botrytis cinerea*, assessed from mycelial inoculation of cane wounds on 8 to 10 August, with tolerance of infection, assessed from the subsequent size and ability to grow of the axillary buds of petioles inoculated with *D. applanata* on 22 July or with *B. cinerea* on 11 August. On average, buds infected with *D. applanata* were 79% of the size of healthy buds on 7 November but resistant genotypes usually showed less reduction; buds infected with *B. cinerea* were reduced to 86% of the size of healthy buds with no significant differences due to genotype. For both pathogens the reduction in bud size due to infection was relatively severe for two cultivars with large buds. Differences in the ability of the buds to grow will be recorded in spring 1984. A positive correlation between resistances to *D. applanata* and *B. cinerea* was noted as in previous experiments, but it was lower among eight cultivars ($r = 0.52$) than in backcross derivatives of *Rubus pileatus* and *R. occidentalis* ($r = 0.89$).

In experiments with mycelial inoculation of canes with *Leptosphaeria coniothyrium* segregation for resistance was found among first backcross hybrids of *R. pileatus*, but the lesions were small, as in 1982, and consequently discrimination between genotypes was not satisfactory. Possible explanations for this are being sought.

Thirty-two advanced selections and parents were assessed for fruit resistance to *Botrytis cinerea* by studying grey mould development on fruit samples obtained from the field on three picking dates. From 21 – 87% of fruit developed grey mould when incubated for up to 6 days at about 20°C with high humidity. This indicated a wide range of resistance. Fruit resistance was not closely related to either fruit firmness or cane resistance to *B. cinerea*, and so these characters could not be

used to predict fruit resistance reliably, although it was probably significant that the most resistant genotypes were all firm fruited.

(D. L. Jennings, E. Carmichael)

Field populations of cane midge (*Ressesliella theobaldi*) were too low to permit a realistic assessment of the resistance to the pest of first backcross hybrids of *R.crataegifolius*. Histological studies on earlier material confirmed the association of resistance with an ability to produce abundant wound periderm.

(R. J. McNicol)

Strawberries: identifiction of genotypes adapted to Scotland

Frosts during early flowering killed many primary flowers and caused considerable fruit malformation. This provided an opportunity to screen selections for tolerance of conditions not conducive to good fruit set – a very important attribute for cultivars grown in Scotland.

The advanced selections ET115A and WC64 continued to crop well in observation plots and larger plots of them were planted. They were also recommended for inclusion in the next NFT Multicentre Trial. Nine new selections, including two autumn-fruiting types, were sent to NFT Brogdale for further testing.

(R. J. McNicol)

NEW CULTIVAR OF HYBRID *RUBUS*

TUMMELBERRY

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

A stock is being propagated and selected propagators will be supplied by NSDO. Breeders' number 73153C4.

Origin	From a cross Tayberry × 69102/18 (69102/18 is a selection from the same family as Tayberry).
Canes	Vigorous, sturdy shoots produced in moderate to high numbers, spreading to semi-erect but slightly more erect than Tayberry. Dark green with anthocyanin pigments less intense than in Tayberry and with dense, moderately sized spines.
Fruiting laterals	Usually about 30 cm long and displaying fruit well.
Fruit	Medium large, short conical, red/purple and slightly glossy. The plug remains within the fruit when picked. Compared to Tayberry the fruit is less long conical and less purple. The flavour is slightly acid without the aromatic characteristics of Tayberry.

Season of ripening	Extends over a long period, starting and finishing a week later than Tayberry.
Hardiness	Sufficient for most situations in Britain and slightly superior to that of Tayberry.
Yields	The yields obtained in NFT, Brogdale, were slightly less than Tayberry in a season which followed a mild winter and slightly more in a season which followed a severe winter.
Diseases and pests	Susceptible to raspberry leaf and bud mite (*Phyllocoptes gracilis*).
Use	Dessert, freezing and jam making; less satisfactory canned.
Mode of propagation	By root cuttings, leaf-bud cuttings or rooted stem tips.
Identification	Distinguished from Tayberry by the difference in colour and shape of the fruit and by the lower intensity of purple pigment in fruiting canes.

I. H. McNAUGHTON

Work was initiated to produce new, and possibly useful so-called somaclonal, variation through callus culture. Haploid donor plants were used because most induced mutations are likely to be recessive and therefore masked by dominant genes in a diploid or polyploid but revealed in a haploid or auto-diploid (doubled haploid).

A new, important part of the cytological work was concerned with mitotic counts and meiotic analysis of the products of pollen irradiation experiments. Such studies are vital to the understanding of the mechanisms involved in gene transfer by this technique.

PU 2(d) Study genetics and biochemistry of cereals and develop breeding methods

There was an increase in the amount of cytological screening for the Cereal Breeding Department and it has been necessary to develop efficient and reliable techniques for both mitotic and meiotic analyses. Liaison with the cytogenetics group at PBI has proved helpful in this respect. An aerated tank system has been developed to obtain roots, from mature barley plants, suitable for chromosome analysis. Although results can be obtained by this technique it is labour intensive, unreliable and does not provide the same quality of metaphase plates as those produced by primary roots.

Ploidy checks have been made on material produced by the hap-initiator gene technique and the *Hordeum bulbosum* technique. Root-tip preparations of 350 barley plants regenerated from callus tissue by JII have been checked for gross chromosomal anomalies. A sample of microspore culture derivatives produced at the JII and thought to be diploid, were found to contain a tetraploid plant when checked mitotically.

Pollen irradiation

Of the crops being investigated, barley is the most suitable for a cytogenetic investigation as it has a small number of large chromosomes. Both the irradiated and the untreated barley plants screened in the first generation had the normal somatic chromosome complement ($2n = 2x = 14$).

Meiotic analysis of 12 of the M_1 plants showed that three contained quadrivalents, due to the occurrence of translocations. Two of the three plants were partially fertile whilst the third, with the highest quadrivalent frequency, was sterile. All irradiated material showed a high frequency of bridges (but not fragments) at anaphase I.

Fifty M_2 barley progeny were screened mitotically; only two had detectable karyotype abnormalities. One was trisomic ($2n = 2x + 1 = 15$); the other showed a chromosomal translocation, both these aberrant types came from parents with translocations. The sibs of these plants had apparently normal karyotypes. Analysis of meiosis in the M_2 generation has yet to be completed.

(E. M. Borrino)

PU 5(h) Investigate novel combinations of genomes to produce breeding material

Embryo rescue of inter-specific hybrids

Further artificial *Brassica napus* forms ($2n = 38$, aacc) were produced by embryo rescue techniques following crossing between autotetraploids of *B. campestris* ($2n = 40$, aaaa) and *B. oleracea* ($2n = 36$, cccc). Transfer of deformed embryos to a second, shoot proliferation medium resulted in some plants being established which might not otherwise have survived. Haploid *B. napus* ($2n = 19$, ac) plants, produced from diploid *B. campestris* ($2n = 20$, aa) and *B. oleracea* ($2n = 18$, cc), were treated with colchicine. Micropropagation from treated axillary buds was used to improve the chances of establishing doubled chromosome plants.

Development of parents for inter-specific and inter-generic hybridisation

Diploid and autotetraploid inter-subspecies hybrids of *B. campestris* were grown in the field and further selected to provide vigorous, leafy parental material for *B. napus* synthesis. At least one hybrid would seem to have potential in its own right, sufficient seed of which was produced for agronomic assessment in 1984. Diploid F_2 hybrids showed a wide range of variation, particularly in leaf morphology, and provided material for genetic studies by the Forage Brassica Breeding Department.

Diploid and tetraploid inter-specific *Raphanus* hybrids, obtained from *R. sativus* (fodder radish) and *R. maritimus* (sea radish), were grown for further selection. These hybrids are now virtually free from premature flowering, have persistent, mildew resistant foliage and are truly biennial with good winter hardiness.

Seed of various colchicine induced autotetraploids, mainly *B. oleracea*, was sent to the NVRS Gene Bank for conservation.

Somaclonal variation – callus culture

In order to investigate the possibilities of inducing useful somaclonal variation (mutations induced *in vitro*) haploid *B. napus* plants, produced

by embryo culture from *B. campestris* × *B. oleracea*, were used to initiate callus cultures. Callus was derived from leaf petiole segments placed in a medium containing 2 mg/l 2,4-D. Development of callus was better under low illumination than in complete darkness. The efficiency of several media, varying in auxin:cytokinin ratios and concentrations, is being examined for plant regeneration. Spontaneous chromosome doubling is expected. Any induced mutations should be true breeding.

Micropropagation of haploid *B. napus* was carried out, (a) to provide plants for mutagenic studies, (b) to provide additional material for colchicine treatment. Up to 20 proliferated shoots could be obtained from one axillary bud in a period of 4 weeks. Some chromosome doubling occurred during micropropagation, probably due to small amounts of callus being formed. These results suggest that haploids are unstable *in vitro* and also indicate an alternative method to colchicine treatment for chromosome doubling.

(I. H. McNaughton, D. E. Middlefell Williams)

Pollen irradiation

In order to obtain an insight of the cytological implications following inter-specific and inter-generic pollen irradiation, two sets of 'crosses' were carried out; *B. napus* × *B. campestris* (an easy hybridisation with normal pollen) and *B. napus* × *R. sativus* (an extremely difficult cross, true hybrids being very rarely reported).

B. napus cultivars (swedes and forage rapes) were emasculated and irradiated pollen (treated at 100, 150, and 200 grays with ϑ -rays, Cobolt-60 source) applied to stigmas. Unirradiated pollen was used as a control.

From the 'cross' *B. napus* × *B. campestris*, substantial numbers of seeds were obtained from all three treatments and controls. Samples of seed, from the 200 grays treatment and controls, were germinated and plants raised for observation. M_1 plants were predominantly full allotriploid hybrids ($2n = 29$), others proved to be partial hybrids ($2n = 25$ to $2n = 28$) with evident elimination of chromosomes from the paternal genome, presumably due to radiation damage.

B. napus × *R. sativus* 'crosses' yielded small numbers of seeds, but some were obtained from each treatment. A sample of M_1 plants, grown on, proved to be morphologically indistinguishable from *B. napus*, with no *Raphanus* characters apparent. These were examined cytologically and all possessed $2n = 38$ chromosomes. Such matromorphic plants are known to occur in quite high numbers from *B. napus* × *R. sativus* (untreated pollen) crosses. The M_1 plants are being retained to see if electrophoretic techniques can reveal, in changes of biochemical constitution, any evidence of gene transfer.

(I. H. McNaughton, J. E. Middlefell Williams)

Work on the inter-specific cross *B. napus* ($2n = 4x = 38$) × *B. campestris* ($2n = 2x = 20$) revealed that the majority of M_1 plants had a chromosome number similar to that of the F_1 ($2n = 3x = 29$) rather than that of the maternal self. This indicated that the irradiated pollen derived material was hybrid in constitution and not parthenogenetically derived from the seed parent. Approximately half of the M_1 seedlings examined were hypoploid with up to four chromosomes absent from the F_1 complement. Chromosomal rearrangement (e.g. telocentric chromosomes) was also observed. Aneuploidy in the untreated F_1 was rare.

Cytological support for tissue culture included somatic chromosome counts of micropropagated plants derived from hybrids of *B. campestris* ($2n = 2x = 20$) × *B. oleracea* ($2n = 2x = 18$) obtained by embryo culture. Almost half the plants screened proved to have the full amphidiploid complement ($2n = 2x = 38$) and several mixoploids were found. The numerous reports of somaclonal variation, spontaneous doubling and mixoploidy in most aspects of plant regeneration underline the need for careful screening of material.

(E. M. Borrino)

PU 6(a) Breed cultivars of potato improved for agronomic characters as demonstrated in field trials in the UK

In vitro conservation of germoplasm

One hundred and thirty potato clones have so far been placed in long term *in vitro* storage. These are comprised of sets of field resistance standards and differentials for late blight pathotyping, part of the breeders' museum collection and several clones introduced from South America via CIP. Alar or B-nine at 50 mg/l proved the most satisfactory of several growth retardants tried, and produced compact plantlets with short internodes suitable for storage under low light and low temperature conditions.

(I. H. McNaughton, J. E. Middlefell Williams)

PU 6(c) Study the genetics of potatoes and improve breeding and trialling methods

Pollen irradiation

The cytology of potatoes is difficult and only small numbers (*c.* 60 clones) of exact chromosome counts have been possible. The parental cultivars showed the expected chromosome number ($2n = 4x = 48$) but the controls (i.e. the F_1 and maternal selfs), contained a low level of aneuploidy. Plants derived from the irradiated pollen crosses also showed some aneuploidy but the sample size was too small to assess whether it was more frequent in the M_1 than the F_1. Results do, however, show that most of the M_1 material has the euploid chromosome complement

and that aneuploidy, when it occurs, is not severe, with a maximum loss of two chromosomes being observed.

(E. M. Borrino)

PU 6(d) Develop new potato breeding material from primitive and novel germplasms

The routine screening of material for the diploid potato breeding and evaluation scheme occupied much of the year. Three hundred 'improved' diploids have been assessed for pollen fertility and diploandroid production. Diploid plants with relatively high levels of diploandroid (2x) pollen can be considered as potential pollen parents in future crosses with tetraploid potatoes. The ploidy level of progeny from many such previous crosses has been checked from root-tip squash preparations. From 565 seedlings screened this year, 495 new tetraploid hybrids were identified. Screening of more complex crossing schemes, involving these synthetic tetraploid hybrids and dihaploids, revealed that 185 of 187 seedlings examined were tetraploid. Pollen fertility of 260 various tetraploid hybrids was also estimated.

Screening of ploidy level undertaken for the dihaploid production programme, identified 22 of the 85 plants examined as dihaploids.

A small number of *S. tuberosum* cultivars have been examined meiotically to investigate possible causes of high levels of aneuploidy in their progeny. Irregularities of meiosis (laggards, univalents, unequal segregation ratios) have been noted and work on quantifying these aberrations is continuing.

(E. M. Borrino)

PU 13(a) Provide improved cultivars of raspberry and study relevant characters

Work on *Rubus* only recently started. From the morphology of the prospective parents it was believed that they were hexaploid, but chromosome numbers were found to range between the hexaploid and septaploid level. As these hyperploids are highly fertile it must be assumed that the plants have a high tolerance of aneuploidy.

(E. M. Borrino)

PU 13(c) Provide improved cultivars of blackberries and other *Rubus* fruit

Two clones of Tayberry were examined to determine if morphological variation observed in the phenotype had a basis in aneuploidy. A technique was developed for staining mitotic chromosomes of *Rubus* and the variants were shown to be euploid ($2n = 6x = 42$).

(E. M. Borrino)

MYCOLOGY AND BACTERIOLOGY

R. A. FOX

On a world basis, potato late blight caused by *Phytophthora infestans* is the most important potato disease challenging both pathologists and breeders. From mid-1982 there has been a progressive increase in work on this disease and a corresponding decrease in work on red core root disease (*Phytophthora fragariae*) of strawberry and, latterly, on chocolate spot (*Botrytis fabae*) of field bean. However, some work will continue on both species of *Phytophthora* as part of a project on the genetics of pathogenicity in the genus. There are evident similarities in some problems of race definition and 'race-specific' host reactions in both disease complexes, problems that may be resolved more readily by studying also other species that are more amenable to mating techniques for genetic analyses. The hazards of introducing A2 mating strains, currently limited to central and northern South America, of the heterothallic *P. infestans* are unacceptable. However, 'selfed' oospores have been induced in A1 strains using a membrane technique and A2 mating strains of other *Phytophthora* spp. (see p. 115). Surprisingly, when the technique has been used mechanically without the biological stimulus of a compatible mating strain, some *P. infestans* isolates have behaved as if they were from a homothallic species and produced abundant oospores.

Many isolates of *P. infestans* are variable and unstable and appear to both lose and gain specific virulence when tested over a period of time on R-gene differential hosts. This unpredictable variability can, at worst, mislead breeders and others especially in relation to horizontal or race non-specific resistance and, at best, greatly increase a workload by the need for constantly checking isolates used for screening. The Department can now store many isolates in liquid nitrogen, and thereby maintain absolute stability, and both R-gene differential hosts and horizontal resistance standards can be maintained by axenic micro-propagation. Thus the Department now offers a service, initially limited to establishments in the UK, of providing each year both pathogen strains and plant genotypes of proven reaction.

The reaction of axenic host plantlets to pathogen isolates proved free of contaminating bacteria are unlike field reactions. These and other observations suggest that field symptom development is moderated by other micro-organisms and there is preliminary evidence, suggestive of that previously reported for *B. fabae* and bean, of the involvement of

bacteria. Moreover, symptom expression and lesion development may be affected also by growing conditions of the plants before infection.

Many potato cultivars suffer from an evident imbalance between shoots and roots; they are prone to water stress and respond well to irrigation in areas where the rainfall is adequate for many other arable crops. Surprisingly little work has been done on the size and efficiency of the potato root system and of its pathology, rhizosphere and mycorrhiza interactions. The past year and a half has also seen a movement away from studies of fungal pathogens of the tuber towards those of roots and these are already proving both rewarding and interesting.

PU 3(a) Study the epidemiology and etiology of fungal root diseases of cereals

Effect of Fusarium nivale *on spring barley emergence growth and yield*
Seeds of barley cv. Golden Promise were inoculated with *Fusarium nivale* by steeping in a suspension containing 3×10^6 spores/ml for 30 min and drying overnight. Triadimenol and fuberidazole dust (Baytan, Bayer Ltd) was applied to half of the inoculated seeds at 2 g/kg seed and to a similar quantity which had been soaked in water. Inoculated and non-inoculated, fungicide-treated and untreated seeds were sown in a Latin square design with an Oyjord drill in 10×1.7 m plots at Invergowrie on 18 March. When emergence was counted on 14 April there was a significant difference between fungicide-treated and untreated seeds (59.2 and 142.7/m^2 SED 3.61, respectively) but not between inoculated and non-inoculated seeds, while on 9 May the difference between fungicide-treated and untreated seeds was less but still significant (206 and 231/m^2 SED 3.61, respectively). The fungus was isolated from 6% of stem bases of plants grown from inoculated, untreated seeds sampled on 9 May and not from plants in any other treatment. On 14 June an average of 13% plants were infected with no significant differences between treatments and 5% of the harvested seeds were infected regardless of initial treatment. Grain was combine harvested on 6 September, the moisture content of a small sample determined and yields corrected to 15% moisture content. Mean yield was 374 g/m^2 with a small significant reduction of 9.6% from plots sown with fungicide-treated seed and no differences associated with seed inoculated with *F. nivale*.

When seeds were inoculated with standard spore suspensions of several isolates of *F. nivale* and incubated at 15°C in pots of soil, large differences in pathogenicity were observed. Some isolates killed seedlings while others produced superficial lesions on coleoptiles but had no effects on growth. A moderately pathogenic isolate reduced the growth of seedlings more at 5-10°C than at 20-25°C but caused death only when seedlings were exposed to sub-zero temperatures after inoculation. Seedlings were most susceptible when inoculated and exposed to freezing

temperatures 10-14 days after sowing at 15°C, before the first leaves emerged from the coleoptiles.

F. nivale was not able to utilise cellulose in sterilized barley straw or filter paper and it could not be isolated from pre-colonised straws after they had been buried in field soil for 2 weeks at 10 and 20°C, nor from autoclaved straws buried in field soil amended with spores of *F. nivale*. Isolates of *Penicillium* sp., *Trichoderma* sp. and *Papulospora* sp. were shown to be strongly antagonistic towards *F. nivale* by several *in vitro* test methods. However, the fungus could infect healthy seedlings 20mm distant from an artificially infected seedling or agar culture presumably by mycelial growth through the soil and it was isolated from bait plants grown in soil collected monthly from a barley field for one year after the crop had been harvested. Perithecia which had been buried in field soil for up to 6 months produced colonies of *F. nivale* on agar and infected barley seedlings in soil.

(D. A. Perry, M. Al-Hashimi)

Snow rot on winter barley

Several fields of winter barley cv. Igri were observed in March with patches of dead and dying plants from which *Typhula incarnata* was isolated. Damage was most frequent where winter barley was grown for the second or third time on the same land and although some compensatory growth occurred from weakened plants as temperatures rose later in the season, secondary tillers were small and late maturing. A yield loss of 25% was estimated on one field. Abundant sclerotia were formed on dead foliage and roots which produced basidiophores in pots out of doors from 30 September onwards. Basidiophores were also seen in the field in early November on trash from a previous winter barley crop which had not been buried. A field trial to test the ability of fungicides applied to seeds and seedlings before winter to control the disease was initiated in collaboration with ESCA.

(D. A. Perry)

PU 4(a) Study the epidemiology and etiology of fungal diseases of brassica forage crops

The fungicidal effect of calcium cyanamide on clubroot development in four swede cultivars, Doon Major, Marian, Ruta Øtofte and Sator Øtofte was examined in a field trial. A granular formulation containing 20% N and 55% CaO (Perlka, SKW Trostberg, Aktiengesellschaft, Germany) was incorporated into the soil at 1,000 kg/ha with a rotary cultivator 10 days before transplanting. Seedlings of the four swede cultivars were inoculated with a pathogen population supplied by G. R. Dixon[1] from the Craibstone trial site which was pathogenic to

[1]Horticulture Division, NSCA

Doon Major but caused only mild symptoms on the other three cultivars. Inoculated and uninoculated seedlings were transplanted into the calcium cyanamide-treated soil. The addition of calcium cyanamide reduced the mean disease category (scored on a 0-9 scale) of inoculated plants of Doon Major from 5.9 to 3.6 ($P<0.01$). The mean root fresh weights of Marian and Ruta Øtofte were reduced from 24.2 to 19.5 kg/plot and 21.6 to 15.8 kg/plot respectively, suggesting that calcium cyanamide was phytotoxic at the rate used in this trial.

The effect of different rates of calcium cyanamide (0, 8, 40 and 80 g Perlka/50 kg soil) on disease development was examined in a pot test. The four swede cultivars were inoculated with Pb8023 which is not pathogenic to Marian, moderately pathogenic to Ruta Øtofte and Sator Øtofte and strongly pathogenic to Doon Major. The 8 g rate of application did not affect disease development or plant fresh weight while 40 and 80 g significantly reduced the amount of diseased tissue and increased root fresh weights. The results indicated that less calcium cyanamide was required to control clubroot on the moderately susceptible cultivars Ruta Øtofte and Sator Øtofte than on Doon Major. There was no evidence of phytotoxity in this test.

The field trial to examine the effect of powdery mildew on swedes (Ann. Rep. 1982, 60) was repeated in 1983 with ten cultivars. The ranking of cultivars for severity of infection was similar to the previous year, the least affected were Magres, Melfort and Angus and the most severe mildew occurred on Acme and Doon Major. The highest fresh weight yield from infected plots was obtained from Marian and the lowest from Sator Øtofte which had relatively low and high mean mildew scores respectively. Plots which had received two applications of triadimefon (Bayleton) produced higher yields for each cultivar than untreated, infected plots. Although the susceptible Sator showed the greatest yield increase of 37.7% following fungicide treatment, the yield of the more resistant Magres also increased by 28.7% suggesting that factors other than powdery mildew may have influenced yield.

The method of Asher *et al* for estimating spore numbers using near infra-red reflectance analysis (Ann. Rep. 1981, 147-148) was adapted for use with *Erysiphe cruciferarum*. Collecting spores from brassica leaves was difficult with the cyclone spore collector but satisfactory results were obtained when spores were washed from leaf surfaces with Tween 80 (0.2 ml/l). The ten cultivars used in the swede mildew trial were included in a seedling test in which mildew was assessed both as the percentage of infected leaf area and as the number of spores produced per unit leaf area. Both estimates gave similar results but there were some differences in ranking of the cultivars when compared with the field trial. Further

work is needed to determine if this represents a difference between seedling and adult plant resistance.

(C. J. Williamson)

PU 4(b) Study the components of pathogen virulence and of host resistance in fungal diseases of brassica forage crops

Resistance in *Brassica campestris* and *B. napus* is predominantly oligogenic but it is not clear how many resistance genes are involved even in genotypes used as differential hosts. However in *B. napus* the response of swede and rape cultivars to *Plasmodiophora brassicae* populations differing in pathogenicity appeared to support the hypothesis that there are five resistance genes. A diallel crossing programme of the four swede cultivars, Doon Major, Marian, Ruta Øtofte and Sator Øtofte, used in studies on the effect of environment on host-pathogen relationship, was completed and the progenies will be assessed in 1984.

(C. J. Williamson)

PU 4(c) Study the epidemiology, etiology and components of the chocolate spot disease complex of field beans

Lesions established on field bean leaflets after inoculation with conidia of *Botrytis fabae*, were held at different relative humidities at two temperatures and either kept in darkness or were exposed to normal laboratory lighting and intermittent irradiation with near-u.v. light. In darkness at 10°C sporulation occurred between 92 and 100 but not when kept at <90% r.h. At 20°C, light and u.v. irradiation had little effect on sporulation compared with continuous darkness, but when lesions were irradiated at 10°C, spores were produced between 83 and 100 but not when kept at <77% r.h. Conidia were not produced on agar in continuous darkness, but only after irradiation. At 100% r.h. under laboratory lighting and with u.v. irradiation, abundant spores developed on leaves at 10, 15, 20 and 25°C but only a few were produced at 5 and 30°C. Conidia were not produced on agar when the temperature was >24.5°C.

Bean plants in the field were inoculated with *B. cinerea* by spraying them with an aqueous suspension of conidia. One week later the mean numbers of chocolate spot lesions per leaflet on inoculated and uninoculated plants were 23.7 and 1.8 respectively. *B. cinerea* was isolated from 64% of lesions from inoculated plants and from 28% of lesions from control plants. The percentage of successful isolations of *B. cinerea* and *B. fabae* from various farm crops between 1975 and 1983 increased as the season progressed. Statistical analysis showed that while levels of *B. fabae* increased rapidly during mid-summer, levels of

B. cinerea increased at a slower but more steady rate over the whole growing season. Bean leaflets in a glasshouse were inoculated with conidia of *B. cinerea* and kept at 100% r.h. for 2 days before exposing them to ambient humidities. After a further 2 days all the original inoculation sites were black and these, together with a surrounding area 1-10 mm wide of green tissue, had become dry and brittle. *B. cinerea* could not be recovered from the green brittle tissue, but was readily isolated from the inoculation sites. These lesions were identical in appearance and location of the pathogen to those induced previously, in a similar way, by *B. fabae*. Both pathogens survived equally well in dormant lesions out of doors, being recovered from four out of five lesions 4 days after inoculation. Either species was often the only one isolated from spreading lesions when detached leaflets from the field bearing non-aggressive chocolate spot lesions were kept at high humidities. These results suggest that *B. cinerea* may be an important cause of chocolate spot of beans.

Plants in a farm crop of field bean cv. Maris Bead were sprayed to run-off with benomyl (as 0.2% w/v Benlate, du Pont 50% a.i.) in water at intervals of 3 weeks on each of four occasions during summer 1983. Unsprayed plots served as controls. There were few chocolate spot lesions up to and including 17 August, but when leaves were re-examined on 1 September many small lesions were present; there was no apparent difference between sprayed and unsprayed plots. Pieces of lamina bearing a lesion were placed on agar either containing or without benomyl. *B. cinerea* was recovered from 49 and 46% of the lesions from sprayed plants and from 37 and 52% of lesions from control plants on agar with and without benomyl respectively. *B. fabae* was recovered from 34% of lesions from unsprayed plants on agar without benomyl. It was not isolated at all from benomyl-treated plots or on agar containing benomyl. All *B. cinerea* isolates from benomyl-treated plots and 96% of those from untreated plots grew well on agar containing 10,000 ppm benomyl, while all isolates of *B. fabae* completely failed to grow on this medium, demonstrating that, whereas benomyl-tolerant strains of *B. cinerea* were extremely common, all *B. fabae* isolates were benomyl-susceptible.

In a similar field experiment to that carried out in 1981 and 1982, plants of two field bean cultivars sown during March were sprayed to run-off with 0.15% chlorothalonil every 2 weeks on four occasions during summer. Plants were harvested in September when most of the leaves had fallen off. Spraying with fungicide had no effect on the oven-dry yield of seeds of either cultivar, perhaps reflecting the low disease levels observed during 1983.

(J. G. Harrison)

PU 5(k) Improve, and use on brassica breeding material, screening methods for fungal and virus disease resistance

Screening for resistance to clubroot

Over 30,000 seedlings from the swede, forage rape, kale and turnip breeding programmes and new accessions from the swede gene bank were screened for resistance to clubroot. As resistance is incorporated into more of the plant material in the breeding programmes the demand for screening tests increases, and this has been met by increasing plant density in seedling tests from *c.* 450 plants/m^2 in 1979 to *c.* 1130 plants/m^2 in 1983. However, improved screening methods are required both to increase throughput and enhance precision. To achieve the latter depends on a better understanding of the genetic control of resistance and pathogenicity but may also be improved by manipulation of environmental factors such as temperature and soil pH.

The major source of resistance which has been used in the swede, rape and turnip breeding programmes has come from the Dutch stubble turnips. However, other sources are required and work is continuing on the development of resistant kale genotypes so that resistance from both *B. campestris* and *B. oleracea* can be incorporated into *B. napus,* and on the introgression of resistance genes from *Raphanus* into *Brassica* species in collaboration with the Tissue Culture and Cytology Unit.

(C. J. Williamson)

PU 9(c) Study the epidemiology and etiology of fungal and bacterial diseases of the growing potato plant

Blackleg etiology: field studies

The susceptibility to blackleg of 17 of the 18 cultivars tested in 1982 (Ann. Rep. 1982, 128) and of cv. Vanessa instead of cv. Pentland Raven was examined in the field by planting tubers inoculated by vacuum infiltration in suspensions containing 10^3 or 10^6 cells/ml of Eca. Although the summer was drier than in 1982, the disease incidence was greater because the soil was regularly irrigated. The high inoculum concentration caused an average blanking level of 4.4% and mean blackleg incidences of 7.6% in July, 13.8% in August and 27.7% in September and plants which yielded 17% less than those from seeds inoculated with the low concentration. Seed tubers inoculated with the low concentration produced <1% diseased plants in September.

The relative susceptibility of most of the 17 cultivars tested in 1982 which included 11 of the 12 cultivars tested in 1981 (Ann. Rep. 1981, 91), was confirmed. They could be divided into three susceptibility groups based on the percentage of diseased plants grown from seed inoculated with the higher number of bacteria in September. Cultivars Maris Piper, Croft, Pentland Squire, Cara, King Edward, Pentland Dell,

Vanessa and Pentland Crown were classed as resistant with 1.9 to 19.6% diseased plants, cultivars Record, Pentland Hawk, Desiree and Bintje were intermediate (25.6-35.9%) and cultivars Pentland Lustre, Guardian, Maris Bard, Estima, Pentland Javelin and Wilja were susceptible (42.6–59.5%). The ranking order of certain cultivars was however different when blanking incidence was included in the susceptibility assessments. Thus, Pentland Squire and Pentland Crown would be classed as intermediate with disease levels of 33.3 and 30.5% respectively and cv. Desiree and Bintje as susceptible with 45.2 and 47.6% respectively.

The effect of soil moisture level on blackleg development was examined by planting tubers of Bintje inoculated with Eca and applying overhead irrigation daily for *c.* 1 h at the rate of 0.5 cm/h to maintain the soil at near field capacity for 3, 7 and 15 days in July and August. Soil was near field capacity in June because of high rainfall, but there was no blanking and the blackleg incidence in the irrigated and in the non-irrigated (control) plants was <4%. Blackleg incidence in plots subjected to 3, 7 and 15 days of irrigation in July was <3% 1 week after treatment ceased, and 7, 28 and 45% respectively a month later with no significant further development. In contrast, the levels 1 week after irrigating for 3 and 7 days in August were 14 and 19%. One month later after 3, 7 and 15 days irrigation the levels were 41, 49 and 64% respectively.

(M. C. M. Pérombelon, R. Lowe)

Contamination of VTSC stocks by E. carotovora

The annual survey of VTSC stocks in the process of multiplication was continued at three commercial farms using the tuber rot test (Ann. Rep. 1978, 82). Contamination was not detected in the first 3 multiplication years and was low in the third year, ranging from 0 to 30%. Nearly all tubers were contaminated in subsequent years on two farms but only 10-15% on the third farm. Quantitative estimates using a commercial potato peeler and a viable count method showed that $>10^3$ erwinia cells/tuber occurred only on stocks in their fifth and later years of multiplication on the two more contaminated farms. Populations tended to increase after grading by a factor of 100, and >75% of isolates from the three farms were Eca.

(M. C. M. Pérombelon, L. J. Hyman)

A comparative study of blackleg epidemiology in Scotland and in Israel

Field experiments in Israel and in Scotland (SCRI) were planted with tubers from the same high grade seed stocks of several cultivars selected for low levels of erwinia contamination and inoculated with suspensions of Ecc, Eca and Echr soon after the harvest in 1982. The crops were planted in Israel in February at two sites with different climates, Gilat and Bet Shean Experimental Stations, and at Invergowrie in April where,

however, seed inoculated with Echr were not used because the organism is not endemic in Scotland. Planting time was unusually wet in both countries and the growing season in Israel was unusually cold and wet, whereas in Scotland it was warm and dry. Differences between disease development in the two countries were not as great in 1983 as in 1982 when climatic conditions were closer to average (Ann. Rep. 1982, 130-131).

Blanking occurred in Scotland as well as in Israel with an overall average of 6 and 12% respectively in plots planted with seed of cv. Desiree and cv. Pentland Crown inoculated with Ecc and Eca. Blackleg incidence was higher in Scotland (34.3%) than in Israel (11.6%) in plots of both cultivars planted with Eca inoculated seed. In both countries blanking was attributed equally to Ecc and Eca but only the latter pathogen caused blackleg. However, within Israel Pentland Crown was more affected than Desiree and the disease was most severe at Bet Shean which has a hotter drier climate than Gilat. Blanking (caused by Eca and Ecc) and blackleg (caused by Eca) in Pentland Crown were 14.4 and 0.3% respectively at Gilat and 22.3% and 20.3% at Bet Shean. In contrast, blanking and blackleg in Desiree at Gilat were both nil and at Bet Shean they were 14.1 and 22.1% respectively. Blackleg and blanking developed in plots planted with seed inoculated with Echr in Israel and levels in Pentland Crown were 19 and 13% respectively at Bet Shean and 22.3 and 4.4% at Gilat while in the more resistant Desiree blanking was <1% at both sites and blackleg levels were 12.3 and 0.8% at Gilat and Bet Shean respectively.

Blackleg in commercial crops grown in autumn 1982 in Israel from locally produced seed was caused mostly by Ecc (84% of isolates tested) and to a lesser extent by Echr (11%), but 98% of isolates obtained from diseased stems in crops grown in the spring from imported Scottish seed were Eca. Equivalent data for isolates obtained from crops grown from imported Dutch seed were Ecc, 64; Eca, 23% and Echr, 13%.

Although the rank order of six cultivars for resistance to blackleg was similar, the incidence in plots planted with inoculated seed was 20 times greater in Scotland than in Israel contrary to previous experience and probably due to non average weather conditions.

Blackleg incidence in plots of Desiree was 33% when seed inoculated with Eca was planted in soil infested with *Verticillium dahliae* and it did not occur in non-infested soil. These results justify more work to clarify the apparent synergistic effect of *V. dahliae*, a persistent soil-borne fungus pathogenic on a wide range of crops in warm areas, on Eca.

(V. M. Lumb, M. C. M. Pérombelon)

Sources and pathways of contamination of potato stocks in the field by E. carotovora

The contamination of progeny tubers by different antibiotic marker

strains of Ecc was followed by (1) inoculating seed tubers, (2) burying partially rotted tubers at tuber level in July and August and (3) spraying leaves in July, August and September. Leaves, rhizosphere soil and progeny tubers were sampled at weekly or fortnightly intervals from early July until the end of the growing season and the bacteria identified. Leaves inoculated in August were contaminated throughout the season but no contamination of leaves inoculated in July, or of unsprayed leaves, was detected at any time. Marker strains from leaves were occasionally found in the rhizosphere soil from sprayed plots, more frequently in September than in August, but never from unsprayed plots. In contrast to 1982 (Ann. Rep. 1982, 128-129), strains from seed or placement tubers were found in the soil and on leaves from inoculated plots from mid August and in plots without inoculated tubers in early September. Regular overhead irrigation maintained the soil moist and favoured decay of the inoculated tubers. Soil from all plots was heavily contaminated (10^2-10^3 cells/g soil) with tuber strains after haulm pulverization in late September. Whereas leaf strains were detected at similar levels only in plots which were inoculated 1 week before haulm pulverization and at trace levels only in plots inoculated in August. Although contamination was detected in most progeny tubers by the end of August, populations were too low to be quantified. However, numbers rose in mid-September in plots planted with inoculated seed and with rotted tubers placed in July and by mid-October tubers from all plots were heavily contaminated by both tuber and leaf marker strains. Bacteria isolated from leaves in August and September were mostly Ecc from the tubers; equal numbers of Ecc and Eca also from tubers were found in soil and, when leaf marker strains were present, they were mostly Ecc. In October, the soil was contaminated with both leaf marker strains (Ecc, 85% and Eca, 15%) and tuber marker strains (Ecc, 90% and Eca, 10%). Field plots of 12 micropropagated plants of cv. Desiree were sprayed twice weekly with 250 ml of streptomycin (Agrimycin-17; Pfizer Ltd: 0.2 g/l), cupric ammonium carbonate (Fungex; Murphy Ltd: 6.25 ml/l) or copper oxychloride (Cuprokylt; Universal Crop Protection Ltd; 5.0 g/l) respectively commencing on 14 June, 20 July and 26 August. In addition, Cuprokylt was applied at weekly or fortnightly intervals commencing 14 June. Leaves, rhizosphere soil and progeny tuber contamination was determined at weekly intervals during the growing season by enrichment techniques. Erwinias were not detected on leaves in June but they were found in September when the haulm of a potato crop in the same field was pulverized. Subsequently, contamination increased irrespective of the spraying treatments until the end of the month when leaves from 44 of the 48 plots were contaminated. Rhizosphere soil was contaminated in mid-September more in the untreated plots than in those treated with Agrimycin and Fungex. The bacteria were not detected in soil from plots treated with Cuprokylt once

and twice per week until the end of September when the soils from all other treatments were equally contaminated. The level of progeny tuber contamination in October was *c.* 10^3 cell/tuber irrespective of treatments except in plots sprayed twice weekly with Cuprokylt where it was too low to be quantified. Identification to sub species level showed that 90, 70 and 80% of isolates obtained from leaves, soil and progeny tubers respectively were Ecc.

(J. G. Elphinstone, M. C. M. Pérombelon)

Incidence of selected fungi on potato roots following continuous cropping

Plants raised in the glasshouse from axenic plantlets of cv. Maris Piper were planted in field plots in which Maris Piper had been grown from seed tubers for differing numbers of successive years. The harvesting sequence and method of culturing fungi from roots was similar to that described in 1982 and the same fungal species were enumerated (Ann. Rep. 1982, 108).

Polyscytalum pustulans (skin spot) was detected only infrequently, the incidence rising from <1% on the first sampling date in July to *c.* 6% in late September whereas in 1982 the figures ranged from 22 to 32% for plants grown from tubers. Notwithstanding the low incidence, the number of previous potato crops influenced incidence: following none, one, two, three and four previous crops the overall mean frequency of detection was 0.5, 1.6, 3.2, 3.3 and 4.5% respectively suggesting that this fungus may persist more readily than is often assumed and, allowing for seasonal differences, indicating the importance of the mother tuber as a source of inoculum.

Rhizoctania solani (black scurf and stem canker) occurred even less frequently than *P. pustulans*, never exceeding a frequency of >2% on roots at any one sampling date compared with incidences ranging from 0 to 13% in 1982 when the plants had been grown from tubers. The frequency on roots was again associated with the cultivation history being 0, 0.04, 0.26, 0.97 and 1.76% for none to four successive potato crops respectively.

The incidence of *Colletotrichum coccodes* (black dot), which ranged from 10 to 20% for successive harvest samples in 1982, was also low varying between 1.3 and 1.7% until the last sample when it rose to 2.0%. The effect of previous crops was again clear with incidences of 0.34, 0.53, 1.03, 3.01 and 3.44% for the increasing years of previous potato cultivation.

Cylindrocarpon destructans, which in 1982 reached incidences as high as 50% in some root samples and had an apparently suppressive effect on other fungi, was unaffected by the previous cropping history, but in the seven successive harvest samples the incidences rose being 1.6, 5.7,

6.3, 7.9, 10.3, 17.6 and 24.2% respectively, but there was no evidence of suppression of other fungi.

The frequency of *Verticillium* spp. rose from 12 to 20% between the first two harvests and then varied between 21 and 28% for the remaining samples. There were no effects due to past cropping history but there were large inter-plot differences which were similar from one harvest date to another and which had been detected in the same plots in previous years. In contrast to the results of 1982, when the majority of species were described as *V. 'tricorpus*-like', the most common species was the hot climate wilt pathogen *V. dahliae* which accounted for 95% of all verticillium isolates obtained. At the end of the growing season leaves and peticoles from plots in which the frequency of *V. dahliae* had been highest in the roots also showed most systemic infection.

In addition to the enumeration of selected fungi, two other observations were of interest; first, >50% of the planted root samples yielded no fungi for up to the eighth week after planting, and second, the root surface flora was affected by the peat compost for the Jiffy pots used in the glasshouse which provide a food base for lignicolous and cellulolytic fungi.

The effect of cropping history and Verticillium *incidence on senescence of different genotypes*

In 1982, the rate of haulm senescence increased in proportion to the frequency of previous potato cropping and there were also proportionate decreases of tuber yield. These effects were attributed to root pathogens in general, in the absence of any dominant major pathogen. More than 75% of the isolates of *Verticillium* spp. were identified as *V. 'tricorpus*-like' and a revised view of their pathogenic potential follows from the inoculation experiments described below. In 1983 a wide range of potato genotypes, selected for their known variations in susceptibility to *V. dahliae* following field trials in Israel, were planted in plots with a history of none or four previous potato crops. Glasshouse grown plants raised from micropropagated plantlets of cv. Maris Piper served as bait plants, and revealed high levels of *Verticillium* spp., >90% being *V. dahliae* regardless of the plot history.

When the verticillium test genotypes were scored on a scale 0 (no senescence) to 4 (complete senescence) in late September the mean scores were 2.5 for the tolerant, 2.2 and 2.0 for the susceptible, 0.6, 0.8, 0.9, 1.3, 1.3 and 1.3 for the resistant and 1.3 for an immune genotype, reactions broadly in line with those anticipated. At a second assessment 2 weeks later the ranking order remained the same although the individual figures were higher ranging from 3.3 for the tolerant genotype to 0.3 for one of six unclassified genotypes. The overall plot means of senescence scores were in reasonable agreement with the root baiting figures although variation was expected because of other pathogens present.

Again, there was some agreement between senescence scores and the frequency with which *V. dahliae* was isolated from petiole segments. General agreement was not to be expected because it is known that the phenotypic expression of disease following infection is variable because plant response may be affected by one, two or three reactions, to a toxin, to root tip death, or to water loss. Overall, the results suggest that it may be possible to screen for resistance to *V. dahliae* locally by site selection or manipulation and by shielding to withhold water as is often done when screening against common scab. This suggestion was further supported by consistent yield trends both between plots, reflecting plot levels of infection, and between genotypes that reflected their performance in field trials in Israel.

Pathogenicity tests of Verticillium *spp. isolated from potato*

The roots of three tomato cultivars, Kondine Red, Eurocross and Moneymaker were dipped in a mixed suspension of conidia prepared from cultures of true *V. tricorpus* and *V. 'tricorpus*-like' isolates obtained from potato roots (Ann. Rep. 1982, 108-109). They were planted in universal compost in 20 cm pots and grown in a heated glasshouse together with non-inoculated controls.

No true wilt symptoms developed but the lower leaves of the inoculated plant showed premature senescence at the green fruit stage and the vascular region was discoloured when stems were cut. When leaf petioles and roots were cultured >96% of the verticillium isolates from roots were *tricorpus*-like whereas those from petioles were initially white and similar in appearance to a type isolate of *V. albo-atrum* and, like it, they formed dark hyphae as the mycelium aged. The incidence of this white strain ranged from 100% for petioles of the lowest leaves to 5% of the topmost leaves in a sample collected 15 weeks after inoculation. The three tomato cultivars showed the same pattern of leaf infection and discolouration although signs of leaf senescence developed earlier in Kondine Red and in a sample of 200 roots from 10 replicate plants the respective frequency of *V. tricorpus*-like colonies was 28, 14 and 10% respectively for Kondine Red, Eurocross and Moneymaker.

Isolates of *V. dahliae, V. tricorpus* and common *V. tricorpus*-like strain, isolated from potato roots in 1982, were compared with a type culture of *V. albo-atrum* for pathogenicity towards micropropagated plantlets of cv. King Edward and cv. Pentland Croft. No symptoms developed 17 days after watering the plants with a dense conidial suspension and the inoculum was then supplemented with small pieces of agar culture applied to the stem bases. At intervals thereafter, over 4 weeks, whole plantlets were washed, divided into stem root and leaf pieces, surface sterilized, rinsed and plated on to tap water agar containing antibiotics.

There were no differences between the two host cultivars; *V. albo-atrum* was recovered from 22% of the leaf pieces as compared to 5% of leaves from plants inoculated with *V. dahliae* and none from leaves of plants inoculated with either *V. tricorpus* or *V. tricorpus*-like isolates. In contrast, the frequency of infection of stem pieces was 60, 50, 20 and 20% for plants inoculated with *V. albo-atrum, V. dahliae, V. tricorpus* and *V. tricorpus*-like, differences which were not reflected in root infection where the incidence was 18, 23, 23 and 26% respectively. These results suggest that the *V. tricorpus*-like isolates may be 'good' root pathogens but do not help to resolve the problem of identity.

Incidence of fungi on the surface of commercial cv. Pentland Crown at planting time

In 1982, >75% of the verticillium isolates detected in roots and on tubers of potato plants growing in field plots with varying numbers of previous potato crops had cultural characteristics similar to those of *V. tricorpus* but were not affected by cultivation history implying that tuber-borne inoculum was their major source. A random sample of 40 apparently clean seed tubers (FS grade) Pentland Crown were either washed and dried or left unwashed before removing five eye plugs per tuber. These were incubated for one week at 10°C in the light and the identity of *Verticillium* spp. determined from conidial transfers to agar plates. In unwashed plugs the incidence of *Verticillium* spp., *P. pustulans, R. solani* and *S. atrovirens* was 32, 7, 20 and 96% respectively compared to 27, 2, 21 and 89% for the unwashed plugs. All of 35 conidial transfers made from the plugs developed into cultures typical of the *V. 'tricorpus*-like' strain. The preponderance of this species on seed tubers, if it is a general occurrence, could explain the high incidence on roots and tubers in 1982 and the apparent lack of influence of cultivation history.

Post-planting lesion development in seed tubers

Seed tubers, cv. Pentland Crown, inoculated by rotating them in a cement mixer containing a mixture of comminuted mycelial mats of *Phoma exigua* var *foveata* and small sharp stones (*c.* 5-15 mm), were stored at 3-4°C; small gangrene lesions were visible on some tubers when planted 2 weeks later at the end of April. Six tubers were harvested from each of four plots 6, 8, 11 and 14 weeks after planting. Two mean lesion indices were calculated, one based on external lesion size and the other on lesion volume. The effective (viable) lesion indices were similar on the first two sampling dates but then decreased rapidly as a result partly of tuber shrinkage but largely because of loss of lesion integrity by soft rotting and, notably, invasion by a *Chaetomium* sp. together with feeding activity of soil fauna. No lesions were noted on the shoot bases at the time of the last sample.

(R. A. Fox, E. P. Dashwood)

PU 9(d) Study the epidemiology and etiology of fungal and bacterial diseases of stored potato tubers

Sources and pathways of contamination of stored potato stocks by E. carotovora

Contamination of seed tubers during grading was examined by adding one artificially rotted tuber inoculated with a streptomycin-resistant strain of Ecc to 200 tubers of cv. Pentland Crown which were passed over a 5 m length of a commercial reciprocating grader. The marker strain contaminated all tubers with an average of 10^5 cells/tuber. When the number of rotted tubers was increased to 10 the contamination increased to 3×10^6 cells/tuber. After one lot of 200 tubers containing one rotted tuber was passed over the grader, a second bulk of 250 kg was graded immediately afterwards and 45% of the tubers were contaminated. Detection of the marker strain ceased only after 2500 kg of tubers had been graded. Wounds inflicted during grading were assessed by staining with ρ-cresol and 50% were scuffed and 40% had deep wounds. A second grader of a different make caused only scuffing on 40% of tubers and no deep wounds. However, tuber contamination immediately after grading was similar from both graders but, whereas contamination from the first grader was high during 3 months storage at 4°C, that from the second grader fell gradually during storage and although still present it could not be quantified after 3 months

Tubers were disinfected immediately after grading by dipping them in 10% chloros solution (1% available Cl^-) or by applying a fine mist of an experimental bactericide (CGA78039, Ciba Geigy Ltd). The bacteria could not be enumerated following these treatments and were rarely detected by an enrichment test. Transmission of the bacteria to tubers during further grading was prevented by disinfecting the grader with chloros solution after it had been contaminated.

(J. G. Elphinstone, M. C. M. Pérombelon)

Susceptibility of tubers to infection by E. carotovora

The relative susceptibility to decay of tubers of different cultivars inoculated with Eca using the infectivity-titration procedure were similar to those found in 1981 and 1982 (Ann. Rep. 1981, 83; 1982, 112). Five cultivars were tested in addition to the 30 examined previously and Rhona and Spunta possessed resistance similar to Pentland Hawk and Home Guard, whilst Kirsty, Moira and Provost were comparable to the intermediate rating of Pentland Dell and Majestic.

Tubers of 18 cultivars were harvested in August and in October and stored at 5°C until inoculated in November. Tubers of cultivars previously classed as susceptible were more susceptible when they were harvested early rather than late and the situation was reversed with the resistant cultivars.

Tubers of six cultivars were harvested in October and stored at 4°C until November when they were kept at either 1 or 15°C for 26 days and then those which were at 1°C were transferred to 15°C and vice versa for a further 14 days. Although the cultivars always maintained their resistance ranking when determined before and after every change in temperature regime, resistance gradually increased with age. Tuber resistance expressed in terms of ED50 values (number of Eca cells) was ten times greater when tubers were transferred from high to low temperatures than the reverse, irrespective of the cultivars.

(R. Lowe, M. C. M. Pérombelon)

Effect of length of interval between haulm kill and harvest on gangrene incidence

Tubers, cv. Pentland Crown, grown in 1982 from commercial FS seed, were harvested with an elevated digger 1, 10 or 20 days after haulm destruction by flailing at the end of September, stored overwinter in a refrigerated store at 3-4°C and damaged in January on a reciprocating grader. The mean incidences of gangrene, assessed at the end of April, were low and at 6.2, 1.5 and 5.8% for the three successive harvests did not increase as usual with delay between haulm destruction and harvest. The results could be attributed to the weather; the highly significant low incidence at the second harvest was associated with exceptionally wet soil conditions so that large quantities of soil, adherent to the tubers and to the rods of the elevator web, cushioned the tubers and markedly diminished harvesting damage.

(R. A. Fox, E. P. Dashwood)

Incidence of selected fungi on potato tubers following continuous cropping

Tubers, cv. Maris Piper, were harvested in early October 1982 from plots with a history of none, 1 or 2 previous successive cultivations of the same cultivar. They were stored in a 5°C refrigerated store and washed samples were examined at intervals from early February to late March for symptoms of common scab (*Streptomyces scabies*), black scurf (*Rhizoctonia solani*), silver scurf (*Spondylocladium sativum*), skin spot (*Polyscytalum pustulans*), and black dot (*Colletotrichum coccodes*). Eye plugs from each tuber were then individually incubated in compartmentalised transparent plastic dishes for up to 14 d at 15°C under fluorescent light to induce fungal sporulation. The fungi named above were identified directly; *Verticillium* spp. were identified following culture on diagnostic media after using small agar blocks for conidial transfer.

The only macroscopic symptom to be affected by plot history was black scurf which at each successive assessment date was absent on tubers from plots with no previous cultivation but its incidence on tubers from the other plots did not differ significantly ranging from 70-80%.

Results from the eye plug tests also showed an association of *R. solani* with field history; the mean frequency of infected plugs was 1.2, 16.4 and 27.5 respectively for 0, 1 and 2 successive crops but fell to 22% following a third cultivation – an anomaly reflecting a similar pattern for root infection found in the parent plants. The incidence of *C. coccodes* similarly changed with incidences of 1.9, 2.2, 6.7 and 4.9% respectively for the successive cultivations. The relative frequency of various species of *Verticillium* was in the same order as that found in the roots and 75% of the conidial transfers formed *V. 'tricorpus*-like' colonies (Ann. Rep. 1982, 109) and *V. nubilum, V. nigrescens* and some identified white species occurred at only low frequencies.

(R. A. Fox, E. P. Dashwood)

PU 9(e) Study the components of pathogen virulence and host resistance in fungal and bacterial diseases of potato

Active defence mechanisms

Isolates of *Erwinia carotovora* sub sp. *atroseptica* (Eca), *E. carotovora* sub sp. *carotovora* (Ecc) and *E. chrysanthemi* (Echr) were compared for their ability to rot potato tubers and to elicit the accumulation of phytoalexins. Phytoalexins were measured using a high-pressure liquid chromatography method with a silica column and u.v. detection at 210 nm.

Tubers were more susceptible to rotting by all isolates of both *Erwinia* spp. at 22 and 30°C than at 15°C and mean rot weights were inversely correlated with mean rishitin concentrations. Within each treatment there was variation between tubers in their rishitin concentration, none being detected in rots from some tubers at 22 and 30°C, but this variation was not correlated with the extent of rotting; those rots containing most rishitin were not always smaller than those containing least rishitin. This suggests that factors other than rishitin concentration also affect resistance.

The concentrations of phytuberin and solavetivone were affected less by temperature than those of rishitin. Eca isolate 1 induced the accumulation of more phytuberin and solavetivone at 15°C than at 30°C, but isolate 28 showed the reverse trend. No rishitin, phytuberin or solavetivone was detected in rots caused by Echr isolate 408 at 22°C. Compounds with the same retention time as authentic 15-dihydrolubimin and 3-hydroxylubimin were detected in tissue rotted by Eca at 15°C, with a mean concentration of 1200 and 669 μg/g dry weight respectively. Compounds with the same retention times as lubimin and 10-epilubimin were detected only in trace amounts and the concentrations were not correlated with any particular temperature or treatment.

When Eca was grown at 25°C and then suspended in 0.1% peptone water containing rishitin (500 μg/ml) it was more sensitive to rishitin at higher temperatures when incubated between 10 and 30°C.

(G. D. Lyon)

The effects of natural plant products on recognition sites on pathogens

Effect of rishitin on Erwinia carotovora, *ultrastructure and cytochemistry*

Rishitin, at 500 μg/ml modified the cell wall of *Erwinia carotovora* sub sp. *atroseptica* (Eca) isolate V615/1 by removing an outer layer (possibly lipopolysaccharide) and causing holes through which the cell contents were extruded. The use of cationized ferritin revealed negative charges on the outer surface of these rishitin-treated cells but not on non-treated cells. Electron histochemistry using the Periodic acid-thiosemicarbazide-silver proteinate reaction has demonstrated within cell walls a single layer that in rishitin treated cells stained less intensely than that within walls of untreated cells. In rishitin treatments, carbohydrate-stained layers of adjacent cells were fused where cells had aggregated. Viable non-treated cells of Eca do not bind to a range of FITC-labelled lectins or to rhodamine-labelled avidin suggesting that the carbohydrates for which these lectins are specific, and proteins containing exposed trytophan, for which the avidin is specific, were absent at the cell surface. However, after incubation with rishitin, Eca cells did bind to FITC-labelled lectins from *Ricinus communis, Solanum tuberosum*, and *Triticum vulgaris* (specifically binding to β-D-galactose or N-acetyl-D-galactosamine, N-N-diacetylchitoboise, and N-acetyl-D-glucosamine respectively) and also bound to rhodamine-labelled avidin. Rishitin-treated cells did not bind to lectins from *Dolichos biflorus, Arachis hypogaea, Glycine max* or *Ulex europeus*.

These results suggest that the phytoalexin rishitin may modify existing recognition sites or receptors, or may expose previously blocked sites and could therefore indicate a reinforcement of a recognition process.

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

Pectic enzymes production by E. carotovora

Continued studies on the effect of temperature on pectic enzymes produced by Ecc and Eca showed that Polygalacturonate lyase (PL) was not produced by six Eca strains at 30°C in shaken pectate broth cultures aerobically but was detected when they were grown in anaerobic conditions. In contrast, 14 Ecc strains produced the enzyme under both incubation conditions although more occurred in the absence than in the presence of O_2. PL activity was greater in extracts of rotting tissue of cv. Pentland Crown tubers stab inoculated with 0.02 ml of suspensions containing 10^6 cells/ml of three strains each of Ecc and Eca and

[1]Zoology Department

incubated in 10% O_2 and 90% N_2 at 15°C than at 30°C. Polygalacturonase activity could not be detected at 30°C in tubers and only low levels were present at 15°C.

Two different pH optima, 8.75 and 10.0, were detected for the activity of PL produced *in vitro* and in tubers respectively suggesting that isoenzymes were produced and perhaps could have different roles in pathogenesis.

(R. Lowe, M. C. M. Pérombelon)

Cryogenic storage of Phytophthora infestans

Cultures of *P. infestans* were stored in a liquid nitrogen refrigerator. Of those grown on pea broth agar, only a few (usually <20%) survived and only when a glycerol-skimmed milk cryoprotectant was used. In contrast, recovery from inoculated leaf pieces of axenically grown micropropagated plants of cv. Craigs Royal was good.

Maintenance and use of R-gene differential series and the field resistance standards

All the R-gene differential hosts, with the exception of the clone containing R-6, used for identifying races of *P. infestans*, and the field resistance standards have been established as micropropagated plants in axenic culture. Plants are also grown in pots in the glasshouse to meet requests for tubers in addition to those for axenic plantlets. Colour slides showing characteristic details of the tubers, sprouts, foliage, and flowers of the differential hosts and resistant standards have been prepared as an aid to their rapid identification.

(J. M. Duncan)

The differential hosts for identifying races of *P. infestans* and the standards for field resistance are also maintained at Pentlandfield where they provide a supply of uncontaminated material for experimental studies. Similarly, a collection of experimental clones used for field resistant studies and occasionally as parents inbreeding for resistance to blight are being stored *in vitro*.

(J. F. Malcolmson)

The conventional method of identifying races of *P. infestans*, using leaflets detached from differential host plants raised in the glasshouse, is not always satisfactory. Plants raised during short days or in hot, sunny conditions may be unsatisfactory; moreover, blight does not develop on leaflets contaminated with mildew (*Erysiphe polyphaga*) which is common and often severe in glasshouses and leaves may be contaminated with *P. infestans* from external sources. When explants of the differential host series grown *in vitro* were compared with leaflets detached from glasshouse grown plants, positive infection was recorded in some plants but not in leaflets of the same clones.

(J. F. Malcolmson)

Six R-gene differential genotypes, established from micropropagated plants, were grown in growth cabinets for 2 months at a night temperature of 10°C and a 16 h day at a temperature of 17°C with two light regimes: high, 300 μmol/m^2/s and low, 100 μmol/m^2/s. Detached leaflets from these plants (GC), and from plants of the same genotypes grown in the glasshouse (GH) from tubers, were individually inoculated with separate zoospore suspensions of several *P. infestans* isolates. Leaflets from both sets of plants gave similar reactions except that the lesions on the GC leaves were very clearly defined, being black with sharp edges, contrasting with the brown and more diffuse edged lesions on GH leaves. Sporulation was also much heavier on GC than on GH leaves. Among the GC plants, there were no substantial differences between leaves from the high or low light regimes. The very uniform response of GC plants, one generation from axenic culture, indicates that they afford an excellent substitute for GH plants which, especially in winter, often give anomalous results.

(J. M. Duncan, J. F. Malcolmson)

Response of micropropagated potato plants to P. infestans

Micropropagated axenic plants, initially supplied by S. Mathews[1], became covered with downy fungal growth when inoculated with *P. infestans* but the tissues neither discolour nor rot and characteristic compatible R-gene responses are absent. These results, obtained in separate experiments at Mylnefield and Pentlandfield, may be compared with those previously reported for chocolate spot of field bean (Ann. Rep. 1982, 104-105) in which pectolytic bacteria (*Bacillus lentus*) may contribute to the rate of lesion expansion in the aggressive phase. The involvement of endogenous or phylloplane bacteria in the potato's normal reaction to *P. infestans* might explain the inconsistent reactions often observed with leaves or plants of different ages or from different sources and has important implications for the assessment of blight in test material as noted below.

(R. A. Fox, J. F. Malcolmson, J. M. Duncan)

Electron microscope studies of the potato plant and P. infestans

Studies of *P. infestans* continued on the Cambridge S180 Scanning Electron Microscope at the MRC Clinical and Population Cytogenitics Unit, Edinburgh. The studies have concentrated on observing events, *in vitro* and *in vivo*, between the release of sporangia from lesions and germination of zoospores produced by them. The effect of different techniques of sample preparation has been considered and, as a result, an adhesive, probably involved in the attachment of sporangia and zoospores, has been observed. Recognition of its absorption in the near

[1]Botany Division, NSCA

i.r. spectrum has been studied with a view to identification and estimation of the substance in mycological and pathological experiments.

The uncontaminated tissue available from *in vitro* cultured plants has proved invaluable in the SEM and i.r. studies. During the former, it was noted that tubers of such plants formed only one bud in the 'eye'. Stomata were present in the bud scales and where lenticals were formed on the tuber surface, they consisted of a localised, thin layer of collapsed cells which readily sloughed off. The skin did not become suberized, even in old tubers, and when aerial tubers formed, numerous hairs were present over the entire surface. Hairs were not observed on tubers which formed in the culture medium. Such botanical features must necessarily be taken into account when using *in vitro* cultured plant material for studies of disease.

(J. F. Malcolmson)

PU 9(f) Study the autecology, physiology and genetics of fungi and bacteria causing diseases of potato

Survival of E. carotovora *in soil and water*

Monthly surveys started in 1981 (Ann. Rep. 1981, 83-84; 1982, 113-114) to detect *E. carotovora* in rhizosphere soil of weeds and crops in fields at Invergowrie, on two commercial farms and in the Alyth Burn were completed.

The number of contaminated soil samples from fields where potatoes had not been grown recently was <5% during most of the year but increased to *c.* 50% for 1-2 wk any time during autumn or winter. At least 90% of the isolates were Ecc. Contamination of fields cropped with potato in 1982 fell from 100% after harvest to <5% by May 1983 and Eca predominantly initially although the proportion or Ecc gradually increased with time.

Plants of several crops and weeds grown in pots of equal parts of a field soil and peat in the open were inoculated with 100 ml/pot of suspensions of either Ecc or Eca containing 10^4 cells/ml. Survival of the bacteria in the rhizosphere soils was monitored weekly using an enrichment procedure. Eca was not detected on four common weed species 2 wk after inoculation and Ecc after 4 weeks at a time when the plants were dead. Eca survived <2 wk on barley, wheat, cabbage, rape and turnip but Ecc was present after 8 wk. In potato rhizospheres Eca survived <2 wk and although Ecc was present after 8 wk, only a few plants were contaminated after the first week.

Survival of erwinias in the rhizosphere of grass in a field inoculated in November with 3 l of suspensions/m^2 containing 10^4, 10^6 and 10^8 cells/ml was marginally better than in bare soil. The longevity in soil was

proportional to the inoculum concentration and Ecc survived <64 days and Eca only <40 days after 10^8 cells/m^2 were applied. Moreover, Ecc was detected on grass leaves for <40 days and Eca for only 18 days. These results explain why Ecc tends to predominate in the soil and suggest that rainfall does not usually contribute significantly to soil contamination. Indeed, erwinias were rarely found in rain water within 24 h of collection during the summer and autumn near and far from potato fields and when present, numbers were <10 cells/l although they are known to be present in significant numbers in the air during and immediately after rain.

Results obtained from samples of the Alyth Burn and its main tributary streams in Perthshire generally agreed with those obtained previously (Ann. Rep. 1981, 83-84; 1982, 113-114) although numbers of erwinias were *c.* a tenth of those in 1982. Only Ecc was detected except on one occasion in July when large numbers of Eca occurred at all sites downstream from the upper reaches of the river. The origin of Eca on this occasion was not determined but they may have come from potatoes dumped in or near the Burn. To verify this suggestion, five tubers inoculated with a marker strain of Ecc in an advanced stage of decay were placed in the Burn in November. A week later the numbers of marker strain detected was 10 times greater than the expected natural contamination level 5 km downstream from the origin. Thereafter the numbers declined but the strain was still detected 4 weeks later.

(M. C. M. Pérombelon, L. J. Hyman)

Genetics of E. carotovora*: development of techniques for gene manipulation*

Studies on the development of a molecular cloning system in Ecc strain SCRI 193 are in progress. The Holmes and Qingley, Birnhoim, Hansen and Olsen, and Klein techniques modified to remove extraneous endonucleases to yield restrictable plasmid DNA have been used successfully for the isolation of plasmid cloning vectors. In addition an efficient and reproducible transformation system has been developed for strain 193 yielding 4.1×10^4 transformants/μg of plasmid pBR322 DNA.

Attempts have been made to develop a system of transposon mutagenesis in strain 193 to facilitate the manipulation of genes including those believed to be involved in pathogenesis. Several suicide plasmids co-integrated with a transposon used successfully in other bacterial species were introduced in strain 193 by conjugation. Mutagenesis caused by transposon integration in the bacterial chromosome was not obtained because plasmids (transfer frequencies/recipient shown in parentheses) pSP60 (5×10^{-8}) pSP601 (7×10^{-5}) pNJ5000 (1×10^{-3}), pSUP2021 (1×10^{-5}) and other pBR325::*mob* derivatives were stable in the bacterium. However, preliminary results suggest that pJB4JI may prove to be useful because of some instability in strain 193.

Certain bacteriophages can be used to mediate generalised transduction in bacteria which is a useful tool for fine mapping of bacterial chromosome. Unfortunately, *E. carotovora* phages are rare and none of those available infected strain 193. New phages were isolated from river water at a frequency of *c.* 20 phages/l following treatment with a virus concentrator and they were virulent to 26% of 42 Ecc strains tested but not to strain 193. Phages were not obtained from soil and sewage and screening erwinia strains for temperate phages using the mitomycin-C induction technique was also unsuccessful.

Amber-suppressing mutations can be used in the study of essential genes and in gene product identification. Using a derivative of plasmid RP4 which has amber mutations in two of its antibiotic resistance genes, a suppressing strain of 193 was isolated. Its phenotypic identity was tentatively confirmed by the use of *incP* plasmid-specific phages which themselves carried amber mutations.

(J. Hinton[1], G. Salmond[1] and M. C. M. Pérombelon)

Studies on P. infestans

As in recent years, race 1, 3, 4 was predominant among isolates of *Phytophthora infestans* from field crops in the east of Scotland in 1983. One sample yielded race 4, 10, 11 and another race 1, 2, 3, 4, 5, 7, 10, 11.

(J. F. Malcolmson)

A selective medium, developed to isolate *P. infestans* from infected plants, consists of filtered pea broth containing, per litre; 15 g agar, 0.01 g benomyl, 0.01 g pimaricin and 0.03 g rifampicin, Na salt. All attempts to isolate the fungus from blighted foliage samples from Ayrshire were successful. The fungus was also recovered from *c.* 30% of extensively rotted leaflets that had been used for race determinations, but the success rate increased to *c.* 50% after the leaflets had been stored for a week at −20°C.

(J. M. Duncan)

Oospore production by P. infestans

Oospores were induced to form in several single isolates of the heterothallic *P. infestans* using a membrane pairing technique and the A2 mating type isolates of *Phytophthora palmivora* and *P. nicotianae* var *nicotianae*. Some isolates behaved as though they belonged to a homothallic species and formed oospores when the technique was used without applying an A2 isolate on the reverse of the membrane.

(J. M. Duncan)

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PU 10(a) Study the epidemiology and etiology of fungal diseases of cane fruit

Effect of fungicide sprays on infection of raspberry flowers and fruit by Botrytis cinerea

The effectiveness of dichlofluanid in protecting raspberry fruit, cv. Malling Jewel, against infection by *B. cinerea* increased with increases in the number of sprays applied up to the maximum tested of six. When assessed by isolation techniques, sprays applied at flowering were better than those applied during the green fruit stage. However, post-harvest decay was affected by the total inoculum on the ripe berry which included superficial contamination as well as cryptic infection in, for example, spent anthers and their filaments so that late pre-harvest sprays were important in lessening post-harvest decay (Ann. Rep. 1981, 81; 1982, 123).

In 1983 no more than three sprays were applied and the combinations were: a single early spray applied at flowering, a single late spray applied one week before ripening, a combination of these early and late sprays, two successive sprays applied 2 weeks and 1 week before ripening, all three sprays, and unsprayed controls. The method of tagging flowers, sampling fruit and culturing on agar was similar to those described previously (Ann. Rep. 1981, 89); in addition, whole ripe fruit were incubated individually.

When ripe fruits were collected on 21 July, dissected, surface sterilized and cultured, the lowest incidence of *B. cinerea* was in the sample from the three spray treatment with 32% of the berries infected; there was 52 and 62% infection following the single early and single late spray respectively and 100% infection in the unsprayed control fruit. In the whole fruit decay test, the proportion of berries which developed grey mould ranged from 65% for the three spray treatment to 100% in the unsprayed controls, the single and double spray treatment showed intermediate but variable effects. There were marked differences in the severity of infection assessed by estimating the area of fruit covered with conidia. Based on an arbitrary index of 1.0 for the control sample, the index for the early and late single spray treatments were 0.77 and 0.66 respectively, the early/late and intermediate/late sprays had indices of 0.58 and 0.77 respectively and the three spray treatment an index of 0.44. The differences were less marked than for equivalent sprays in 1982 (Ann. Rep. 1982, 123-124) but they again demonstrate the importance of early spraying. The supplementary late spray significantly improved control and the best protection was provided by the three spray programme.

When a fruit sample was collected 2 weeks later, as a check on fungicide persistence, the levels of airborne inocula were high. In culture tests, the lowest incidence of *B. cinerea* was 72% following the three

spray treatment, and 97 and 95% for the early and late single sprays, 92 and 75% for the early/late and the intermediate/late combinations, and 100% for the controls respectively. The corresponding incidences in the whole fruit test was 50% following three sprays, 95 and 85% after the early and late sprays, 70 and 45% after the early/late and intermediate/late combinations and 95% in the unsprayed controls. The equivalent indices for grey mould in the same order were 0.47, 1.0, 0.88, 0.68, 0.45, and 1.0 respectively. In contrast to the first sample, the early spray had had little effect because at the time of application the buds would have been tightly closed.

Effect of dichlofluanid on the level of cryptic infection by Botrytis cinerea *in green fruit*

Cryptic infection of flowers and green fruit was assessed before each fungicide application (see above), to assess the effectiveness of each spray application. At flowering, when the first spray was applied, 13% of flowers were found to be infected following surface sterilization and culture, but when assessed 4 days later the level was only 3% and although it rose to 40% after 2 weeks the level in the unsprayed fruit was 66%. The second spray maintained the level at *c.* 40% compared to 84% in the controls and the third spray reduced it to 32% compared to 100% in unsprayed fruit by which time the combination sprays of early/late and intermediate/late gave levels of 60 and 77% respectively. These results emphasise the importance of continuous control of infection.

Effect of dichlofluanid on saprophytic fungi in flowers and green fruit

The number of flowers or green fruit with superficial and deep-seated colonisation by common saprophytes was determined concurrently with the assessments of *B. cinerea* infections. In the first pre-spray sample, partly open flowers were collected aseptically in separate compartments of transparent plastic trays, covered with a thin layer of molten malt extract agar and incubated for 6-7 days. The same number of flowers were surface-sterilized, halved and cultured in Petri dishes to detect deep-seated fungi which survived surface sterilization. In later harvests, at the green fruit stage, all the berries were collected in the compartmentalised trays, each fruit was then halved and one set of halves covered with molten agar while the other set were surface-sterilized and cultured on plates. The aim was to relate superficial and deepseated colonisation by various fungi, to examine the effect on their popultions of dichlofluanid and to assess if these populations affected colonisation and infection by *B. cinerea.*

Colonisation in the first sample of partly open flowers was low: the most common species was *Cladosporium herbarum* detected in 28 and 13% of the flowers in trays and culture plates respectively, the equivalent incidence of *B. cinerea* was 37 and 13%. *Epicoccum nigrum* and *Fusarium* spp. together affected 75% of the flowers in trays but were

eliminated by surface-sterilization prior to culture. Other fungi which occurred on unsterilized flowers were *Trichocladium roseum* (8%), *Phoma macrostoma* (5%) and *Alternaria* spp. (3%).

Four days after spraying the incidence of *C. herbarum* in cultured flowers was 33 and 61% in those sprayed and non-sprayed respectively whereas the corresponding incidences for the surface population in compartments was 78 and 71%. In the same sample the incidences of *B. cinerea* in unsterile flowers was 7 and 40% for sprayed and unsprayed samples respectively showing its sensitivity to the fungicide and the incidence was only 3 and 8% in the surface-sterilized cultured flowers, sprayed and non-sprayed respectively. *E. nigrum* and *Fusarium* spp. again failed to survive surface-sterilization confirming their role as surface contaminants but surface levels of *Alternaria* spp. rose to 5% in the controls and 23% in the sprayed flowers in inverse frequency to the incidence of *B. cinerea*.

After a further 2 weeks, during which no sprays were applied, *C. herbarum* was found in nearly all samples whether tested by the culture or the tray method. The proportion of unsprayed fruit with superficial or deep colonisation by *Alternaria* spp. was 30 and 2%, for *Ulocladium consortiale* 14 and 0%, *E. nigrum* 23 and 12%, *Fusarium* spp. 2 and 0% and *B. cinerea* 49 and 66% respectively. The corresponding incidences in sprayed fruit were 43 and 8% for *Alternaria* spp., 25 and 5% for *U. consortiale*, 10 and 9% for *E. nigrum*, 2 and 0% for *Fusarium* spp. and 40 and 35% respectively for *B. cinerea*. The effect of surface-sterilization was to eliminate *Fusarium* spp., reduce the numbers of *Alternaria* spp., and *U. consortiale* by >85% and reduce the incidence of *E. nigrum* by half. The incidence of *B. cinerea* was apparently increased by sterilization of fruit from the unsprayed sample suggesting that it is susceptible to competition by the other fungi on the fruit surface.

One week after the second dichlofluanid spray another sample of nearly mature but still green fruit was collected. The effects of the sprays were generally to enhance the effects described above particularly for the results following surface disinfection. The incidence of superficial and deep-seated colonisation by *Alternaria* spp. following two sprays compared with one late spray, one early spray or no sprays was 55 and 22%, 47 and 15%, 52 and 10%, and 21 and 9% respectively. Corresponding figures for *U. consortiale* were 22 and 10%, 20 and 0%, 21 and 9%, and 7 and 3% respectively. The incidence of *E. nigrum* was variable and those for superficial levels of *B. cinerea* were very variable. However tissue colonisation by the latter fungus showed a relationship with spray treatment and the ranges of incidence, listed in the same order as above, were 22 and 42%, 60 and 50%, 49 and 75%, and 16 and

83% respectively. The last pair of results, in which mycelium of *B. cinerea* developed from 83% of sterilized fruit halves in culture but from only 16% of unsterile halves in the trays shows the effects that antagonists may have in suppressing its development on maturing fruit.

Effect of dichloflanid on the incidence of saprophytes in ripe fruit

The incidence of saprophytes in culture plates containing surface-sterilized fruit parts being tested for *B. cinerea* infection were observed for harvest samples collected 1 and 3 weeks after the last fungicide application. *C. herbarum* was again ubiquitous and not enumerated. The incidence of *E. nigrum* in the early sample was high compared to that on the green fruit, ranging from 67% in unsprayed fruit to 15% in fruit which had received three sprays, a trend similar to that of *B. cinerea* in these samples. The incidence of *Alternaria* spp. was also high ranging between 35 and 40% of berries from the sprayed plots but in the non-sprayed fruit the incidence was only 7% which was associated with nearly 100% infection by *B. cinerea*. The incidence of *U. consortiale* and of yeasts was low and variable and not related to any treatment.

When whole fruit were incubated in moist chambers only a few of the post-harvest rots were induced by fungi other than *B. cinerea* and these were recorded in the early ripe fruit sample only; 7% were caused by *Alternaria* spp., 4% by *Trichoderma viride*, 1% by *E. nigrum*, and <1% by *Fusarium* spp., *Rhizopus* spp., or *Penicillium* spp. None were induced by *C. herbarum* despite its ubiquity in culture. The effects of removing the superficial flora by surface-sterilization before incubating the fruit showed that whereas these saprophytes rarely caused post-harvest decay they depressed grey mould development, the index for the latter being markedly lower in berries that had not been disinfected. For the range of increasing spray frequencies the indices for unsterile fruit were 0.68, 0.61, 0.42, 0.35, and 0.30 compared to 0.98, 0.75, 0.83, 0.57, 0.75 and 0.43 respectively for disinfected fruit.

In the later harvested sample the frequency of saprophytes was not recorded but their suppressive effect on the incidence of *B. cinerea* was again evident although smaller. The difference could be explained by supposing that with time infection by *B. cinerea* becomes too well established for the surface flora to have a great a suppressive effect.

Site of B. cinerea *infection in ripe fruit*

Fruit samples, collected on 21 July and 4 August from flowers that had been tagged on 20 June and 4 July, were separated into druplet shells, plugs and husks all parts being surface-sterilized and cultured on plates. The husks are defined as the sepals together, with the stamens and filaments attached to the basal ring around the plug. In both samples all berries on unsprayed plots yielded *B. cinerea* from some part; 67, 87 and 3% of the shells, husks and plugs respectively in the first sample and

100, 60 and 0% respectively for the second sample, confirming previous observations that the plugs tend to remain free of infection (Ann. Rep. 1982, 125). Infection of fruit from plots that had been sprayed three times was 32 and 72% for the early and late samples respectively with incidences of 17% for both shells and husks in the early and 72 and 50% for shells and husks respectively in the late sample. The plugs from all the fruit were sterile. These results confirm previous findings of the importance of the collar of tissue to which the stamen filaments are attached as a potential source of post-harvest infection (Ann. Rep. 1982, 125). Observations of grey mould development in individually stored fruit showed that the druplets adjacent to the collar were often those on which conidia of *B. cinerea* first developed.

(R. A. Fox, E. P. Dashwood)

Effect of inoculation of raspberry flowers with Botrytis cinerea *on grey mould*

The infection of flowers and fruits of three cultivars by *Botrytis cinerea* was studied in an attempt to explain observed differences in their resistance to grey mould. Flowers of the cultivars Malling Jewel, Leo and Glen Prosen at five stages of maturity from 'closed bud' to 'green fruit' were inoculated in the glasshouse with conidia of *B. cinerea*. There were no observed effects on the flowers and no pre-harvest moulding. Mature berries from inoculated and non-inoculated flowers were compared by incubating fruits individually at high humidity; berries from inoculated flowers moulded more rapidly than those from non-inoculated flowers. The stage of maturity at which flowers were inoculated had no effect on the incidence of grey mould, but mould developed later following inoculation of closed flower buds. Berries of Glen Prosen developed mould later than Leo and Malling Jewel, a result which confirmed other tests using berries picked in the field.

The germination of conidia dusted on to the styles of emasculated pollinated and non-pollinated flowers of a *Rubus idaeus* hybrid in the laboratory and the subsequent intercellular growth of hyphae through the transmitting tissues of the styles was followed by u.v. microscopy after softening tissues in 1N sodium hydroxide and staining in 0.1% aniline blue. In both pollinated and non-pollinated flowers, conidia germinated within 24 h and hyphae grew proximally through the styles to the carpels within 7 d of inoculation. In contrast the pollen tubes reached the ovules by the same route within 24 h. The restricted growth of the mycelium within the mesocarp may represent a type of latent infection.

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

[1]Soft Fruit Breeding Department

Midge blight

The relationship between *Leptosphaeria coniothyrium* and cane midge *Resseliella theobaldi* was examined when the pest incidentally affected a replicated cane blight field trial. In spring all the overwintered canes of the cultivars Malling Jewel, Willamette and Glen Isla in a new plantation were cut at soil level and the young canes which grew were wound inoculated with *L. coniothyrium* (isolate 902) 30 cm above soil level at six fortnightly intervals from 14 July to 22 September. Other canes distributed randomly amongst the inoculated canes and wounded by scalpel served as controls. The incidence of stripe lesions at inoculated wounds (cane blight) and of stripe and patch lesions at the base of the same canes (midge blight) was recorded after scraping canes in March 1983.

Less than 1% of the non-inoculated wounded canes developed stripe lesions at the scalpel wounds and no stripes developed at their bases, but patch lesions were present on many of them. This result showed that natural inoculum of *L. coniothyrium* was very low in this plantation although the fungi associated with patch lesions (*Fusarium avenaceum* and numerous *Phoma* spp.) were available, probably from the soil. Most inoculated canes of the three cultivars developed serious stripe lesions spreading from the point of inoculation. The incidence of patch lesions at the base of inoculated canes, where midge larvae had damaged periderm in natural splits, differed between cultivars, but stripe lesions also spread at the base of patch-affected canes. The date of wounding and inoculation affected the incidence of stripes, late inoculations producing fewer stripes, but wound inoculation had no effect on the incidence of patch lesions. The incidence of stripes at the base of patch-affected canes was strongly influenced by inoculation date, there being 66, 71, 38, 9, 7 and 3% of patch-affected canes with stripes at their bases following inoculation on 14 and 28 July, 11 and 25 August and 15 and 22 September respectively. The concurrence of stripe and patch lesions at the base of inoculated canes, in the absence of fruiting canes and cane stubs (potential wounding agents and sources of inoculum) provides circumstantial evidence that *L. coniothyrium* can infect periderm attacked by midge larvae in Scotland.

(B. Williamson)

R. theobaldi attacked the autumn fruiting cultivars September and Fallcrop in a plantation in Oxfordshire in 1983. Samples of affected canes were collected in early September, scraped to remove stem periderm and isolations were made from vascular tissues. *Phoma eupyrena, P. macrostoma* var. *macrostoma* and several other fungi were isolated from lesions associated with first generation cankers, but *Fusarium lateritium* and *P. exigua* var. *exigua* sporulated on the cane surface. Lobate patch lesions caused by second generation midge yielded

mainly *spp., Fusarium avenaceum* and *F. equiseti* whilst a stripe lesion spreading from a patch lesion gave both *Leptosphaeria coniothyrium* and *F. avenaceum*.

Midge attack of autumn fruiting cultivars has not been noted previously in the UK, but yield loss would not be expected because the berries are picked before extensive vascular lesions develop. The range of fungi isolated from patch and stripe lesions is similar to that found on canes of cv. Glen Clova in Scotland (SHRI Ann. Rep. 1976, 64).

(B. Williamson, J. Allen[1])

Spur blight

The variation in virulence of *Didymella applanata* (Ann. Rep. 1982, 119) was further studied in a replicated field trial by using 32 isolates from localities throughout the British Isles to inoculate scalpel wounds on young canes of SCRI selection M30 in late August 1982. The lengths of lesions were measured in mid-September 1982 and sporulation (production of pseudothecia) assessed in mid-March 1983. All isolates produced lesions and there were significant differences between them, but the variation in lesion length and sporulation was small and their virulence on M30 was not related to their origin.

In the glasshouse, 13 isolates of *D. applanata* were inoculated on young canes of the cultivars Malling Jewel, Glen Prosen, Glen Clova, Leo, Meeker, Willamette and Chilcotin, one isolate per cane on the petiole of the 15th, 17th, 19th and 21st node from soil level. Four nodes at the same postions on another cane were used as non-inoculated controls. The lengths of axillary buds at treated nodes were measured on 16 November 1982 and the emergence of lateral shoots was assessed on 19 April 1983. Differences in bud length between cultivars and between isolates were significant as was the cultivar × isolate interaction. The axillary buds at inoculated nodes were shorter than at non-inoculated nodes; the cultivars Chilcotin and Glen Prosen showed the greatest contrast (39.7 and 36.7% reduction respectively) and Meeker, Leo and Willamette the least (18.0, 21.4 and 21.5% respectively). Emergence of lateral shoots at inoculated nodes was strongly suppressed (15th, 17th, 19th and 21st), when compared with the adjacent non-inoculated ones above them (16th, 18th, 20th and 22nd node); the emergence for inoculated nodes ranged from 17% in Meeker to only 8% for Leo.

Fourteen isolates were inoculated to the 15th node on young canes of the same cultivars (cv. Haida also included), in mid-July 1982, in a replicated field trial. The length of axillary buds, measured on 24 November, differed between cultivars and between isolates at inoculated nodes and in all eight cultivars they were shorter at inoculated

[1] ADAS Reading

than at non-inoculated nodes. In mid-May there were more emerged laterals at inoculated nodes in the field than in the glasshouse. In Willamette and Glen Clova, 85 and 80% respectively of laterals emerged, whereas in Malling Jewel and Glen Prosen only 45% emerged; the emergence of Glen Clova and Malling Jewel agreed with previous studies on natural infection which indicated that Glen Clova is relatively tolerant of *D. applanata* (Ann. Rep. 1978, 85-86). Although isolates differ in aggressiveness, joint regression analysis showed that the isolate × cultivar interactions were small and did not affect the rank order suggesting that when screening selections for resistance the choice of isolate is relatively unimportant.

(B. Williamson, H. S. Pepin[1])

Raspberry yellow rust

To test for interactions between host genotypes and rust isolates, the youngest fully expanded leaf of 3-month-old plants of the cultivars Glen Clova, Malling Delight, Malling Jewel, Glen Prosen, Meeker and Chief were inoculated with 2 mg of urediniospores ot two isolates of *Phragmidium rubi-idaei* and the plants then incubated in a growth cabinet with a 16 h photoperiod (*c.* 250 μ mol/m^2/s) at 20°C and 65-70% r.h. for 3 wk.

Sporulating uredinia developed on all cultivars except Chief, on which only chlorotic flecks occurred on the adaxial leaf surface after 15 d. The latent period was shortest (9 d) on Malling Delight which also had the most uredinia/cm^2 (108.5) and the highest yield of urediniospores/d (104.2 μg/cm^2). The cultivars showing incomplete resistance, especially Meeker, had many characteristics typical of 'slow rusting' genotypes, namely, a long latent period, few uredinia and low urediniospore yield. The ranking of cultivars for susceptibility was similar for both isolates, but significant cultivar × isolate interactions occurred because the Bangor (Welsh) isolate had a longer latent period, fewer uredinia 13 d after inoculation and gave a lower urediniospore yield on Meeker than the Grampian (Scottish) isolate. This suggests that there may be regional variations in pathogenicity as has been reported from North America.

(V. M. Anthony[2], B. Williamson)

The inheritance of resistance to *P. rubi-idaei* was investigated in a 5 × 5 diallel cross between the cultivars Boyne, Glen Clova, Glen Prosen, Malling Jewel and Meeker planted in August 1982 with clonal plants of the parents in a randomised block design within a rust-infected Glen Clova plantation so that each test plant was adjacent to an infector plant. In October, the plants were transferred to an unheated glasshouse at

[1]Agriculture Canada, British Columbia
[2]University College of North Wales

SCRI, where the disease developed in 2 wk. After being assessed for telia, the plants were cut to 10 cm, the dormancy of the roots was broken using a cold treatment and then new growth was induced by growing them at 18°C with a 16 h photoperiod. The first fully expanded leaf on one stem of each plant was then inoculated with a isolate of urediniospores from the Grampian Region, previously bulked on cv. Malling Delight. The latent period and the number of uredinia/cm^2 13 and 18 d after inoculation were used to assess resistance.

The American cv. Boyne produced no uredinia in the field or the glasshouse and is defined as completely resistant. Discontinuous segregation for complete resistance and susceptibility in all the progenies related to Boyne and the identical reactions of Boyne and its ancestor cv. Chief provide strong evidence that it is heterozygous for a single dominant gene for resistance.

The other four parental clones produced uredinia and their descending order for resistance was Meeker, Glen Prosen, Malling Jewel, Glen Clova. Reciprocal crosses, available for only three of the ten possible crossbred families, showed no evidence of maternal effects on the expression of incomplete resistance. This form of resistance showed continuous variation and data from the field and glasshouse showed that additive and non-additive gene action were of equal importance and that there were no effects of inbreeding depression. A Wr/Vr analysis showed that Meeker, the parent with the strongest expression of incomplete resistance, contributed the most dominant alleles for resistance to its progenies.

Five families of the diallel segregated for gene *H*, which determines cane hairiness, and two of them segregated for gene *S*, which determines cane spineyness. The non-hairy segregates (phenotype *h*), showed more resistance than the hairy segregates (phenotype *H*) but there was no significant difference between the resistance of spiney and spine-free plants.

(V. M. Anthony[1], B. Williamson, D. L. Jennings[2])

PU 10(b) Study the components of pathogen virulence and host resistance in fungal diseases of cane fruit

Phytophthora fragariae *and Tayberry*

Young canes of the hybrid berry Tayberry were drenched individually with zoospore suspensions of two *P. fragariae* isolates, one isolated from Loganberry and the other representative of a group of isolates with the widest range of pathogenicity to strawberry. No disease developed under conditions conducive to infection and microscopic examination showed no evidence of the fungus within the roots.

(D. M. Kennedy)

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[1] University College of North Wales
[2] Soft Fruit Breeding Department

Verticillium *wilt of raspberry*

Dipping the root ball, including the adherent compost, into a conidial suspension of *Verticillium dahliae* (6×10^4 conidia/ml) for 4 h then repotting in J.I. compost No. 2, proved to be the most satisfactory method of screening *Rubus* genotypes in the glasshouse. Symptoms appeared in 3 to 4 weeks and assessment, based on the percentage length of cane with wilted leaves, was done after 5 to 6 weeks when the most susceptible canes were fully wilted. The black raspberry cultivars, Munger and Cumberland together with the red and black raspberry cross, 60C11, wilted significantly more than the red raspberry cultivars Lloyd George, Glen Clova and Malling Jewel.

(D. M. Kennedy)

PU 10(c) Devise methods to control fungal diseases of cane fruit

Cane blight

The spring-loaded rubber belts of the SIAE Mark I fruit catching device pre-disposed young canes to cane blight (*Leptosphaeria coniothyrium*) less than the catching device of the Littau harvester (Ann. Rep. 1981, 85-86). The belts made no obvious wounds or bruises but with high natural inoculum levels, or using a severe inoculation method many young canes developed vascular lesions spreading beneath belt marks. A modified device (Mark III), exerting less force, was evaluated in a replicated field trial by inoculating young canes of cv. Malling Jewel with mycelium of a highly pathogenic isolate of *L. coniothyrium* (No. 902; IMI 190198) on the belt marks immediately after a single harvest on 21 July 1982. On 8 February 1983, they were scored for the incidence and severity of vascular lesions. These had developed in only 6.6% of the inoculated canes, a value similar to that obtained by inoculating unwounded controls (2.5%). There was no natural infection at non-inoculated belt marks, whether covered or uncovered by rubber bandage and only 2.5% of non-inoculated scalpel wounds became infected.

Because the Mark III device does not pre-dispose young canes to cane blight when gathering them to the centre line of the row for berry collection it offers the prospect of allowing raspberries spaced at the conventional Scottish 2 m to be harvested annually by machine in areas where conditions favour cane blight.

(B. Williamson)

PU 10(e) Study the biology of *Phytophthora* and *Verticillium* infecting strawberries

Chemical control of red core disease of strawberry

The control achieved in pot tests with a mixture of metalaxyl and copper at concentrations of 0.05 and 0.12% a.i. respectively was similar to that obtained with a standard band spray of 0.05% a.i. metalaxyl alone.

(D. M. Kennedy)

Resistance to red core disease of strawberry

Micropropagated plantlets, of the nine genotypes used to distinguish physiological races, were established in axenic culture and then plants were grown from them in a peat-sand compost. After 4-5 weeks, when they had reached a suitable size, they gave similar results in virulence tests as glasshouse grown plants when inoculated with reference isolates of the fungus.

Micropropagated plants of cv. Cambridge Favourite survived storage for 1 year on agar, containing a range of sucrose concentration, and it should be feasible to provide all the year round large numbers of uniform plants needed for virulence testing.

(D. M. Kennedy)

Isolates of *P. fragariae* obtained in 1981 from field plots of the cultivars Saladin and Cambridge Favourite (Ann. Rep. 1982, 127) were examined for differences in pathogenicity using a score of 0 (no root infection) to 5 (76-100% root length infected). Fifty single zoospore isolates (SZI) were prepared from mass isolates obtained from each of the two cultivars. Saladin SZI, when inoculated to Saladin, could be assigned to three scoring groups: 31 (score 4 or 5), 4 (2 or 3) and 15 (0 or 1). Whereas Cambridge Favourite SZI gave: 6 (4 or 5), 6 (2 or 3) and 38 (0 or 1). Thus Cambridge Favourite, which is attacked by all races of the fungus and is reported as less field resistant than Saladin, yielded isolates that were less pathogenic to Saladin than those from that cultivar. Isolates from both cultivars which scored 2 or 3 on Saladin had similar scores when inoculated to the race differential series as did standard isolates of race B66-11, which attacks all cultivars. Isolates that scored 4 or 5 on Saladin also had higher scores on most of the differential hosts but scored significantly less (0-2) than the standard isolates (4-5) on cv. Talisman indicating a cultivar/isolate interaction. All the isolates that scored 0 or 1 on Saladin, regardless of origin, belonged to race B66-3.

Single zoospore isolates from different mass isolates from different roots of the same plant were of several races demonstrating mixed populations on one plant. Single zoospore isolates were also obtained which gave different race reactions to their parent mass isolate indicating mixed populations within single mass isolates and hence within single roots of plants, variations which might be due to mixed race populations within a root or due to heterokaryosis within hyphae.

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

Resistance to Verticillium *wilt of strawberry*

The strawberry cultivars Cambridge Vigour (susceptible) and Redgauntlet and Talisman (both tolerant) were used as standards in glasshouse tests of five breeder's selections for susceptibility to wilt caused by *V. dahliae* and *V. albo-atrum*. None were as tolerant as Redgauntlet although 69GU94 and 71WC64 show some tolerance.

(D. M. Kennedy)

Epidemiology of Phytophthora fragariae

P. fragariae was detected by root tip testing, in November 1982 in elite grade runner beds of cv. Cambridge Favourite and cv. Cambridge Vigour growing on the same site that previously had been permanent pasture. Several field inspections in the next 3 months revealed a small patch of diseased plants in a single row. Runner samples were lifted at 3 m intervals from all rows in February 1983, scored for symptoms, and then planted individually in pots each with a bait plant of *Fragaria vesca* clone VS1. When examined after 5 weeks there was good agreement between the original score and bait plant infection although a few plants developed disease that had shown no symptoms when initially checked. The overall pattern of infection suggested that it was of recent origin and that it was still spreading rapidly along rows from a few foci. The major area of infestation was close to the entry to the field suggesting an origin from contaminated implements or tractor wheels. However, a nearby drainage ditch, bordering two sides of the field, originated 300 m distant in another field alongside another strawberry plantation which proved to be affected by red core. Bait plants in pots were placed at 20 m intervals along the drainage ditch for 3 weeks and when transferred to the glasshouse some developed symptoms suggesting that spread to the elite stock by drainage water might also have occurred. These observations emphasise the need for care in the selection of sites for runner beds.

(J. M. Duncan)

Oospore germination in Phytophthora fragariae

Different buffers, covering a wide range of pH values, were incorporated into agar adjusted to give the same osmolalities. Tests on them showed effects of both pH and buffer on oospore activation and germ tube formation; the effects of acetate buffers were notably deleterious.

Infected roots containing many viable oospores were immersed in solutions or suspensions of four fungicides: captafol, dichlofluanid, aluminium ethyl phosphonate, and metalaxyl, all at 1000 μg a.i./ml, in distilled water and in KH_2PO_4/NaOH buffer (pH 6.5). The numbers of empty oogonia, and dead and viable oospores were recorded after 6 and 20 days. Only in unbuffered aluminium ethyl phosphonate, pH <3, were the numbers of dead oospores higher than in the controls and germination levels were significantly lower only from roots treated with unbuffered and buffered metalaxyl. Apparently viable oospores were used to inoculate bait plants of *Fragaria vesca* clone VS1 and these pre-treatments resulted in the lowest numbers of infected bait plants there being none with oospores from buffered metalaxyl. The effect of aluminium ethyl phosphonate was probably due to a pH effect which, however, did not apply to metalaxyl which whilst not apparently affecting viability does affect the germinability and infectivity of oospores.

(J. M. Duncan)

PU 14(a) Study the epidemiology and etiology of root disorders of carrots

Cavity spot of carrots

Three crops of Chantenay carrot grown for canning were selected in east Scotland and metalaxyl was sprayed at 250 mg/m^2 a.i. in 200 ml water on to four plots 2 m long × 1 m wide within each crop with a knapsack sprayer on 14 June and on 11 August. Carrots were harvested in October from the sprayed areas and from equivalent adjacent untreated areas. Cavity spot incidence was reduced significantly from 18.7 to 2.2% and from 36.9 to 0.9% on two farms, while on the third the incidence on the untreated plot was too low to obtain significant results. An increase in yield from 2.1 to 2.6 kg/m row (SED 0.18) was obtained at one farm due to an increase in root number but not size. A single application of metalaxyl at the same rate on 14 June in another trial reduced cavity spot from 8.0 to 0.4%, indicating that a single spray may be sufficient to control the disease, while 5 l/m^2 solutions of 0.5 mM NH_4Cl and KNO_3 and 0.1 mM o-,m-,p-hydroxybenzoic acids had no effects.

Soil from East Seaton, Arbroath, the site of a trial in 1982, was passed through a 10 mm sieve and put into sixteen 150 mm diam pots in a glasshouse. Two hundred ml of a solution of 1 g/l metalaxyl was added to half of the pots and allowed to drain. Carrot seeds were sown on 26 January and thinned to 15/pot after emergence. A second similar drench was applied on 7 May and four fungicide-treated and four untreated pots were stood in water 50 mm deep in plastic trays while the remainder received normal watering. Cavity spot severity was recorded on a 0-5 basis and expressed as a percentage of the maximum possible when carrots were harvested on 4 July. High soil water increased the disease index from 18 to 34% and metalaxyl reduced it from 26 to 3%.

Control of cavity spot by metalaxyl suggested that oomycete fungi were involved in the development of symptoms and a collection of pythiaceous fungi were obtained when lesions were plated on a selective medium (French bean agar with rifamycin, pimaricin and benomyl). However, none of the isolates caused progressive lesions when inoculated to carrot roots through injuries in the periderm, although some caused the secondary phloem to collapse when disks of agar culture were placed on uninjured periderm. Histochemical studies showed that phenolic compounds accumulated in the root tissue adjacent to a developing lesion.

Investigation of an affected crop in 1982 in Suffolk showed that the highest incidence of cavity spot was associated with areas where the soil was <pH 5.5 and least where it was >pH 7.0. Soil in areas of low pH also had a low buffering capacity compared with other parts of the field. Similar trends were observed in 1983 when carrots were grown again on the same field.

(D. A. Perry, M. R. Groom)

PU 14(b) Study the anaerobic microflora of rhizospheres and soils associated with carrots and other crops

Characterisation and autecology of pectolytic clostridia

The major volatile components of anaerobic fermentation of a collection of 50 isolates of pectolytic clostridia cultured in a basal medium containing 10 g/l glucose were analysed by gas chromatography. All isolates produced detectable amounts of n-butanol and all but two produced butyric acid. Quantities of both compounds varied and there was no positive or negative relationship between them. Acetic acid and ethanol were detected in 90 and 40% of the cultures respectively.

Crude pectic enzyme preparations were examined by pectin acrylamide gel electrophoresis. Bacteria were cultured in P1 pectate plates until the solid pectate layer was liquefied and a cell-free supernatant prepared by centrifuging at 10,000 g for 20 min. The supernatant was stored at −25°C while the residue was suspended in 0.1 N NaOH and protein determined by the Lowry method. Lots of 20 μl of each enzyme preparation were run in acrylamide gels containing 1 g/l pectin, incubated in buffers at pH 4.0 or pH 7.5 for 4 h and stained in 0.2 g/l ruthenium red. Standard enzyme preparations of polygalacturonase (PG), pectin methylesterase (PME) and pectin lyase (PL) were included. Bands of darker stain than the background and clear zones occurred with the majority of preparations tested and comparison with patterns of the standards and the incubation pH showed that PL was present in all preparations, PME occurred in most but PG was not detected in any. Variation in band patterns indicated that several isoenzymes of PL were present. Subsequent standard assays of PG by viscometry, PL by spectrophotometry and PME by a colorimetric plate test confirmed the conclusions. PL activity determined spectrophotometrically varied between 0.23-3.32 units/mg protein but did not correlate with apparent activity in pectin acrylamide gels.

Trends in the population of pectolytic clostridia within a crop of potatoes, cv. Maris Piper, planted on 15 April were followed by plating rhizosphere, tubersphere and soil suspensions on P1 pectate agar. Seven samples were taken at 3 week intervals between 1 June and 23 September and populations in surrounding soil varied between $4.9\text{-}25.0 \times 10^3$ cfu/g dry soil with minimum values in August. In the rhizosphere they were $6.1\text{-}60.3 \times 10^3$/g and the R:S ratio was always >1.0 with a maximum of 9.1 on 24 August. Populations $>6 \times 10^5$/g were found on the surface of mother tubers as they rotted in the soil and numbers on daughter tubers after initiation were similar to those found on roots.

(D. A. Perry)

ZOOLOGY

D. L. TRUDGILL

During the year the Zoology Department's new glasshouse block was commissioned. The control of the heating and ventilation by a microcomputer is an innovation which should provide a cost-effective and accurate management of the glasshouse environment. The new facilities provide greatly improved conditions for culturing and studying the nematode, and insect and mite pests on which to work.

The transfer to the new glasshouses caused minimal disruption. More serious problems were caused by the summer drought which stressed unirrigated crops and spoilt a number of our trials; nevertheless, some important advances were made in the field studies. Evidence was obtained that, even though roguing is an important means of reducing the spread of potato leaf roll virus (PLRV), it may be responsible for substantial amounts of PLRV spread in years when the plants are already infested with aphids. Preliminary results were obtained which showed that damage by potato cyst nematodes could be partly off-set by a higher plane of plant nutrition and that if tolerant potato cultivars are grown the amount of nematicide necessary for satisfactory control can be reduced. Improvements in pesticide application in both potato and raspberry were also demonstrated. Brassica cyst nematode was shown to be widespread in arable land in Scotland and a substantial proportion of raspberry planting stocks was found to be infested with *Pratylenchus penetrans*. Field studies have also quantified the degree of aggregation of different nematode species and this has been used in devising sampling strategies.

In the laboratory, further evidence was obtained that carbohydrates are involved in virus retention within vector nematodes, and in the inheritance of their ability to transmit viruses: two types of salivation behaviour were identified in the virus vector *Xiphinema diversicaudatum*: and accumulated temperature above a threshold was shown to be a major factor controlling the emergence of adults of the raspberry cane midge and the population dynamics of *Longidorus elongatus*.

NEMATOLOGY

PU 9(k) Study the management of cyst nematodes in seed potato production and control of damage in ware crops

Ware crops – effects of tolerance and rates of nematicide

The relative tolerance of potato cultivars to damage by potato cyst nematodes (PCN) affects the amount by which nematicides increase

yields at infested sites. The effects of three rates of the nematicide aldicarb (Temik 10G; 1.2, 2.4 and 4.8 kg a.i./ha) on the yields of ten potato cultivars/clones which differed in their tolerance was therefore tested at three sites in collaborative trials with the ADAS.

The results showed that, compared with no treatment, all rates of aldicarb significantly ($P<0.05$) increased mean tuber yields at all sites. The 1.2 kg rate increased yields by between 61 and 74% of the increase given by the 4.8 kg rate, and the 2.4 rate increased yields by between 69 and 91% of the 4.8 kg rate. However, there were marked differences between cultivars/clones; at two sites infested with *G. rostochiensis* the 4.8 kg rate increased the yields of Maris Piper and clone 11305 by an average of 6 and 9% respectively compared with average increases of 49 and 55% for Pentland Dell and clone 11234. At the third site, heavily infested with *G. pallida*, the 4.8 kg rate increased the yield of the most tolerant cultivar by 46%, and the yield of Pentland Dell and 11234 by 93 and 87% respectively.

Control of PCN increase

In the experiment described above the 2.4 kg rate of aldicarb did not prevent PCN populations from increasing on non-resistant cultivars at the two sites infested with *G. rostochiensis*, but the rate of increase was reduced from *c.* $\times 7.4$ for the untreated plots to between $\times 3.6$ and $\times 5.2$. At the site heavily infested with *G. pallida* the increase in the untreated plots was only $\times 1.1$ but in plots treated with 2.4 kg aldicarb there was an $\times 0.25$ rate of increase (a 75% decrease).

Several of the cultivars/clones tested in this experiment possessed either partial or complete resistance to one or both species of PCN. In almost every instance where resistant cultivars have been grown the density of PCN in the soil after harvest has not increased compared with that before planting, and populations were markedly decreased with the most resistant cultivar/clone. Applying aldicarb to the most resistant cultivars/clones did not further decrease post-harvest populations of PCN.

Effects of fertilisers on PCN damage in ware crops

Earlier studies (SHRI Ann. Rep. 1977, 112-113) showed that damage by PCN decreased N, P, K uptake and content in the leaf dry matter. The effect of the interaction between two rates (1 and 2 t/ha) of compound fertiliser (S.A.I. No. 1S; 14:14:22) and the nematicide aldicarb (4.8 kg a.i./ha) on the yields of four potato cultivars was therefore tested at a site moderately infested with *G. rostochiensis* (54 eggs/g soil). In plots not treated with aldicarb, doubling the amount of fertiliser significantly ($P<0.05$) increased the mean tuber yield from 31 to 42 t/ha and had almost the same effect as applying aldicarb which increased the mean yield from 30 to 42 t/ha. In the plots receiving fertiliser at 1 t/ha,

aldicarb increased the mean yield from 23.7 to 37.8 t/ha and from 36.4 to 46.1 t/ha in plots receiving 2 t/ha fertiliser.

When the yields were compared for Pentland Dell and Maris Piper, the least and most tolerant cultivars respectively, they clearly responded differently to the two treatments. At the lower rate of fertilisers application, aldicarb increased the yield of Pentland Dell (14 to 34 t/ha), much more than Maris Piper (29 to 35 t/ha). In plots treated with the higher rate of fertiliser aldicarb again produced large, significant ($P<0.05$) increases in the yield of Pentland Dell (27 to 40 t/ha) but had almost no effect on the yield of Maris Piper (48 to 49 t/ha). The cost effectiveness of treating the soil with aldicarb was therefore quite different for the two cultivars and was decreased, particularly for Maris Piper, by increasing the rate of application of fertiliser.

(D. L. Trudgill)

PU 1(g) Investigate the control of nematodes by nematotoxic chemicals

Control of nematodes by systemic nematicides applied as side-band dressings

A trial in 1982 (Ann. Rep. 1982, 140) tested the effect of delaying the application of aldicarb until tuber initiation on the control of tobacco rattle virus spraing in potato. Aldicarb applied as side-band dressings at tuber initiation controlled spraing but not as effectively as microband in-furrow treatments applied at planting time.

In a similar field trial in 1983 little spraing occurred and it was not possible to evaluate the efficacy of the treatments. However, tuber yields from both trials indicated that later applications of aldicarb using the side-dressing machine did not adversely affect tuber yields.

A replicated pot study was made to determine the effect of granular placement on the efficacy of spraing control, and whether oxamyl and aldicarb are translocated across the parent tuber. This was done by allowing two separate stems, each with their own root system, to develop from one tuber. One root system was treated with aldicarb, the other was untreated. Juveniles of *Meloidogyne incognita* (root-knot nematode) were added to both root systems and the numbers of galls which had developed after 8 wk were counted. Both aldicarb (80 mg a.i./5 kg soil) and oxamyl (130 mg a.i./5 kg soil) greatly decreased the number of galls formed on the treated root systems. However, little evidence of translocation through the parent tuber was found, the numbers of galls on the untreated roots usually being unaffected.

(T. J. W. Alphey)

Efficacy of nematotoxic chemicals

Control of plant parasitic nematodes by the fungicide quintozene was compared in a pot experiment with that of two systemic nematicides

(aldicarb and oxamyl). The chemicals were added in water (8 ml) at 10 ppm a.i. together with 40 *L. elongatus* to small pots 4 cm (25 ml) containing a ryegrass (*Lolium perenne*) or (*Petunia hybrida* seedling. Surviving nematodes were extracted and counted after 2, 4 and 8 wk and the numbers of root galls produced by nematode feeding recorded. Under ryegrass quintozene decreased *L. elongatus* numbers significantly more than oxamyl. Under *P. hybrida* all treatments greatly decreased numbers of nematodes and root galls.

The effect of oxamyl (1.43 mg a.i./pot), aldicarb (0.88 mg a.i./pot) and quintozene (23.3 mg a.i./pot) applied to field soils infested with either *Pratylenchus penetrans* or *L. elongatus* was tested in 10 cm (520 ml) pots. The pots were sown with ryegrass and after 12 wk in a glasshouse, the numbers of surviving nematodes were determined. Compared with the untreated control, all treatments decreased numbers of *P. penetrans* and *L. elongatus* but oxamyl and aldicarb were more effective than quintozene. These results differ from previous findings (Ann. Rep. 1982, 140) which showed that in pots sampled after longer time periods (22 and 66 wk) quintozene had failed to control *Pratylenchus* spp. but had controlled *L. elongatus* more effectively than aldicarb or oxamyl.

(T. J. W. Alphey)

PU 6(f) Improve, and use, screening methods for resistance and tolerance to pests and diseases of potatoes

The acquisition and transmission of tobacco rattle virus (TRV) by trichodorid nematodes

In small-pot studies, trichodorid nematodes reproduced on virus infected *Nicotiana tabacum* but subsequently failed to transmit TRV to similar virus-free plants. When the roots of the virus host plants were tested by immunosorbent electron microscopy (ISEM), TRV particles were readily detected; however, no TRV was detected in suspensions of groups of 10 comminuted nematodes following 4 wk access to those roots. It therefore seems possible that the failure of these nematodes to transmit TRV was the result of their not having ingested and acquired the virus during their feeding on the manually infested plants.

(T. J. W. Alphey, D. J. F. Brown)

PU 10(h) Study the role of nematodes in, and the control of, planting disorders in soft fruit

Distribution of Pratylenchus penetrans

P. penetrans is a damaging pest of raspberry in Scotland and several surveys of its distribution were made. In the first investigation, several samples were taken from 3-year-old plantations of raspberry in Angus,

Fife and Perthshire. *P. penetrans* was detected on 16 of 24 farms and in 23 of 43 plantations sampled. *P. crenatus,* which is thought to be less damaging, was also widespread occurring in 25 of 43 plantations, often together with *P. penetrans.* Of a total of 150 samples taken, 36 contained only *P. penetrans*, 37 only *P. crenatus* and 11 a mixture of both. Of the 36 samples infested only with *P. penetrans*, most contained more than 25 per 200 g of soil and 13 contained more than 100.

In a second investigation *P. penetrans* was found in four out of 20 different soil samples collected for experimental purposes from areas adjacent to the entrance gates of raspberry plantations in Angus and Perthshire.

The distribution of *P. penetrans* in raspberry plantations in the NSCA advisory area was also investigated. Of 60 samples derived from 20 plantations, 13 were found to contain only *P. penetrans*, 36 only *P. crenatus* and 7 a mixture of the two species.

P. penetrans is a migratory endoparasitic species which can be spread in infested planting material. A survey was therefore made to estimate the proportion of infested planting stocks in commerce, samples being supplied by the DAFS and the ESCA. Of 39 stocks examined by root sampling, eight contained only *P. penetrans*, 11 only *P. crenatus* and six a mixture of these two species.

The distribution of species of *Pratylenchus* in 17 arable fields in the Strathmore area of Perthshire was also examined, fields being chosen in which, as far as could be ascertained, raspberries had never been grown. *P. crenatus* was found to be widespread, occurring in every field sampled. *P. neglectus* was found in 15 fields but *P. penetrans* was comparatively rare being found in only three fields.

(D. L. Trudgill)

PU 4(d) Investigate the pathogenicity and control of nematode pests of forage crops

Plant parasitic nematodes associated with turnip and swede in Scotland

The species of nematodes associated with turnips and swedes in Scotland were investigated to identify potential problems. One hundred farms were chosen in proportion to the area of swede and turnip grown by farm type and geographical area from the DAFS 1981 returns.

The brassica cyst nematode (*Heterodera cruciferae*) was found in *c.* 20% of sampled fields. Hoplolaimid species were found in 73% and *Longidorus* and *Tylenchorhynchus* species were found in 45 and 53% of the samples respectively.

(B. Boag)

The identification of plant parasitic nematodes from the British Isles

The identification of nematodes is a necessary prerequisite to studying and eventually controlling nematodes. The computer program used to help identify nematodes, and first developed for the genus *Longidorus*, has been extended to include members of the genus *Pratylenchus* and 154 species of *Helicotylenchus*. The practical use of the system was again demonstrated when a new *Helicotylenchus* species from Scotland was revealed in samples from turf grass (*Deschamsia caespitosa*). This nematode is characterised by a relatively long spear and an oesophagus which superficially appears to abut onto the intestine with virtually no overlap.

(B. Boag, M. Shamin Jairajpuri[1])

PU 1(c) Study the structure and functioning of plant parasitic nematodes

Carbohydrate histochemistry

The site of virus retention within the odontophore of *Xiphinema diversicaudatum* was examined for the presence of carbohydrates using the periodic acid-thiosemicarbazide-silver proteinate (PA-TSC-SP) reaction.

Thin sections through the odontophore of nematodes carrying particles of arabis mosaic virus (AMV) and stained with PA-TSC-SP has revealed electron-translucent 'clouds' of stained carbohydrate material not found in similar sections through virus-free nematodes. As PA-TSC-SP does not stain the virus particles, alternate sections were stained with uranyl acetate and lead citrate and these showed that clouds of carbohydrates occurred in conjunction with particles of AMV. The source of this carbohydrate is unknown but it is thought to be either secreted by the dorsal oesophageal gland cell or derived from the host plant and it may be a factor influencing the specificity of virus retention.

(W. M. Robertson)

Structure of the feeding apparatus of Xiphinema

An electron microscope study was made to clarify the understanding of the structure and functioning of the musculature associated with the spear in *Xiphinema* spp. This study showed that the protractor and retractor muscle slips are connected to syncytial cytoplasm in the body wall just behind the nerve ring – seven nuclei are associated with the protractors and one with the retractors. These muscles may be developed from arcade tissue. The anterior muscles of the body wall have one muscle per quadrant that contains an inner band of myofilaments arranged so that they can compress the cheilostome. The cheilostome is probably retracted and opened by the *'Dilatores buccae'* which are slips of yet another somatic muscle and have longitudinally arranged myofilaments.

(K. A. Wright[2], R. F. Carter[2], W. M. Robertson)

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[1]Commonwealth Institute of Parasitology, St Albans

[2]Zoology Department, University of Toronto, Canada

PU 1(d) Investigate the ecology of ectoparasitic and migratory endoparasitic nematodes

Effect of temperature on the hatching, life cycle and rate of multiplication of Longidorus elongatus

Using a new, simple technique which enables large numbers of eggs to be studied, the development of *L. elongatus* eggs, to hatching, was shown to be temperature dependent and slow at low temperatures. At 10°C eggs did not develop beyond the 8-16 cell stage: a 15°C and 25°C development to hatching took 26 days and 11 days respectively: at 30°C only 30% of the eggs developed to hatching, taking 9 days. A diurnal rhythm of 10 and 20°C gave hatching times similar to those produced at a constant 15°C.

The effect of temperature on the life cycle of *L. elongatus* was also investigated using single female nematodes feeding on strawberry in pots. Development from adult to adult took 21 weeks at 15°C and 10 weeks at 25°C. After 4 months at 15, 20 or 25°C the mean numbers of *L. elongatus* per pot were 8, 39 and 136 respectively. After 7 months there were 64, 931 and 1,108 nematodes respectively per pot. At 10°C no juveniles were recovered after 4 or 7 months.

These results demonstrate the strong influence of temperature on the hatching and subsequent development of *L. elongatus* and provide an explanation for its relatively slow rate of population increase under Scottish conditions.

(B. Boag)

The detection of low density field populations of virus vector nematodes

Small populations of virus vector nematodes are difficult to detect and yet certification schemes, the production of disease-free nuclear stocks and the statutory requirements for the export of plant material, commonly require soil or plants to be free from these nematodes. As an aid to the detection of low density populations of virus vector nematodes information from a large data bank was used to quantify the frequency of joint occurrences between vector and non-vector nematode species. Analysis of the results using the Chi-squared test for contingency showed that the occurrence of many species was significantly and positively correlated and that information on non-vector species could be used to predict the likely presence of vector species. For example, the occurrence of trichodorid species – the vectors of tobacco rattle virus – was closely correlated with that of *Hemicriconemoides* and *Hemicycliophora* species, whilst longidorid species were often found together with *Macroposthonia rustica* and *Criconemoides informis*.

(B. Boag, P. B. Topham[1])

[1] Data Processing Department

The distribution of migratory plant parasitic nematodes in the field

Plant parasitic nematodes are not distributed regularly or randomly in the soil but commonly are aggregated and their variable distribution needs to be taken into account when devising sampling strategies. The negative binomial distribution has been used to describe and measure aggregation of nematodes but an alternative measurement is provided by Taylor's power law. Using this law the index of aggregation ('b') was calculated for several nematode species at different sites and depths. Differences were found, mononchids, *Pratylenchus crenatus* and *Longidorus goodeyi* were nearly randomly distributed whereas *L. elongatus* and *Paratylenchus microdorus* were strongly aggregated with 'b' values of approximately 2. *Rotylenchus robustus* and *Tylenchorhynchus dubius* were moderately aggregated with 'b' values of approximately 1.5. Using the same pattern of sampling the 'b' value for each species was found to be unaffected by host or by sampling depth.

Once the 'b' value for a given species is known it can be used to devise sampling strategies and to produce a transformation of the results which is more accurate than the log $(\times + 1)$ transformation usually used to normalise nematode counts for statistical analyses.

(B. Boag, P. B. Topham[1])

Longidorus vineacola *from the island of Tiree*

L. vineacola is rare within the British Isles, being recorded only once each from Ireland, England and Scotland. Fourteen samples taken during July 1983 from the island of Tiree were examined and four were found to contain *L. vineacola*. The nematode was not confined to one soil type but was found from sand dune and cultivated loamy soil. The only other Scottish record is also from a Hebridean island. In neither of these islands was any other longidorid species found. The confinement of this species in Scotland to the Hebridean islands indicates that it is either a remnant species which has been superseded on the mainland by other nematodes or that it has been introduced from continental Europe where it is more widespread.

(B. Boag)

European Plant Parasitic Nematode Survey

Using data supplied by collaborating European nematologists an atlas was produced of the distribution of plant parasitic nematodes in Belgium; computer files were established for the production of Maltese and Bulgarian atlases; and files were established for an ecological study of Norwegian nematodes. Further work was undertaken to produce sub-routines to restructure data files into a format acceptable to the data base management program RAPPORT.

(T. J. W. Alphey, P. B. Topham[1])

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[1]Data Processing Department

Reproduction and crossbreeding of female X. diversicaudatum *from different populations*

The reproduction on strawberry of *X. diversicaudatum* from several populations was compared using single females in small pots at 18°C. Over a 12 wk period females from populations from Bulgaria, Italy, New Zealand, Norway, Scotland, Switzerland and the USA had similar rates of increase, producing a mean number of 36 juveniles. In contrast, females of *X. diversicaudatum* from Belgium, England and France had significantly ($P<0.05$) lower rates of multiplication, producing a mean of 10 juveniles. A Spanish population produced a mean of only 2.5 juveniles and these developed more slowly than those of all the other populations. The rate of multiplication of this population was not increased when it was given access to several other host plants.

The same methods were used to show that females from each of these populations would mate with the males from the Scottish population and hence that they all belong to the same biological species. However, with the Spanish population only one of 20 females became gravid and it produced only four juveniles during the first 12 wk compared with a mean of 36 juveniles per female for all the other crosses. From these results it seems likely that nematodes from the Spanish population require a higher temperature for efficient reproduction than those from the other populations.

(D. J. F. Brown)

PU 1(e) Study nematode feeding behaviour and mechanisms of virus transmission

Transmission of viruses by cross-bred lines of Xiphinema diversicaudatum

A population of *X. diversicaudatum* from Italy was shown to be a much less efficient vector of the British type strains of arabis mosaic virus (AMV-T) and strawberry latent ringspot virus (SLRV-T) than a population from Scotland (Ann. Rep. 1982, 142-143). The inheritance of the ability to transmit these viruses was examined by making crosses between and within these two populations and determining the rates of virus transmission by the F_1 and the F_2 progeny.

Seventy-five percent of progeny with exclusively Scottish percentage transmitted AMV-T and SLRV-T whereas less than 5% of nematodes with exclusively Italian percentage transmitted these viruses. When the progeny from crosses between Italian females and Scottish males were tested only 16 and 22% transmitted AMV-T and SLRV-T respectively. When Scottish females were crossed with Italian males 36 and 55% of the F_1 and F_2 progeny respectively transmitted AMV-T but none of the F_1 progeny and only 15% of the F_2 progeny transmitted SLRV-T.

These experiments demonstrate that differences in the ability of populations of *X. diversicaudatum* to transmit virus have a genetic basis. However, the effectiveness of the hybrid nematodes as vectors was also affected by the choice of maternal line indicating that extra-nuclear, cytoplasmic elements may also be involved.

(D. J. F. Brown)

Feeding and salivation behaviour in Xiphinema diversicaudatum

Previous work has shown that feeding by *X. diversicaudatum* induces the formation of root-tip galls containing enlarged, multi-nucleate cells. These changes are almost certainly induced by secretions (saliva) from the large gland cell in the oesophageal bulb. Detailed observations on feeding nematode indicate that *X. diversicaudatum* has two quite distinct types of salivation behaviour. On ryegrass (*Lolium perenne*) seedlings growing in agar *X. diversicaudatum* used its long stylet to feed progressively deeper within the plant root. Usually each cell was fed upon before the next deeper cell was penetrated. Feeding in each cell usually consisted of several short periods of ingestion pumping, each separated by a short pause during which saliva was rapidly injected into the plant cell. Occasionally, however, this pattern changed, with feeding nematodes becoming inactive for long periods (up to 1 h); these inactive periods were usually followed by even longer periods of continuous ingestion in the same cell without salivation.

This latter type of feeding behaviour is similar to that observed for *Longidorus elongatus* (Ann. Rep. 1982, 143) in which a long initial period of salivation is followed by an even longer period of continuous ingestion.

(D. L. Trudgill, W. M. Robertson)

Radioactive labelling of Xiphinema *and* Longidorus *species*

In a preliminary study with $^{14}CO_2$ radioactively labelled ryegrass plants 12 of 24 *X. diversicaudatum* allowed feeding access for 7 days were sufficiently radioactive to be readily detectable by autoradiography. Nematodes immersed overnight in ^{14}C labelled glucose or ^{3}H labelled leucine also became labelled, and *X. diversicaudatum* also labelled in ^{14}C glucose were still radioactive after feeding for 4 wk on the roots of unlabelled ryegrass.

(W. M. Robertson, M. A. Mayo[1])

PU 1(f) Study the cell, root and plant response to attack by plant parasitic nematodes

Histological changes in root-tips attacked by Xiphinema diversicaudatum

Feeding by *X. diversicaudatum* on a good host (stawberry cv. Cambridge Favourite) has been shown to cause progressive increases in the DNA

[1]Virology Department

content and size of the nuclei in root-tip cells. After 4 days feeding the mean DNA content had increased to 3.9 compared with a mean of 2.2 in the controls. Nuclei size had increased from a mean of 17 μm^2 in control root-tips to 49 μm^2 in attacked roots. There were also many fewer dividing nuclei observed in attacked root-tips than in the unattacked controls, but attacked root-tips contained many multinucleate cells not present in the unattacked. This apparent conflict in the data may be due to two factors: greater synchronisation and/or a reduction in the time taken for mitosis in attacked roots.

(W. M. Robertson, B. S. Griffiths[1])

Mechanisms of tolerance to damage by potato cyst nematodes

Previous studies have shown that potato cv. Cara is consistently tolerant of damage by potato cyst nematodes (PCN) whereas cv. Pentland Dell is usually intolerant (Ann. Rep. 1982, 137). The effect of PCN on yield is indirect, the invading juveniles damaging the root system and so reducing the uptake of mineral nutrients. As a consequence the rate of top growth is slowed and the proportion of available radition intercepted by the canopy is decreased. In a series of ten collaborative trials with the ADAS and the NSCA it was shown that PCN decreases the top growth of Cara and Pentland Dell by a similar proportion but, because Cara produces a much larger top, the effect on intercepted radiation is considerably different. A re-analysis of published data showed that in a field trial the proportion of radiation intercepted by Pentland Dell was decreased by 42% in plots heavily infested with PCN compared with only 15% for Cara. Part of this difference between the cultivars was also due to heavily infested Pentland Dell senescing prematurely when heavily infested, an effect which is probably a consequence of differences between the two cultivars in the reaction of their root system to PCN attack. When heavily infested Cara is stimulated to produce a larger root system than when uninfested, whereas the weight of root of Pentland Dell is reduced.

To separate the contribution that the top and the root make to the tolerance of Cara, reciprocal grafts were made between single stem plants of Cara and Pentland Dell, and the resultant plants transferred to large pots (30 cm diam) containing field soil either heavily or lightly infested with *G. pallida*. Plants were harvested on nine separate occasions and the results demonstrated the importance of top type in determining overall patterns of growth and total dry matter productively (see p.152). A preliminary analysis of the results suggests that root type made a major contribution to nematode tolerance; plants with a Pentland Dell scion on a Cara root system being consistently the most tolerant. In the heavily infested soil the tuber yield at the final harvest of Pentland Dell

[1]MISR

grafted on to Cara was 82% of that in the lightly infested soil compared with 70% for Cara on Cara, 55% for Cara on Pentland Dell and 50% for Pentland Dell on Pentland Dell.

(D. L. Trudgill)

ENTOMOLOGY

PU 9(j) Study epidemiology of aphid-transmitted potato viruses

Recent experiments on the epidemiology of potato leafroll virus (PLRV) have established the importance of early infestations of aphids in potato crops and the need to prevent colonies developing on infected plants before roguing. Results in 1982 showed that normal roguing methods could be responsible for the movement of vectors. A trial was designed to compare the relative importance of *Myzus persicae* and *Macrosiphum euphorbiae* on the spread of PLRV. The layout was similar to that described previously (Ann. Rep. 1982, 146) in which a small number of PLRV-infected plants was distributed systematically in replicated plots of FS1 cv. Maris Piper, but in 1982 each PLRV 'infector' was inoculated in mid June with five apterae of *M. persicae* or *M. euphorbiae*, or left uninoculated. Three weeks later all the PLRV infectors were removed, either by conventional roguing, i.e., digging out the infected plant and transferring foliage and tuber directly to a sack for disposal, or by more careful roguing in which each stem was cut at the base and transferred into an adjacent polythene bag, taking great care to try and avoid dislodging aphids. After haulm removal in mid August tubers were harvested from all the plants which were immediate neighbours of each PLRV infector, and grown in 1983 to assess the proportion that was infected.

Although natural infestations were expected to be late in 1982 following an exceptionally cold January, small numbers of migrants were found in early June and aphids, mostly *M. euphorbiae* were found on the foliage of uninoculated infector plants when those were rogued in early July. However, the tuber infection results demonstrated the importance of early infestations of *M. persicae*. In plots inoculated with *M. persicae* 31% of the tubers were infected with PLRV, compared with 13% in plots infested with *M. euphorbiae* and 12% in uninoculated plots. Careful roguing halved the incidence of PLRV in plots inoculated with *M. persicae* and decreased it by 80% in the uninoculated plots. However, careful roguing had no effect on the incidence of PLRV in plots inoculated with *M. euphorbiae*, probably because it was more difficult to avoid dislodging *M. euphorbiae* when cutting the stems of infested plants.

Aphids taken from the foliage of infector plants were identified and used in glasshouse experiments in an attempt to assess the proportion

able to transmit PLRV. In these tests, 14 out of 17 *Physalis floridana* plants infested with *M. persicae* became infected compared with only 4 out of 45 *Datura stramonium* plants infested with *M. euphorbiae*.

In a similar experiment in 1981 using young Maris Piper potatoes as indicator plants, *M. euphorbiae* collected in early July from PLRV-infected plants in the field infected seven out of 39 plants with PLRV but *M. euphorbiae* collected 2 wk later transmitted PLRV to only two out of 38 plants. In 1982 further attempts were made to transmit PLRV to potato plants using *M. euphorbiae*. The aphids were first fed on leaves excised from PLRV infectors and then transferred in groups of three to stem cuttings of the cultivars Desirée or Maris Piper. Tubers from these plants were grown in 1983 to assess PLRV infections. Only three out of the 51 plants tested were found to have been infected with PLRV. These results confirm previous observations of the low efficiency of *M. euphorbiae* as a vector of PLRV, but do not rule out the possibility that this species could be important if large populations develop on infectors before roguing.

The spread of PLRV depends not only on aphid numbers and their efficiency in transmitting the virus, but also on plant susceptibility. In a field experiment in 1982 groups of 10 apterous *M. persicae* infected with PLRV were caged for 1 wk on single-stemmed plants of FS1 Maris Piper. There were four inoculation dates at 3 wk intervals starting on 17 June. Tubers from 10 inoculated plants were harvested at intervals of 3, 4, 5 and 9 wk after inoculation and grown in 1983 to assess infection. Only one out of 40 plants inoculated in mid August produced infected tubers. Plants inoculated in June or July showed a sharp increase in the number of infected tubers when harvested 4-5 wk after inoculation. With this interval between inoculation and harvest 36% of the tubers from plants inoculated in mid June were infected with PLRV. There were progressive decreases in the number of infected tubers with later inoculations. However, the maximum proportion of infected tubers, which was found in plants harvested in August after inoculation in mid June, was only 50%. This suggested that the results were somewhat atypical, either because of problems with the inoculation technique or because PLRV did not reach tubers in these test plants which grew in very dry soil.

In an experiment in 1979, using groups of 15 viruliferous *M. persicae* confined on a single lower leaf we found that almost all the tubers were infected in plants inoculated at the end of June and harvested from the end of July onwards but inoculations in mid-July or mid-August produced only 16 and 7% infected tubers.

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

Control of aphid vectors of potato viruses

The 1982 field trial to compare the relative importance of *M. persicae* and *M. euphorbiae* as vectors of PLRV and the effect of different

methods of roguing on PLRV spread was also replicated in plots treated at planting with thiofanox. As noted in previous years, this treatment prevented aphid multiplication until early August. PLRV incidence in tubers harvested from plants neighbouring infectors was decreased in all plots treated with thiofanox. The greatest reduction (from 31 to 5%) was found in plots that had been inoculated with *M. persicae*. However, it was evident that some *M. persicae* had survived on infectors treated with thiofanox because the incidence of PLRV on thiofanox-treated plots which had been inoculated with *M. persicae* was halved by careful roguing.

Another insecticide trial, started in 1982, compared the effectiveness of granular systemic insecticides applied as side-band dressings to emerging potato crops (Ann. Rep. 1982, 148-149). Samples of tubers harvested from plants neighbouring PLRV infector plants were grown in 1982 to assess the incidence of PLRV after treatment with two rates of aldicarb or thiofanox applied in-furrow at planting, or with low rates of these pesticides side-banded into potato drills 6 wk after planting. The infectors in this experiment were not rogued and the incidence of PLRV in untreated plots was considerable (67%). All the treatments decreased spread significantly, the greatest reductions resulting from in-furrow applications of aldicarb at 86 or 43 g/100 m. There were no significant differences between the in-furrow treatments, which were superior to the side-banded treatments, although the differences were only significant in comparisons between in-furrow applications of aldicarb and side-banding with thiofanox at 56 g/100 m.

A similar experiment was started in 1983 to compare the control of aphids and PLRV following in-furrow application of aldicarb at 86 or 43 g/100 m and thiofanox at 112 g/100 m, or aldicarb applied as a side-band dressing at 43 g/100 m just before the crop emerged, 4 wk after planting. The efficacy and persistence of these treatments and an untreated control was assessed from aphid samples at 2 wk intervals and from bioassays of the toxicity to *M. persicae* of 50 excised leaves/treatment. The bioassays were started in mid-June and done at 2 wk intervals alternating with the field sampling for aphids.

On untreated plots aphid populations increased from mid-June and peaked in late July. There were significantly fewer aphids on all the treated plots in July, with aldicarb applied at planting at 86 g/100 m giving the best control of *M. euphorbiae* and thiofanox giving the best control of *M. persicae*. The side-band treatment with aldicarb (43 g/100 m) was slightly better than aldicarb applied in-furrow at this rate, and in two bioassays in June the side-band treatment was as effective as the in-furrow treatment at 86 g/100 m and superior to the in-furrow treatment with aldicarb at 43 g/100 m.

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

Air-assisted spraying

Air-assisted spraying of raspberry was evaluated again in 1983 with sprays of fenitrothion (a contact insecticide) being applied to control the large raspberry aphid (*Amphorophora idaei*). The cross-flow sprayer treatments were fenitrothion at 0.55 and 0.73 l a.i./ha in 350 l water/ha, using air velocities of 11.3 and 12.9 m/sec and these were compared with a standard commercial application of 0.55 l a.i./ha fenitrothion in 2000 l water/ha. The sprays were applied on 2 August, later than in previous years (Ann. Rep. 1982, 150), into a dense canopy of fruiting and primocanes.

All sprayer treatments significantly reduced aphid numbers compared with the untreated control and no significant difference was detected between the cross-flow and conventional hydraulic sprayer treatments. This work confirms experiments in previous years which showed that medium volumes applied with the cross-flow sprayer were as efficient as conventional spraying using 2000 l/ha and suggests that savings in costs of application and improvements in timelines are possible.

(S. C. Gordon, B. Williamson[1])

PU 10(g) Study the ecology and control of insect and mite pests of cane fruit

Raspberry cane midge (Resseliella theobaldi)

Studies on the factors involved in emergence of adult raspberry cane midge from their overwintering cocoons showed that temperature had a predictable effect. Cocoons were extracted from the field in early January and placed in constant environment cabinets at temperatures of 10, 12.5, 15, 18, 20, 22.5 and 25°C. For 50% emergence 200 accumulated day degrees above a developmental threshold of 9°C were required. However, this figure cannot readily be used to predict emergence in the field because it applies to temperatures just below the soil surface where cane midge cocoons are found and the temperature at this zone cannot easily be related to screened air temperatures. Field observations in 1983, showed that midges started emerging in early June with a peak 2 wk later. Egg laying extended over a 5 wk period. Peak larval numbers were observed 2 wk after the egglaying peak.

In a second trial the development of the second generation was followed in the raspberry cultivars Glen Isla, Malling Jewel and Willamette. The bark of Glen Isla does not readily split and consequently it maintained a very low population of larvae whereas both Malling Jewel and Willamette, whose bark splits more readily, had higher, but similar numbers of larvae.

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

[1]Mycology and Bacteriology Department

PHYSIOLOGY AND CROP PRODUCTION

P. D. WAISTER

The sprouting behaviour of the potato mother tuber is critical in determining the subsequent growth and development of the crop. It influences stem number, number of tubers per stem (directly or indirectly) and, depending upon genotype, the phasing of bulking and the onset of senescence. The quantitative data on some of these factors obtained from a number of experiments this year will be useful both for further crop modelling and for improvement in production practices.

The extent to which further research may improve farm yields can be estimated from the gap between achieved yields and potential yields. From the limited monitoring of ten farm crops this season it is apparent that some growers have already closed this gap. Water supply appeared to be the single most important limiting factor in those crops which failed to reach potential. Following the success of the pilot survey this PMB-funded project is being extended to cover crops at sites throughout Britain, aided by ADAS and the Scottish Agricultural Colleges.

Physiological disorders are notoriously difficult to investigate because their occurrence is so erratic. Experiments on growth cracking of potato have confirmed that this disorder is not simply related to fluctuations in water supply, but have so far not identified the additional factor or factors. The causes of bud necrosis in black currant are likewise obscure, but there is increasing evidence that the disorder is more widespread than hitherto thought, and potentially an important yield constraint.

At present there are only very limited resources available for investigations on minor crops or potential new crops, but the small programme on highbush blueberries has been useful judging by the number of enquiries now being received from growers and advisers, particularly from the south. The response of this crop to irrigation has been marked in this second successive dry summer.

POTATO

PU 7(a) Study the physiology of the response of the potato crop to radiation, temperature and water supply

Potato: pre-emergence growth of sprouts

The experiments of the previous year to examine the dependence of time from planting to emergence (E50) on temperature were extended.

In the first experiment unsprouted seed of five cultivars was planted in compost at 5, 7.5, 10, 12.5 and 15°C. Samples of 10 tubers were lifted at five intervals spaced to give similar elapsed thermal time between lifts at all temperatures. The progression of extension growth and internode appearance was measured. Sprout apices were fixed in ethanol and glutaraldehyde for later examination of foliar primordia.

In the second experiment sprouted seed of Maris Piper given 240 day degrees above 4°C in light was planted at three depths and five temperatures. The average extension rates differed with depth of planting. This effect was due to a period during which extension growth is very slow and which is followed by a transition to rapid extension. The transition occurred at sufficiently short sprout lengths that the process leading to emergence can be considered to occur in two sequent phases. If an allowance of 153 day °C above 0°C is made between planting and the notional start to rapid extension growth then a single function of temperature can be used to describe extension growth at all the depths and temperatures measured.

Similar investigations on four other cultivars planted at only one depth have shown a narrow range in the base temperature for sprout extension and in the sprout extension rate.

(D. K. L. MacKerron)

Potato: effects of drought on several cultivars

Six potato cultivars were grown either fully irrigated or droughted. In the droughted treatment the plants were grown through clear polythene laid after emergence to protect the soil from rain. The maximum soil moisture deficit in this treatment was 110 mm as measured by the neutron moderation technique. High rainfall after planting caused waterlogging which delayed emergence and severely limited subsequent growth in a number of plots, so that replication was inadequate for two cultivars.

The four cultivars for which there is complete data were Maris Piper, Désiree, Record and Pentland Dell. Drought reduced total yield in Maris Piper and Désiree by 30% and in Record and Pentland Dell by 20%. In Maris Piper and Désiree, however, the size distributions were affected by the drought so that the reduction in ware yields were 35-40%. This illustrates one important attribute of drought susceptibility or resistance, that whether the dry matter is partitioned into many or few tubers can have as great an effect on yield as can changes in total production.

The similarities between Piper and Désiree and between Record and Dell would not be expected if judged by NIAB ratings, but are consistent with results from other investigations at SCRI. It is possible that the ranking of cultivars for drought resistance is sensitive to the stress patterns imposed.

The dry matter contents in the irrigated treatments were 2% less than in the droughted ones in all cultivars and in all instances were high. Average dry matter content of irrigated tubers was 26%.

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

Potato: water stress and tuber initiation and development

A glasshouse experiment with five severities of water-stress applied by withholding water at two different stages of plant growth examined the relationship between water shortage and tuber initiation and development in the cv. Maris Piper.

As in the previous year there were fewer tubers per stem in treatments of successively greater water stress among plants deprived of water from 50% emergence but not when water was withheld from tuber initiation. Although a good relationship was found between tuber numbers per stem and the sum of daily soil moisture tension greater than 10 kPa for plants deprived of water from 50% emergence, the relationship was not consistent with that found in 1982 (Ann. Rep. 1982, 153). However, using the data from both years a significant ($P<0.001$) negative correlation was established between tuber number per stem and the number of days of soil moisture tension >25 kPa.

The total yield of tubers per plant was 1773 g in the unstressed control, while in the treatments most severely stressed from 50% emergence and from tuber initiation the yields were 130 and 1267 g respectively.

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

Potato: growth cracking

In an experiment designed to observe the natural incidence of growth cracking in tubers and to relate this to weather conditions, tubers of two cultivars were lifted on alternate days throughout the tuber bulking period and the incidence and severity of cracking was scored. The cultivars used were Record and Guardian, both susceptible to growth cracking.

The incidence of growth cracks in Guardian was low (<4%) in this year and that cracking which occurred could not be related to any particular weather pattern. In Record there were two flushes of cracking which occurred after rain had re-wetted dry soil in early and late August. The highest incidence of cracking scored was 21% of tubers lifted but this figure tended to decline in subsequent liftings as wound tissue filled shallow cracks.

In a second experiment plants from four unirrigated crops of the cultivars Guardian, Record and Maris Piper (2 crops) were each apportioned to a number of treatments in mid-August prior to irrigation and the relief of water stress. The control treatment (1) was to lift plants at the start of the experiment and to score for growth cracks. The remaining three treatments were: (2) plants to grow unchecked,

(3) haulm to be removed, (4) plants to be lifted and the tubers re-buried. After 2 weeks the incidence of growth cracks had increased only in Record in treatments (2) and (3) (2-10%) and in one crop of Maris Piper in treatments (2) and (3) (1-12% and 1-17% respectively). In all crops the tuber water content increased in treatments (2) and (3) and tuber dry weight increased in treatment (1).

Fully irrigated and unirrigated conditions and two treatments with fluctuating soil moisture were provided in another experiment on Guardian. Plants were harvested from mid-July to mid-August. On all occasions and in all treatments the incidence of cracking was very low (<1%).

The results from these experiments suggest that although growth cracking is associated with water uptake into the tuber after a dry spell the conditions which predispose a tuber to crack have still to be defined.

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

Potato: light interception and growth

Seephose was used to irrigate this experiment and ensured that water application was even. Soil moisture deficits were kept low but despite this canopy development was poorer in each cultivar than in previous years. This is attributed to the long spell which the seed tubers spent in cold and almost waterlogged conditions between planting and emergence at this particular site.

Cv. Maris Bard was used in the place of one of the maincrop cultivars in order to test the hypothesis that the known high performance of Guardian was associated with its being a first early. Cv. Maris Piper was again the control as a high yielding maincrop cultivar.

Maximum light interception in the cultivars Guardian and Maris Bard was only 0.72 and 0.73 respectively which was achieved by canopies of LAI 3.2 and 2.6. Even Maris Piper which normally has a very heavy canopy developed an LAI of only 4.4 and, at its best, intercepted only 0.88 of available light.

The average rates of dry matter increase for Guardian, Maris Piper ak0 Maris Bard were 1.82 g/MJ, 1.88 g/MJ and 1.57 g/MJ, respectively. The value for Bard was significantly lower than those for the other two cultivars ($P = 0.05$). We conclude that the high value of the radiation conversion coefficient observed in Guardian in each of 3 years is not attributable simply to its maturity class.

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

Potato: canopy expansion in field crops

Three cultivars, Guardian (first early), Maris Bard (first early) and Maris Piper (early maincrop) were examined. Preliminary analysis of measurements of leaf growth shows that leaf appearance on the mainstem was slower in Maris Piper than in the two early cultivars.

Both Guardian and Maris Bard had 10-12 mainstem leaves while Maris Piper had 16-18 mainstem leaves before the inflorescence. Final leaf sizes were measured using diazo blueprint paper and full leaf area profiles are being prepared for each cultivar. Initial scanning of these data suggests that individual leaf area up to leaf nine was greater in the two early cultivars than in Maris Piper.

(W. W. Kirk, B. Marshall)

Potato: leaf development in controlled environments

Growth room experiments at mean temperatures of 6, 10, 15 and 20°C were set up using Maris Piper, grown in UC compost. Measurements of individual leaf lengths from a single stem were made at regular intervals and logistic growth curves fitted for each leaf. A leaf was considered to have appeared when it attained 0.2 of its final length. Using an iterative regression technique the base temperature for leaf appearance was about 0.0°C. A new leaf appeared about every 30 K days above the calculated base.

The mean maximum rates of leaf expansion, expressed as a fraction of final leaf length, were 0.08 (s.e. 0.004), 0.16 (s.e. 0.005), 0.24 (s.e. 0.004) and 0.30 (s.e. 0.009)/day, for leaf numbers 4-14 at 6, 10, 15 and 20°C respectively. The Julian duration of expansion of individual leaves, between 0.2 and 0.8 of the final leaf length, was calculated from the fitted growth curves. At 6, 10, 15 and 20°C the Julian durations were 36.8 (s.e. 1.23), 19.2 (s.e. 0.2), 12.1 (s.e. 0.27) and 9.48 (s.e. 0.22) days respectively for leaf numbers 4-14. Duration expressed as accumulated day degrees above a base temperature of 0.0°C was approximately 200.0 K days independent of temperature treatment and leaf position.

(W. W. Kirk, B. Marshall)

Potato: diagnosis of ways in which the growth and development of farm crops of potatoes differ from the potential delimited by temperature and radiation

The achieved production of potatoes in many commercial crops is well below the levels believed to be possible. In the past 2 years a model of potato growth has been developed at SCRI and its results have been compared with potential yields for particular sites and seasons, on the basis of solar radiation and soil and air temperatures, assuming other factors non-limiting. The estimates have been checked against yields actually achieved in our 'maximum yield' plots, and found to be very close.

In 1983 a survey was sponsored by the PMB with the aim of coupling these environmental measurements with measurements of crop growth and development on a range of farm crops, in order to indicate sources of yield variation from site to site and the origins of the differences between potential and achieved yields.

Ten sites were chosen from within a 30 km radius of Dundee in co-operation with the ESCA and the farmers concerned. They were selected to comprise fields on which yields were expected to be good, and others where poor yields were anticipated from past experience.

The method used in the survey involved analysis of the growth of the potato crop in three phases, planting to emergence, emergence to full leaf cover and full leaf cover to haulm destruction. Measurements of temperature and of radiation levels allowed an assessment of the relative importance of the three growth phases as yield determinants.

Further measurements, e.g. soil water status, and tissue nutrient levels allowed closer definition of reasons for shortfall in yield.

The results suggested that crops grown from good seed showed no decrease below potential during the first phase of growth. In the second phase of growth canopy expansion was slowest on those sites where soil moisture deficits were greatest. The measurements made throughout the life of each farm crop enabled us to calculate the potential production of dry matter for each site and also gave crop values for comparison. The final observed total dry matter production at three good sites was very close to the calculated potential. This gives us confidence in the model when applied to field crops and emphasises its value in an examination of shortfalls.

(D. K. L. MacKerron, T. D. Heilbronn)

PU 7(b) Study the physiological processes involved in dry matter partitioning in the potato plant

Potato: carbon partitioning and sugar metabolism in growing stolons

Partitioning of ^{14}C was examined in growing stolons of cv. Maris Piper. On a fresh weight basis many stolon tips, which showed no signs of sub-apical swelling, had higher specific activities (CPM/g fresh wt.) of ^{14}C in both ethanol insoluble and soluble forms, than larger visibly tuberised stolons. Furthermore, many tips of low fresh weight had a higher insoluble to soluble ^{14}C ratio than visibly tuberised stolons suggesting greater conversion of soluble ^{14}C to insoluble ^{14}C in the smaller stolons. The results suggest that sub-apical swelling of the stolon is preceded by increased soluble carbon accumulation at the stolon tip together with increased conversion of soluble to insoluble forms of carbon.

Tuberisation was accompanied by a substantial decrease in both total and reducing sugar concentrations (fresh weight basis) in the stolon tip. This was reflected in a negative relationship between tuber growth and ratio of reducing sugars: sucrose. However, a positive and statistically significant correlation existed between the ratio of glucose: fructose and the degree of tuberisation as determined by fresh weight measurement.

This change in metabolism was also observed in $^{14}CO_2$ assimilation experiments. The metabolic pathways of glucose and fructose utilisation in growing tubers are currently under investigation.

(K. J. Oparka, H. V. Davies)

Potato: partitioning of current assimilate

Plants of cv. Maris Piper were labelled with $^{14}CO_2$ in the field at six stages during tuber bulking, and changes in assimilate partitioning examined in relation to increasing tuber size.

Those tubers on a plant which imported the most ^{14}C did not all belong to the same stem and there was no relationship between the amount of ^{14}C in a tuber and its distance from the labelled haulm. However, many small tubers borne on second-order stolons contained significantly lower concentrations of ^{14}C than larger tubers borne in primary stolons. These small tubers were further characterised by low insoluble: soluble ^{14}C ratios, low starch concentrations and high reducing sugar levels.

The relationship between tuber fresh weight and ^{14}C content was approximately linear until a fresh weight of about 40 g was reached. Above this the relationship became more curvilinear and tubers of similar size showed increasing variation in ^{14}C content. Of the tubers on a plant that continued to grow, the insoluble: soluble ^{14}C ratio was relatively constant within a particular harvest and over a wide range of tuber sizes. However, this ratio fell from 2.8 to 0.8 over the six harvests suggesting a decreasing turnover of soluble to insoluble ^{14}C during tuber growth. The percentage of label in the soluble fraction in the tubers increased from 20 to 55% over the course of the experiment and 60-70% of that soluble fraction was recovered in the sugars sucrose, glucose and fructose. Chromatography of these sugars revealed an increasing proportion of ^{14}C in sucrose with each successive harvest. Levels of ^{14}C in glucose fell during the experiment while levels of ^{14}C in fructose remained consistently low (<5% of the total sugars) throughout.

(K. J. Oparka)

Potato: leaf export in relation to vascular anatomy

Labelling a single potato leaf with $^{14}CO_2$ results in an asymmetrical movement of ^{14}C through the plant in a pattern that is consistent with the internal arrangement of vascular bundles in the stem. The pathway of ^{14}C through the plant was determined by autoradiography of successive internodes between the labelled leaf and the tubers. There was no redistribution of label across the stem despite the presence of anastomoses of vascular bundles above leaf nodes. As a consequence tubers borne on stolons vertically below the labelled leaf contained higher concentrations of ^{14}C than tubers on the opposite side of the stem.

Further experiments are underway to determine whether this basic pattern is maintained in field situations where source-sink relations may be altered by shading of supply leaves.

(K. J. Oparka)

Potatoes: stock/scion effects on growth

As part of a study on differences in potato cultivars in their tolerance of damage to potato cyst nematode (see p.140) the cultivars Cara and Pentland Dell were self and reciprocally grafted. The data collected are intended to provide a better physiological understanding of plant responses to nematode attack, but will also contribute to our understanding of genetic differences in the control of assimilate partition. It is the latter that is dealt with here and consideration is given only to plants grown in nematode-free soil.

Plants were grown in pots out of doors and the grafts were made about 5 cm above the level of the compost; thus the root system, stolons and tubers originated from the stock, whilst the aerial parts originated from the scion. Plants were harvested on 9 occasions up to 14 weeks after planting.

Between the last two harvests total dry weight and tuber dry weight still had not reached constant values, so the final values obtained and presented here may not represent the potentials.

Total dry weight at the final harvest for the Cara/Cara (scion/stock), Cara/Dell, Dell/Cara and Dell/Dell combinations were 187 g, 176 g, 148 g and 138 g per plant, showing that the scion was the major determinant of growth. Corresponding values for tuber dry weight were 143 g, 145 g, 123 g and 121 g. Thus again the scion was the more important in determining tuber yields, irrespective of the parent tissue from which tubers developed.

(R. Thompson, D. L. Trudgill[1], H. Taylor)

PU 7(c) Study the physiological basis of intersprout competition in the potato during the pre-emergence growth phase

Potato: the pattern of starch and protein depletion in sprouting tubers

The kinetics and macroscopic distribution of starch and protein degradation were analysed for tubers of cv. Maris Piper sprouted in compost at 12°C in the dark. Substantial hydrolysis of these reserves was initiated some time after emergence (planting depth 15 cm) but continued for some considerable time afterwards. An increase in the number of sprouting eyes per tuber from one to three had no effect on the rates of hydrolysis. The pattern of depletion, as analysed histochemically, showed that breakdown of starch and protein started around inner phloem tissue,

[1]Zoology Department

spreading thereafter throughout the perimedulla. Parenchyma tissue external to the vascular ring was the last to be depleted. Preliminary studies have indicated the suitablility of infra-red analysis for the rapid determination of starch (and probably protein) in freeze dried tuber tissue.

(H. V. Davies, H. A. Ross, I. A. Cowe[1])

Potato: sprout growth from tuber cores

Single cores of various diameters, each bearing a single sprouting eye, were taken down the longitudinal axes of tubers and trimmed to specific fresh weights to provide two variables: core weight, and a differing contribution of tissues external to the vascular ring to the total core mass (designated % cortex). Cores were kept under high humidity for 2 days to encourage periderm formation, then planted in perlite and supplied with distilled water only. Sprout dry weight accumulation increased with an increase in core fresh weight from 2 to 14 g. An increase in % cortex from 20 to 50% in 2 g cores enhanced growth as did an increase from 8 to 20% in 5 g cores; a further increase to 60% had no additional effect. The effect of an increase on % cortex diminished as core weight increased. Although extension growth was severely inhibited by sub-apical tip necrosis in the absence of calcium, the effects of core weight and diameter on sprout dry weight accumulation were also evident in healthy material produced when cores were planted in UC compost. Incubation in compost stimulated dry weight accumulation compared with control samples incubated in perlite. The positive effects of an increase in core diameter may be the result of the inclusion of a larger proportion of tuber tissue with a higher dry matter content, i.e. tissue external and immediately internal to the vascular ring.

(H. V. Davies, H. A. Ross)

Potato: tuber wounding and sprout growth

Tubers of cv. Maris Piper (100 g fresh wt.) were sprouted at 5°C in the dark. Control material, treatment (1), was prepared by removing unwanted eyes (including the extreme apical eye) with a cork borer, leaving tubers with a single sprouting eye at the rose end only. Other similarly treated tubers were then cut in one of several ways: (2) tubers were cut transversely in half; (3) a transverse section was removed and discarded from the heel end (10% by weight); (4) a transverse section was cut off at the rose end (10% by weight, including the sprout); (5) a 1.6 cm diameter core bearing the sprout was taken longitudinally through the tuber and trimmed to 10% of the original tuber weight. The samples were hardened off under high humidity for 2 days then planted in UC compost and maintained at 12°C in the dark.

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[1]Chemistry Department

Over a 15-day period sprout dry weight accumulation was increased significantly by cutting tubers in half but was unaffected by removing a small section of heel end. The use of small pieces of tuber tissue (treatments 4 and 5) reduced dry weight accumulation but stimulated extension growth of the main sprout. This appeared, at least in part, to result from a reduction in the number of branch sprouts per eye and the channelling of dry matter into the dominant sink. Half tubers not only showed the fastest rate of sprout dry weight accumulation but also extension growth rates approximating those for small tuber pieces. This occurred without a significant reduction in the number of branch sprouts per eye.

(H. V. Davies, H. A. Ross)

Potato: sprout growth of cores from tubers of different size grades

In experiments during the last 2 years sprout growth was measured from single-eyed cores taken from similar eye positions on tubers of different size grades, to determine the effect of tuber size, independent of volume of mother tuber tissue.

Cores with a fresh weight of approximately 10 g, each bearing a single eye, were removed and allowed to suberise for 48 hours at 15°C. They were then planted in pots of field soil and the subsequent growth of sprouts was followed by regular sampling. In 1982 sprout growth from cores taken from 50-60 mm tubers was significantly greater than from 35-45 mm tubers, both in dry weight and rate of sprout extension. The same result was obtained in 1983 when cores from 50-60 mm tubers and 30-40 mm tubers were compared. These differences were not related to levels of dry matter in cores from the large and small tubers, but may indicate variation in the size of sprout initials and their accompanying vascular tissue.

(H. A. Ross, P. A. Gill)

Potato: within and between-plant competition

The effect of different amounts of mother tuber material associated with individual eyes was examined using 75-85 g tubers of cv. Maris Piper.

Eyes were excised or eye-bearing cores were removed to give the following treatments: (a) single-eyed tubers; (b) four-eyed tubers; (c) 4 × single-eyed 10 g cores; (d) 4 × single-eyed 20 g cores. These were planted in the field at conventional spacing and trickle irrigated. Samples were taken at intervals up to a leaf area index of 3. In whole tubers (a) and (b), competition reduced stem number per eye from 4.2 to 1.6. Stem number per eye was virtually identical in treatments (b) and (d) (1.6 and 1.5), but was reduced to 1.2 when core-size was reduced (treatment c). The resulting stem numbers per 'plant' for the four treatments (a) to (d) were 4.2, 6.5, 5.0 and 6.1 respectively. At final harvest, total plant dry weight, tuber number and tuber yield were all directly related to these stem numbers.

A second experiment examined the timing of competition between stems and between plants. Single-eyed cores weighing 10 g were planted singly and in groups of four and eight at 30×75 cm and 90×150 cm spacings. Six samples of plants were taken at weekly intervals from emergence onwards for growth analysis.

The point of divergence of growth rates of the single core and multi-core treatments is taken to indicate the onset of stem-to-stem competition. Plant-to-plant competition is measured by comparing growth rates at close and wide spacing.

The onset of stem-to-stem competition this year coincided with that of plant-to-plant, in contrast to 1982 when the former was appreciably earlier. In that year plants may have suffered some early water stress before irrigation was applied. This year plants were never short of water and the results are consistent with the view that growth is temperature-limited not light-limited in the early part of the season, so that little competition between stems occurs when nutrients and water are non-limiting at this time.

Leaf samples were collected throughout both experiments for chemical analyses by the MISR.

(P. A. Gill, P. D. Waister)

Potato: mineral nutrition and intersprout competition

Tubers of cv. Maris Piper bearing either one or three sprouting eyes were planted in perlite, grown in darkness at 12°C, and watered with either Ca $(NO_3)_2$, $CaSO_4$ or a complete nutrient solution. Intersprout competition, i.e. the reduced rate of dry matter accumulation per eye in multi-eyed compared with single-eyed tubers, was reduced with Ca $(NO_3)_2$ compared with $CaSO_4$. Competition was eliminated with the complete nutrient medium, indicating that factors other than nitrogen were involved. By the selective omission of ions the importance of adequate supplies of calcium, nitrogen, phosphorus and potassium was established. Dose response curves for calcium indicated an optimum concentration for growth of 10 m mol dm^{-3}. A reduction in the nitrate concentration of the nutrient solution from 10 to 5 m mol dm^{-3} significantly reduced sprout growth. Similar effects were noted for root growth.

(H. V. Davies, H. A. Ross)

PU 7(f) Examine (with MISR) the effects of mineral nutrition on growth and development of potatoes

Potato: phased N supply

Both growth and dry matter partitioning are affected by N supply. In field experiments analysis of the effects of phasing of N is complicated

by the buffering capacity of the soil. The N supply is more easily controllable in the MM plots (see below) which can be readily leached at intervals during the season. A preliminary experiment has shown that yields were similar when N was supplied only between planting and tuber initiation (119 t/ha) or continuously (100 t/ha). Corresponding values for tuber numbers were 15 and 137 tubers/m^2.

(R. Thompson, H. Taylor, P. Millard[1])

PU 8(a) Study the effects of cultural practices on the growth and development of the potato crop

Potato: measured maximum (MM) yield, cultivar responses

Considerable differences in yield and tuber number of the cv. Maris Piper have been obtained previously between MM plots and 'high' or 'normal input' field soil plots. Responses this year have been examined for the cultivars Maris Piper, Pentland Squire, Record, Cara, Kennebec, Foxton, Maris Bard and Pentland Javelin. MM plots comprise a sand/peat mixture of high nutrient status and are provided with high levels of water and liquid nutrients. High input field soil plots receive similar treatment, but the normal input field soil treatment corresponds to good commercial practice but without irrigation.

Stem numbers ranged between 28 and 48 stems/m^2 for the different cultivars but were not affected by soil treatment. As averages over cultivars total yield for the MM, high and normal input treatments were 71, 84 and 38 t/ha. Corresponding values for 35-55 mm size grade were 31, 24 and 25 t/ha. The differences in yield of the seed-size tubers were a reflection of differences in tuber number which were 116, 76 and 77 tubers/m^2 respectively. This is the third year in which this contrast in tuber number/m^2 has been recorded although last year the effect was only slight. This consistency of effect on tuber number was directly related to the number of tubers/stem as stem number was not affected by treatment. The level of response in tuber number varied between cultivars. When grown in MM plots Pentland Squire, Record, Kennebec and Foxton produced about double the number of tubers of the soil treatment. The other cultivars gave about 28% more from the MM plots.

Rainfall was very low in July and August and the normal input treatment produced significantly lower total yields for each cultivar than either of the other two treatments.

Pentland Squire and Record from normal input plots produced 55% of the yield of high input plots suggesting that, under the conditions of this year's drought, these cultivars were more drought tolerant than the others especially Foxton, for which the corresponding value was 37%.

Total yields from the high input soil plots were greater than those from the MM plots for Cara (107 and 72 t/ha respectively), Pentland Javelin

[1] MISR

(83 and 62 t/ha) and Kennenbec (77 and 36 t/ha). Yields for the other cultivars for the MM and high input treatments were similar and averaged 87 t/ha for Maris Piper, 91 t/ha for Pentland Squire, 58 t/ha for Record, 76 t/ha for Foxton and 87 t/ha for Maris Bard.

The percentage dry matter content of the tubers when averaged over cultivars was 17, 20 and 24% for the MM, high input and normal input treatments respectively. There was however considerable variation in response between cultivars; for example values for the high and normal input plots of Pentland Squire were 20.8 and 22.6% respectively, and the corresponding figures for Kennebec were 17 and 25%.

(R. Thompson, H. Taylor)

Potato: sprouting treatment – cv. Record

Tubers of Record produced in the north of Britain are reported to contain higher levels of reducing sugars than those from further south; this could be due to delayed maturity through the lower temperatures. Earlier maturity may be obtained by increasing the physiological age of tubers prior to planting.

Seed of Record was stored at 5, 10 or 15°C with the aim of producing a range in physiological ages and the resulting crops were harvested on 8 August and 21 September. Though stem numbers and size grades were affected by treatment, there were no significant differences in reducing sugar content at harvest. Sugar accumulation during the storage phase is being monitored.

(R. Thompson, H. Taylor)

Potato: cv. Kennebec and cv. Foxton size grade distribution

Commercial success of a cultivar depends in part on the ease with which its size grading can be controlled. Kennebec and Foxton represent extremes in terms of size grades produced, with Kennebec producing few but large tubers and Foxton many small tubers. Thus, difficulties are experienced with seed production and ware production respectively.

Planting rate is the usual means of controlling size grading. Responsiveness of these two cultivars to spacing at 10, 20, 30 and 40 cm within 72 cm drills was examined, using 40-45 mm seed. Stem densities were similar for both cultivars and averages obtained for these spacings were 43, 23, 15 and 12 stems/m^2.

Total yields did not differ significantly and the overall average was 56 t/ha. There were marked differences however, in tuber number per unit area for each cultivar, resulting in differences in size grade distribution. As spacing was decreased tuber numbers of Foxton increased from 69 to 114 tubers/m^2 and for Kennebec from 37-65 tubers/m^2. Yield of seed of Kennebec was greatest at the closest spacing with 24 t/ha (41% of total). Yields of ware sized tubers (40-80 mm) for Foxton increased progressively as spacing was increased with values of 39, 42, 47 and 53 t/ha.

(R. Thompson, H. Taylor)

Potato: small set performance

There are advantages in terms of the numbers of stems per unit weight of tubers to be obtained from the use of small seed within the normal commercial size range. There is little evidence to indicate whether or not the performance of very small seed equals that of larger.

Seed of the cultivars Maris Piper and Pentland Crown, weighing 6-14, 16-24, 26-34 or 36-44 g was planted at rates giving similar numbers of sprouts/m^2. The progeny from the experiment will be used to provide corresponding seed sizes for next year, i.e. 10 g seed will be derived from 10 g mother tubers.

Numbers of stems/tuber for Maris Piper were 2.6, 3.0, 3.7 and 4.7 and for Pentland Crown were 1.8, 2.7, 3.7 and 3.7 for progressively larger tubers. Stem numbers/m^2 did not differ significantly between tuber sizes and on average were 20 stems/m^2 for Maris Piper and 16 stems/m^2 for Pentland Crown.

The smallest seed took 2 days longer (41 days) to reach 50% emergence than the largest seed (39 days).

In increasing order of seed size total yields were 57, 49, 58 and 67 t/ha for Maris Piper and 55, 62, 63 and 61 t/ha for Pentland Crown (l.s.d. 3.4). Thus although significant differences exist they were not simply related to seed size. There were no differences for either cultivar in the yield of 35-55 mm tubers in relation to seed size but analysis of size grade distributions is not yet complete.

Tuber numbers produced did not differ between the four seed sizes for Maris Piper with an average of 65 tubers/m^2, and only the smallest sets of Pentland Crown with 44 tubers/m^2 differed from the 52 tubers/m^2 from the largest sets. Although differences in performance were detected, these were small and they were difficult to ascribe directly to differences in set size.

(R. Thompson, H. Taylor)

Potato: sprouting treatment

Last year it was found that the timing of a high temperature sprouting treatment had little effect on total yield or size grades. Neither was there an effect on stem numbers. Storage conditions immediately after lifting have been shown elsewhere to influence stem numbers.

This year immediately upon lifting (20 September) tubers of the cultivars Maris Piper and Pentland Javelin were stored at ambient until 29 September followed by 20 or 2°C until 13 October. Subsequently, high temperature treatments (20°C) with light were given for periods of 1 month starting in October, November and December. Stem numbers for Pentland Javelin were lower for the October sprouted tubers given the low initial temperature (25 stems/m^2) than for any of the other

treatments, which were similar and averaged 30 stems/m^2. This treatment also gave the lowest value for Maris Piper (27 stems/m^2) but this differed only from the October sprouted tubers given the high initial temperature (36 stems/m^2); the other treatments averaged 32 stems/m^2. All of these stem densities are at levels unlikely to limit total yield. Thus irrespective of when the high temperature treatment was given, even though dormancy was not broken at the start of storage, there was evidence of only weak apical dominance.

The crop was harvested on two occasions in August and October. Only the yield for Maris Piper increased between these times with 46 t/ha and 63 t/ha. Averaged over harvest date Pentland Javelin gave 45 t/ha. The only major difference in yield resulting from differences in sprouting treatment was the October sprouted Maris Piper given the initial high temperature treatment, which at the first harvest gave a significantly lower yield (39 t/ha) than the December sprouted (51 t/ha). Nevertheless, other small differences in yield were found which, contrary to last year's findings, indicated a small benefit to be derived from late sprouting with yields of 48, 50 and 51 t/ha for the October, November and December sprouting periods respectively.

In 2 years of experiments to ascertain the importance of the timing of chitting treatment, remarkably little effect has been found, possibly because there has been little apical dominance in the early applied treatments.

This year seed tubers have been produced with a greater likelihood of possessing different sprouting characteristics, including apical dominance, from crops planted on different dates. Tubers were planted on 12 April, 20 May, 5 July and 16 August, and produced total yields of 60, 51, 36 and 5.8 t/ha respectively with yields for 35-55 mm sized tubers of 47, 35, 27 and 0 t/ha. Material from this experiment will be used to examine sprouting performance and yield next year.

(R. Thompson, H. Taylor)

Potato: effects of mechanical damage prior to sprouting on subsequent performance of seed

Microscopic examination of sprout initials on commercial seed samples of cv. Maris Piper disclosed a high proportion of tip necrosis. It was not known whether this was caused by mechanical damage or by calcium deficiency.

Seed tubers of Maris Piper were lifted carefully by hand on 25 October and stored at ambient temperature for 1 week. Half of these tubers were passed over a grader twice to simulate 'rough' handling. The 'carefully' handled and 'roughly' handled tubers were subsequently stored at 2°C either in field soil or in open trays until 2 February. Tubers from the four treatments were then planted in either field soil, perlite, perlite with

added $CaSO_4$ or left unplanted in the trays, in a controlled environment cabinet at 10°C. After 45 days, sprout dry weight from 'carefully' handled tubers planted in field soil was 40% greater than from the 'roughly' handled. Storage in soil or air did not differentially affect subsequent performance. Growth was significantly increased in the tubers planted in the soil over all other treatments although growth in perlite + $CaSO_4$ was significantly higher than in the remaining two treatments. Neither the number of sprouting eyes nor the final number of sprouts was affected by damage or calcium treatments.

(H. A. Ross, P. A. Gill)

Potato: haulm desiccant evaluation

Seed tubers from a crop of cv. Maris Piper treated with glufosinate in August 1982, stored over winter and chitted in early 1983 produced varying levels of shoot suppression and malformation. These effects persisted and resulted in the field in a proportion of the tubers failing to produce above-ground shoots or developing above-average numbers of thin, spindly stems; other plants, although late in emerging, produced apparently normal shoots and acceptable yields of tubers. These results suggest translocation from treated foliage into the tubers and may exclude the use of glufosinate as a haulm desiccant, at least in crops grown for seed tuber production. In tests on stored tubers from a 1983 field experiment similar, adverse effects on chitting have been recorded.

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

PU 7(d) Make simulation studies of the growth and development of arable crops

Potato: modelling potential yields

The current SCRI model divides the crop into three major phases: emergence, canopy expansion and the period from canopy closure to haulm destruction. The durations of the first two phases are determined by soil and air temperatures respectively. In the model, emergence is the result of two sequential processes, eye development and sprout elongation, which have base temperatures around 5 and 2°C for cv. Maris Piper, respectively (Ann. Rep. 1982, 154-155).

Using the model, with the 25-year average soil temperature at SCRI, predicted emergence for unchitted seed is only 2 days later for seed planted on 1 April than for seed planted on 1 January. This is because soil temperature does not rise above the base temperature for the development of the eye until mid-March. In the case of chitted seed, the model assumes that the first process (eye development) is complete and only sprout elongation is required. However, predicted emergence of chitted seed is some 2-3 weeks earlier than was observed in crops grown at SCRI. Further experiments are in progress to examine and quantify the mechanisms involved.

Light interception is calculated from the leaf area. Currently, canopy expansion is described by a simple exponential growth of total leaf area. The relative growth rate is a linear function of temperature with an implied base temperature of 2.5°C. Because the function is linear, the predicted accumulated temperature above the base, from emergence to canopy closure, is constant for a given plant density. At 4 plants/m^2 the duration for Maris Piper is approximately 430 K days. Measurements of individual leaf development and expansion are providing direct estimates of base temperatures and will allow a more mechanistic submodel of canopy expansion to be developed.

Conversion of intercepted radiation into dry matter is assumed constant and was originally based on average performances in the field (1.5 g (DM)/MJ). This value is lower than maximum values for other crops and for certain potato cultivars measured at SCRI. This aspect of the model and that of dry matter partitioning require further development.

(B. Marshall)

Sugar beet: modelling light interception

Three models of increasing complexity have been developed. The first describes light interception as a unique function of thermal time; the second describes leaf area index as a unique function of thermal time; and the third describes the emergence, expansion and duration of individual leaves as functions of thermal time, using two distinct base temperatures for development and growth processes. The effects of varying plant density but without competition are accounted for. The models will be assessed against a comprehensive set of data recorded over several seasons by staff at Broom's Barn Experimental Station and RES.

(B. Marshall, P. V. Biscoe[1], G. Milford[2])

PROTEIN SEED CROPS

PU 8(b) Study the effects of cultural practices on the growth and development of protein seed crops

Field bean: cultivar trial

Of the 52 cultivars and breeding lines included in this year's expanded trial eight are also in current National Trials, and others were lines or cultivars obtained from various sources including the PBI/SCRI bean breeding project. Overall average yield was 3.7 t/ha (15% m.c.). The highest yield was again obtained from Minica (4.8 t/ha) which was slightly earlier in maturity than Maris Bead. Of the other named cultivars

[1] Broom's Barn Experimental Station
[2] RES

Stella and Maris Bead with 3.4 t/ha were the lowest yielding. Two of the PBI/SCRI breeding lines (64/16 and HF 12/23) produced high yields exceeding 4 t/ha, and were 9 and 4 days earlier than the Maris Bead.

(R. Thompson, H. Taylor)

Fodder pea: cultivar trial

The same nine cultivars as last year were again examined and included the named Finale, Amino, Columba, Maro and Birte. The earliest was the semi-leafless 159-5 which reached maturity about 20 August, while seed of the latest (Maro) still had *c.* 30% m.c. at the end of August. Yields of the semi-leafless types with a maximum of 4 t/ha were lower than those of the conventional, which did not differ significantly from each other and reached a maximum of 5.8 t/ha for Birte. Protein contents ranged from 23% for Birte and Maro to 18% for an unnamed semi-leafless type (347-5).

(R. Thompson, H. Taylor)

FRUIT CROPS

PU 11(a) Study physiological factors affecting the maturation and quality of raspberry fruits

As little is known about the changes in raspberry fruit composition during ripening, berries were analysed for the major constituents, citric acid, potassium and reducing and non-reducing sugars. Fruits of five cultivars were examined at six stages of ripeness, from under-ripe to very over-ripe as judged by colour. The mean values for the five cultivars were then used to build up the following picture of the chemical changes during ripening.

The percentage of citric acid in the juice (determined by titration) decreased from 2.8 to 1.3% (w/v) during ripening, confirming earlier observations. The percentage of soluble solids (measured by refraction) increased from 8.3 to 9.4% with increasing ripeness, indicating an increase in the total sugar content. Glucose and fructose (measured as reducing sugars) increased steadily throughout the whole range of berry ripeness from 4.3 to 6.3% (w/v). Sucrose (measured as non-reducing sugar) increased initially and reached a peak of about 1.9% (w/v) when the berries were fully ripe; subsequently the sucrose content declined possibly because of the cessation of translocation following the breakdown of the stipes which connect the receptacle to the drupelets.

The potassium in the juice decreased significantly as the berries ripened and reached a minimum of 0.13% K (on a fresh weight basis) when the berries were fully ripe. The potassium concentration then

increased to 0.16% in the very over-ripe fruit, apparently as a result of water loss at this stage.

The osmolarity of the juice (measured by freezing point depression) changed little until the berries were fully ripe.

(D. T. Mason)

PU 11(b) Study dry matter partitioning and compensation between yield components in cane fruits

Carbohydrate distribution in the raspberry plant

Manipulations of the balance between fruiting and vegetative phases has shown the potential for increasing yield. Their impact on fruit composition and processing quality are being examined in a new investigation. Selective removal of primocanes and of leaves and fruits on laterals has been used to establish the main sources of carbohydrate supply for the developing fruits. Analysis of samples has not yet been completed.

(D. T. Mason)

Black currant: bud necrosis

The extent of bud necrosis occurring in the cultivars Baldwin and Ben Lomond from an SCRI plantation were recorded from July and throughout the winter months. Samples of 25 shoots of the current season's growth were taken at regular intervals and the axillary buds dissected. Damage to the meristems occurred soon after the individual flower primordia were discernible, which was early August in Ben Lomond and slightly later in Baldwin. The number of affected buds increased more rapidly in Ben Lomond but by January they had reached a similar level (20%).

There have been reports during the year of a high incidence of damage in some commercial plantations in East Anglia and the West Midlands. In an attempt to quantify the loss in potential yield, the number of flowers present in the primary axillary buds during the dormant period were counted in Baldwin and Ben Lomond. Samples of shoots from midway up the bush were taken from a number of 3-4 year old plantations in Scotland and England. At each site the pattern of necrosis along the shoot was established and its effect on flower numbers examined. Damaged meristems reduced greatly the numbers of viable flowers present without any apparent compensation in adjacent axillary buds.

(P. A. Gill)

PU 12(a) Study physiological and cultural factors affecting the mechanical harvesting of soft fruits

RASPBERRY

Residual effects of mechanical harvesting

The plantation of cv. Glen Isla which had been picked by machine at all combinations of three forward speeds and three vigours of shake in 1982 (Ann. Rep. 1982, 167) was picked by hand in 1983 to record any residual effects of these treatments. Increasing the vigour of shake increased the number of dead canes and buds in the canes tied in for cropping and decreased fruit yields in 1983. Increasing the forward speed of the machine had little effect on bud and cane death except that the detrimental effects of increasing the vigour of shake were most severe at the lowest speed.

A plantation of cv. Malling Jewel picked by machine, by hand and alternately by machine and hand in 1982 (Ann. Rep. 1982, 168) was hand harvested in 1983. Few of the canes retained to fruit were found to be dead at leafing-out but more occurred in the machine plots than in the hand picked, with the alternated plots being intermediate. Yields followed the same pattern.

(M. R. Cormack)

Biennial cropping and mechanical harvesting

In an experiment in which several cultivars grown on the biennial system and harvested by machine are being compared with traditionally grown and hand picked cv. Malling Jewel, the number of canes retained to fruit in 1983 in the biennial plots was between 70% (Glen Isla and 5/32) and 250% (Orion and Meeker) higher than in Malling Jewel. The high winds which occurred shortly before the start of picking caused considerable damage to the laterals of Orion with a consequent reduction in yield. The heaviest yield was produced by 14/106 but the mere 30% advantage over the hand-harvested Malling Jewel was disappointing.

A slight increase over 1982 in the yield of Malling Jewel was a reflection of a similar improvement in number of canes fruiting in spite of a 6% reduction in berry size. On average, however, yields in the biennial plots were about 17% lower than in 1982 in spite of slightly higher numbers of fruiting canes. Reduced berry weight accounted for about 10% of the reduction and berry numbers per cane for about 5%. The unusually dry weather during the 1983 summer seems to have affected the biennial plots rather more than the annual Malling Jewel, possibly because of the very much high cane numbers in the biennial plots.

(M. R. Cormack)

Fruit sorting

In favourable weather conditions a proportion of the fruit picked by machine is suitable for high quality processing outlets. An experiment to test the feasibility of hand sorting on the Littau machine was carried out in a plantation of Malling Jewel. One hand sorter managed to remove about 30% of the unacceptable material and two removed about 50%, but there was no additional benefit from three sorters because they tended to impede each other on the relatively short sorting belt.

Tests with a sloping belt showed that 22% of the ripe fruit collected could be separated as whole fruit only. It appears feasible to incorporate a sloping belt in the fruit conveying system, possibly before the hand sorting belt, to allow a considerable amount of sorting to be accomplished on the machine.

(M. R. Cormack)

Laterals and pedicels

Some preliminary tests were carrried out in an attempt to measure the ability of laterals and pedicels of a number of raspberry cultivars to resist breakage. Correx gauges were used to measure the attachment strengths of laterals to canes and pedicels to laterals and these figures were related to machine harvested samples. It was concluded that the techniques require modification before they could be usefully employed in screening breeder's material.

(M. R. Cormack)

PU 12(b) Select cultivars and devise production methods for soft fruit crops in Northern Britain

Cane vigour control in raspberry

In conjunction with ESCA, experiments were commenced at Castle Huntly to investigate the potential for cane vigour control in the new cultivars Glen Moy and Glen Prosen. Treatments involve removal of the first flush of vegetative canes at 15 cm height every year, every second year or every third year, all in comparison with untreated plots. One series of treatments began in 1983 (when the plantations were beginning their third growing season) and a second series is due to start in 1984.

Cane removal in 1983 gave increases in fruit yield of 45% in Glen Moy and 34% in Glen Prosen, due mainly to the production of more berries per fruiting cane on treated plots. This was offset by very poor growth of replacement canes, which may have been due to the stools being insufficiently well established to tolerate cane removal in 1983, the poor growing conditions caused by the very wet spring and dry summer, or to a combination of both factors. The series of plots due to be treated for the first time in 1984 should provide information on these points.

(H. M. Lawson, M. E. Halford[1], J. S. Wiseman)

[1]Crop Division, ESCA

National Fruit Trial of raspberries, 1980

The poor soil physical conditions of the site of this trial have resulted in unsatisfactory growth. No selection has significantly outyielded cv. Glen Clova, but 7515C5 produced attractive fresh fruit which also had exceptionally good freezing and canning qualities.

(M. R. Cormack)

Strawberry cultivars

Thirteen advanced selections from the discontinued breeding programme were included in a cultivar trial established in spring 1983. They will be grown as spaced plants and compared with spaced Cambridge Vigour and with Cambridge Favourite grown both in matted and spaced plant rows.

(M. R. Cormack)

Yield trials of blackberry cultivars and Rubus *species*

Ashton Cross (18 t/ha) and Bedford Giant (14 t/ha) produced the heaviest yields. Chehalem and Marionberry produced about 9 t/ha, Oregon Thornless about 8 t/ha and Tayberry about 7 t/ha. Fruit quality was good. Tayberry mean berry weight was 6.8 g, Marionberry 4.8 g, Bedford Giant 3.4 g and Chehalem, Oregon Thornless and Ashton Cross about 2.4 g.

A number of species were discarded, including Boysenberry which had proved to be almost completely winter tender at this site.

(M. R. Cormack)

Vaccinium species

Mature plants of highbush blueberry cultivars Bluecrop and Berkeley received either continual drip irrigation throughout the dry summers of 1982 and 1983 or no irrigation. Vegetative growth, measured in the 1982/83 winter, showed increases due to irrigation of 58% in whip numbers and 24% in whip lengths. Whip growth was more prolific in Bluecrop than in Berkeley.

Across cultivars, irrigation increased yield by 60% and fruit size by 54%.

In an experiment designed to test ways of reducing the establishment period of highbush blueberries, both clear and black polythene mulches increased growth rate of young plants.

(M. R. Cormack)

Windbreaks

In a trial of a number of poplar species planted in 1979, the hybrid *Populus trichocarpa* × *tacamahaca*, clone 32, is growing most rapidly at over 1 m per year. It is showing a strong upright growth habit and is amongst the earliest species to break bud and the latest to lose leaves. In other, older experimental windbreaks, *Populus* × *generosa* remains the

most vigorous of a row comprising a number of genera, and *Salix alba coerulea* is the most promising of a number of willow species.

(M. R. Cormack)

PU 1(b) Study weed biology and herbicide activity in crop rotations

Weed seed banks in arable soils

Soil samples collected from 100 fields throughout Scotland which grew swedes in 1982 are being analysed for weed seed content. The objective is to determine the weed flora associated with rotations in which swedes are grown and to develop predictive weed control recommendations for this and subsequent crops. This should permit more effective choice of herbicide and help to prevent the build-up of problem weed species in the rotation.

(H. M. Lawson)

Weed control practices in swede

Information on herbicide usage was sought at the time of collection of the above soil samples and notes were taken on the weed species present. These data together with the results of analysis of organic matter and soil acidity (by MISR) from the relevant soil samples has yielded useful information on the techniques of weed control practised in the swede crop and on their efficacy.

In 1982, swedes were grown mainly on light-medium soils of relatively high organic matter status and of 5.0-6.5 pH range. Spring barley was the most common preceding and subsequent crop. The main herbicide used for annual weed control was trifluralin, although propachlor and a trifluralin/napropamide mixture were popular in north east Scotland. Herbicides were not used on 42% of the fields surveyed. Trifluralin/napropamide gave the best annual weed control, but supplementary hand and mechanical cultivations were an important part of all weed control programmes, averaging 2.6 cultivations/field on untreated crops and 2.2/field on crops treated with herbicides. Soils with 10-20% organic matter required more supplementary cultivation after herbicides than those in the 5-10% range, but soil pH did not affect herbicide performance. Annual grasses and common chickweed (*Stellaria media*) were the main weeds found in autumn on fields originally treated with propachlor or with no herbicide, while brassica weeds and annual grasses predominated in fields treated with trifluralin alone or in mixture with napropamide.

This information will be of considerable help in the evaluation of new herbicide treatments for the swede crop and in the development of weed control programmes suited to different areas of Scotland.

(H. M. Lawson, B. Boag[1])

[1]Zoology Department

Herbicide residues

Following 2 years' reports by Scottish Agricultural Colleges that spring barley crops were being injured by residues of napropamide originating from the use of this herbicide in the previous swede crop, a residue prediction programme has been set up at SCRI. Adapting a model devised by A. Walker[1], 12 years' weather data (temperature and rainfall) from SCRI meteorological records has been used to predict the average persistence of napropamide after application to swedes in May of one year until the likely drilling time of barley (March) of the following year. Current season's data are compared against the long-term average and against years when injury was known to occur. Potential problems are notified to the advisers for dissemination to farmers.

The programme will be extended to include other potential residue hazards from the use of persistent herbicides in agricultural and horticultural rotations in Scotland.

(H. M. Lawson, D. K. L. MacKerron)

PU 9(a) Study herbicide tolerance and control of weeds in arable crops

Herbicide evaluation: potato

Glufosinate applied at 0.6 kg a.i./ha to potato cv. Maris Piper again caused slightly more initial injury to the crop than did the standard rate of paraquat. Application at 35% crop emergence had no adverse effect on tuber yield, but treatment with either herbicide at 80% emergence reduced yield by *c.* 18% in comparison with that of untreated plots. These results confirm that, as is the case with paraquat, glufosinate should be applied strictly pre-emergence to seed potato crops. Bentazone at 1.4 kg a.i./ha appeared safe to the crop at either stage of growth and is worth further examination as a post-emergence herbicide for the potato crop.

Three potential residual herbicides for potato were evaluated for crop safety against a standard – terbutryne/terbuthylazine, with application either 10 days after planting or at 10% emergence of Maris Piper. None of the post-planting treatments adversely affected crop growth or yield. Treatments at 10% emergence with terbutryne/terbuthylazine (1.4 kg a.i./ha) caused yellowing of treated foliage and reduced tuber yield by 11% in comparison with untreated plots; pendimethalin at 2.0 kg a.i./ha caused leaf rolling, which persisted until harvest and a yield reduction of 13% was recorded, while CME 12701 at 2.1 kg a.i./ha caused marginal leaf yellowing and reduced yield by 21%. By contrast, fluorochloridone at 0.75 kg a.i./ha bleached all emerged foliage as well as affecting foliage which emerged over the next few days, but had no adverse effect on subsequent growth or yield.

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[1]NVRS

In the prolonged wet soil conditions which occurred in spring 1983, crop injury in response to applications of residual herbicides at first emergence was not unexpected. Nevertheless, the marked foliar effects of fluorochloridone and pendimethalin and the relatively large yield loss with CME 12701 suggest that for seed potato crops these herbicides would be best applied well before crop emergence.

Tubers from all the above experiments will be chitted early in 1984 and examined for any residual effects of herbicides on shoot development. No adverse effects on chitting or subsequent growth in the field were recorded in tubers from a 1982 experiment treated with glufosinate or paraquat at 20 or 80% crop emergence.

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

Herbicide evaluation: swede

Further evaluation of crop tolerance to tebutam and metazachlor alone and in mixtures with other swede herbicides has confirmed the adequate safety margin of both chemicals when applied pre-emergence. Collaborative trials by the SAC Weeds Group have demonstrated useful improvements in weed control in swede crops when these chemicals have been included in herbicide programmes.

Alachlor, for the second year running, caused more injury to swede cv. Marian than the above two herbicides or propachlor, all applied as pre-emergence treatments alone or in mixtures. This herbicide appears to have insufficient margin of safety for use in swedes at rates required for effective weed control.

Examination of crop tolerance to a range of possible mixtures of post-emergence herbicides, designed to extend the limited spectrum of weed species controlled by clopyralid (3,6 dichloropicolinic acid), confirmed the safety of benazolin in these mixtures; ethofumesate and DOWCO 433 were, however, much too damaging for further investigation to be worthwhile.

A mixture of carbetamide and dimefuron showed promise for pre-emergence application to swede, but post-emergence treatment caused unacceptable leaf scorch at half the suggested rate.

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

PU 10(f) Study herbicide tolerance and the ecology and control of weeds in soft fruit crops

HORTIHERB: an on-line information retrieval system

A herbicide information retrieval system has been produced in co-operation with the Data Processing Department to aid the identification of solutions for weed control problems. The file, named HORTIHERB, is stored on EMAS and is accessed via VIEW, a system for browsing through text which uses either video or hard copy terminals, and displays

one page of text at a time. A particular page is called up by keying CROP, WEED or HERBICIDE and by then proceeding to the appropriate sub-section, or by keying an individual crop, weed or herbicide. The user is able to select herbicides appropriate for use at particular ages of individual crops, verify their weed control spectrum and efficacy, and to consult information on availability, usage and source of supply. A STOP-PRESS section acts as a temporary repository for new information until the file is updated and a FEEDBACK section allows the user to communicate problems and more detailed queries, etc. to the authors via EMAS.

HORTIHERB was made available in March to horticultural advisers of the Scottish Agricultural Colleges and in July 1983 to ADAS via the British Telecom Packet Switched Network. Initial responses have been favourable and the list of users is increasing steadily. The file is also proving useful as a reference source for research workers and others who require access to up-to-date information on herbicides.

(H. M. Lawson, R. J. Clark[1])

PU 14(c) Study herbicide tolerance and the ecology and control of weeds in vegetable crops

Weed/crop competition

Data on dry matter accumulation by weeds in the presence or absence of vining peas at five densities were subjected to Principal Component Analysis as a measure of changes in the structure and behaviour of the weed flora. Analysis showed that most of the variability in weed dry weights could be accounted for by a 'size' component in which all the loadings had the same sign and their size reflected the quantity and so the importance of the various species on each plot. A second component represented a negative relationship between the major species – *Chenopodium album* – and the other species present. Species appeared to be suppressed in proportion to their importance in the first component. Subsequent components varied considerably and seemed to represent random variabliity in weed distribution between plots. The scores calculated using these loadings were subjected to analysis of variance. Those for the first component showed highly significant effects of crop density and date of sampling, agreeing closely with the total dry weight of weeds. None of the subsequent components showed similar effects. The results indicated that increasing competition from the pea crop affected weed species uniformly and did not exert selection pressure. *C. album* competed strongly with other weed species but its relative competitiveness was not affected by changes in crop density.

(H. M. Lawson, P. B. Topham[1])

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[1]Data Processing Department

CHEMISTRY

M. J. ALLISON

The main work of the Chemistry Department concerns the routine estimation of quality factors important in plant breeding. A high turnover of staff reduced the number of samples which were analysed compared with previous years, and where possible they were done on a priority basis. Routine chemical estimations included SMCO in brassicas (950 samples); thiocyanates in brassicas (554 samples); the malting quality of barley (843 samples), nitrogen content (1,980 barley and brassica samples), the digestibility of kale (754 samples) and the total glycoalkaloid of potato tubers by a dye binding method (50 samples).

During the year it was found that estimations of malting quality using the Carlsberg malt analyser agreed well with the results from micro-malting analyses. As the Carlsberg analyser requires only 100 malted grains per sample this test could be incorporated as part of the screening system for malting quality. Electrophoretic separations in SDS PAGE of barley hordein proteins were continued as a means of monitoring gene transfer in crosses with irradiated pollen. A start was made to investigate the use of electrophoretic systems for protein and enzyme evaluation in potato, so that this could be used, like the hordeins in barley, to monitor gene transfer in irradiated pollen crosees. Experiments using near infra-red (NIR) analysis were also initiated to investigate and identify the adhesive material associated with *Phytophthora infestans* zoospores and sporangia viewed under the scanning electron microscope.

Other continuing collaborative work included studies on the cell wall digestibility of kales. This work progressed well and results from a series of digestions of cell walls from different tissues of kale indicated that the amount of vascular tissue, particularly in the lower stem fraction, strongly influences whole plant digestibility.

New work on NIR analysis this year included the application of statistical methods to aid analysis on the Neotec 6350. This included completion of the software for Principal Components Analysis and for a normalisation program (removal of the effects of different particle sizes on overall absorbances). Because of these improvements in spectral data treatment, it was possible to re-analyse some experiments and investigate the main causes of variation in the spectral data. When this was applied to estimates of the malting quality of barley, NIR prediction continued to be unsuccessful. This may be due, at least in part, to the fact that

only a small fraction (0.34%) of the spectral variation showed any correlation with extract values. A more successful application was observed for Italian and perennial ryegrass digestibility (in collaboration with NIAB). In both instances digestibility could be predicted using the first principal component to give values that correlated highly with those obtained using the manual method.

In another collaborative study on mite infestation in animal feeds (with the MAFF Stored Products Laboratories, Slough) preliminary results showed that NIR estimates of mite damage correlated highly ($r>0.98$) with the manual estimates. Some initial work on NIR prediction of the starch and protein content of potato, started this year, also looked promising. The development of NIR methods for the rapid estimation of spore-counts for three major barley pathogens (Ann Rep. 1982, 173) was continued and, after further confirmation of the calibration equation, the method was brought into routine use. There was also a successful extension of the method to include NIR prediction of spore counts of powdery mildew in brassica.

It was evident again this year that there are more important goitrogens in forage rape than those derived from indoleglucosinolates. Methods for the measurement of progoitrin are under investigation. It was also apparent that the autoanalyser method, which includes a separating column for the determination of SMCO, is too slow and new methods are being explored. A lengthy test is also used for the estimation of total glycoalkaloid content of potato (eight samples analysed per 2 days) and, for some samples at least, the test gave variable results. A modification of the ELISA test has been proposed as a more rapid method for glycoalkaloid estimation. New tests, such as this, are needed so that large numbers of samples can be analysed efficiently. It is hoped that the advances made this year in technology will lead to an increase in successful applications of NIR to the routine workload.

(M. J. Allison)

PU 1(a) Develop NIR analyses to predict specific biochemical components in crops and pathogens

Progress was made in developing and using near infra-red analysis (NIR) in three area: improvements in the use of NIR technology, as a tool for plant pathologists, and new applications of NIR.

One factor limiting the potential exploitation of NIR analysis has been the lack of statistical programs for the recognition of trends in the spectral data. Collaborative work with J. W. McNicol[1] and R. Thomson[2] led to the development of a system using Principal Component analysis

[1] Data Processing Department

[2] ARCUS

to highlight trends in the spectral data. A suite of new programs was written (including a normalisation program for removal of the effects of different particle sizes on absorption data) on EMAS for use with the Neotec 6350. Principal Component analysis has a number of applications in NIR work, including the construction of multiple regression equations for prediction of quality factors of interest, the identification of outliers and as an aid to selection of samples for calibration.

NIR combined with Principal Component analysis was used during the year to predict the malting quality of barley, and the digestibility of Italian and perennial ryegrass. The latter was the more successful of the two with predicted digestibility values correlating highly with those from the manual method ($r>0.90$). The prediction of malting quality was relatively unsuccessful, probably largely due to low correlations between predicted and manual values, over the first five Principal Components.

The success of NIR in predicting spore counts of the major foliar pathogens of barley (Ann Rep. 1982, 173) was confirmed this year and the method was brought into routine use. It was confirmed that the high precision of the method permits discrimination between different levels of partial resistance. This method was applied to spore counts of powdery mildew to brassica. Good progress was made during the year on the collaborative work in the NIR prediction of mite infestation damage in flour and on NIR analysis of kale digestibility.

Possible new applications of NIR include the determination of protein and starch contents in potato. It is also likely that the Principal Components facility will allow a wide application of NIR analyses.

(I. A. Cowe)

PU 2(f) Develop and use automated tests for malting, distilling, brewing and milling quality

Screening tests developed at SCRI for early generation selection for the malting quality of barley include measurements made of the energy required to mill samples, and NIR predicted estimates of nitrogen and β glucan contents. These estimates are made on unmalted barley grains and take no account of malt enzyme production. At later stages in the programme there is sufficient grain to micromalt. This year the Carlsberg malt analyser was included among the screening tests in an attempt to estimate malt hydrolase activity at early generation stages.

In this new test 50 malted grains are embedded in a thermoplastic block which is then hardened by heating at 100°C for 10 minutes. The blocks are sanded down to expose the endosperm surface and the cell walls are stained with calcofluor white M2R. This dye forms a fluorescent complex with stretches of β1, 3 and β1,4 linkages in cell wall β glucan polymers. When viewed under u.v. the degree of cell wall breakdown by malt hydrolysis can be estimated visually with reference to standards. Preliminary experiments showed that malt analyser results

correlated highly with extract values obtained after micromalting. However, a small scale malting of about 10 g (minimalting) is required to make the test feasible at F_3 and F_4 generation stages. These preliminary results are promising and the test merits further investigation.

(I. A. Cowe, F. M. Bruce)

PU 2(d) Study genetics and biochemistry of cereals and develop breeding methods

The application of the irradiated pollen method of crossing to achieve a limited transfer of the pollen parent's genome to the progeny continued this year. SDS PAGE was used to monitor gene transfer by investigating HOR 1 and HOR 2 segregation ratios in the M_3 progeny. Many of the crosses analysed during the year produced a marked preponderance of maternal-like progeny, which indicates that the pollen irradiation method can be used to inactivate genes from the pollen parent.

(M. J. Allison)

PU 5(l) Develop and use screening tests for important compounds in brassica breeding material

It became more evident from this year's results that indoleglucosinolate products such as the thiocynate ion are not always the most important goitrogen in the brassica material under investigation. In forage rapes the indoleglucosinolates are at a uniformly low level, whereas progoitrin is present in relatively large amounts.

It was also apparent from this year's results that the automated procedure for the estimation of SMCO is too slow to cope adequately with the gradually increasing numbers for analysis (currently >1,000 per year). The ion exchange column in the system limits throughput to 30 samples per day and so alternative methods of separating SMCO from the free maino acid pool are under investigation. Digestibility estimations were made this year using the cellulase solubility method. It is hoped that the work with M. C. Jarvis[1] on the digestion of brassica cell walls which progressed well this year, will provide a sound basis for the selection of a robust NIR prediction equation for brassica digestibility. Preliminary results indicate that the vascular tissue from the lower stems plays an important role in determining whole plant digestibility.

(M. J. Allison)

PU 6(g) Develop and use screening tests for important biochemical compounds in potato breeding material

The method used during the year to determine the glycoalkaloid content of potato tubers was a modification of the dye-binding method developed

[1]Agricultural Chemistry Department, Glasgow University

at FRI. Operator-dependent results prompted further investigation of the test and it was found that, at least for some potato selections, extractions of the alkaloids was inefficient. The method is also very slow (eight samples per 2 days) and is too slow to screen a breeding programme efficiently. It was reported this year that a modified ELISA test can be used for the rapid estimation of glycoalkaloid content of tubers. As ELISA test equipment is available it will be possible to investigate this option. However, the gas capillary chromatograph was used to establish that solanidine is the major acid hydrolysis product in *Solanum tuberosum* and this will continue to be useful in monitoring breeding material for new alkaloid species which might not be detected by the ELISA method.

(M. J. Allison)

DATA PROCESSING

P. B. TOPHAM

A common approach has been adopted at both sites to microcomputing and support for data acquisition from balances, hand held terminals, barcode readers and laboratory instruments. Some differences remain; for historical reasons work stations are distributed throughout user departments at Pentlandfield but concentrated in DP rooms at Mylnefield. It became clear at Mylnefield that microcomputing was too integrated with mainframe usage to be kept separate there and R. J. Clark now manages both aspects. To avoid overlap and confused responsibilities, programming effort at both sites is being co-ordinated by J. W. McNicol; the importance of this area is shown by the selection of projects in later sections.

A new method of budgetary control was introduced for departmental expenditure on mainframe facilities; departments estimated their requirements in the spring on the basis of previous years' expenditure and received monthly information on the expenditure of their allocation. With a total of 69 user numbers (see below), fluctuations in individual activity tended to balance out and the overall figures were comparatively stable.

COMPUTER USAGE 1983

Department	2988 Log-ons	%	ERCC User Nos.	Graph Plotter No.	%
Cereal Breeding	787	11.7	6	–	–
Chemistry	301	4.5	3	–	–
Data Processing	1316	19.5	8	154	14.1
Estates	46	0.7	2	–	–
Forage Brassica Breeding	300	4.5	4	–	–
Libraries	252	3.7	2	–	–
Mycology & Bacteriology	418	6.2	8	262	24.5
Physiology & Crop Production	1374	20.4	13	427	39.3
Potato Breeding	1044	15.5	13	–	–
Soft Fruit Breeding	172	2.6	3	41	3.7
Virology	104	1.5	1	157	14.4
Zoology	615	9.1	6	43	4.0
	6739	–	69	1084	–

Training and support for users are continuous processes, much of which have to be carried out in real-time. A duty roster of advisers at Mylnefield provides continuous cover. Courses in GENSTAT, EMAS, Pascal programming and biometry were provided locally; many users also attend various ERCC courses.

Planning the data processing facilities in the new building involved discussions with the architects, ERCC staff and users as well as visits to facilities elsewhere.

Contacts have been maintained with the AFRC Unit of Statistics.

Equipment: image analysis

A Quantimet 900 image analysis system was acquired which comprises a Newvicon scanner, image store and image processor controlled by an LSI11/23 minicomputer and a graphics display unit. The scanner is used with either a microscope or macro-viewer. The image is digitised at 896 × 704 picture points and 256 grey levels with an image store of 3 Mbits for grey or binary images; the latter are created by detection of features above or below specified grey level thresholds. Such binary images may be modified by erosion or dilation, edited using a light pen, and combined in different ways to select features of interest. A variety of measurements of the whole image and on individual features may be calculated, such as area, perimeter, Feret (caliper) diameters, and integrated optical density.

The Quantimet is powerful and easy to use. The results of each image processing operation are displayed immediately and applications developed interactively via a series of menus. A fully developed program can then be stored on a floppy disk for subsequent routine use.

It will be used in quantitative histochemistry, using integrated optical density to measure DNA, RNA and protein in selected individual cells in studies of plant-nematode interaction; and in interferometric determination of section thickness for light microscopy. It also has potential for imaging plant viruses; for detecting spots of protein or RNA separated by 1- and 2-dimensional gel electrophoresis; for studying variation in potato shape; for measuring crop canopy cover from photographic slides; for assessing leaf area and number of lesions caused by fungal or viral pathogens; and for studying the effect of nematode invasion on potato root systems.

(P. Smith)

Equipment: general

The equipment providing access to the ERCC mainframe was enhanced at both sites: at Pentlandfield a line printer has improved turnround time. At Mylnefield an eight-port expansion for the PDP 11/10 terminal control processor was installed in March and communications lines taken to various buildings: a visual display unit (VDU) was installed in the

Library to facilitate literature searches, and Apple microcomputers can be used as terminals or with balances in the crop handling buildings of the Forage Brassica Breeding and the Physiology and Crop Production Departments.

At Pentlandfield the Corvus hard disk has run satisfactorily throughout the year supporting two Apples simultaneously; the relatively fast disk access time was of great benefit to program development. Three Apples with Epson FX80 printers were acquired for Mylnefield; they were in such continuous use for data entry and as work stations that the last card punch was discontinued after 15 years, as was the practice of keeping a record of microcomputer usage. The Pentlandfield Wang 2000 minicomputer no longer justified the maintenance costs, and was discarded.

Epson HX20 portable microcomputers were added to the supported computing facilities and proved successful in several data capture applications. Their portability, integral printer, integral cassette drive and battery operated power supply make them suitable for use in any indoor environment. We expect that they will replace the Apples for much existing data capture work and extend the range of data gathering tasks which can benefit from the introduction of computers. For field recording our first impressions were that the Epsons will be more suitable for field recording than the M50F hand held terminals; the former are fully programmable and their liquid crystal display enables the screen to be read in strong sunlight.

Two programs only have been provided for the Epsons. The first is a general purpose data capture program to which small modifications are made to suit each application. The data are assumed to have come from a designed experiment. A maximum of three codes can be used to identify each experimental unit, for which up to 10 variables can be scored. The data can be entered from the Epson keyboard or directly from a Mettler balance. The second program is used to transfer data from an Epson to the UCSD environment on an Apple. The Apple program, which is run concurrently with the Epson program, allows some manipulation of the data. Analysis of the data is carried out either in the UCSD environment or on the mainframe under EMAS.

A BBC microcomputer was purchased for a laboratory instrumentation project for the Mycology and Bacteriology Department, since the ERCC provide appropriate communications and other support for their use in real-time applications. To simplify programming and support, the BBC micro will be used in single-purpose systems which are cheap enough to make idle time acceptable.

(P. B. Topham, J. W. McNicol, R. J. Clark, R. Kidger)

Programming

The efficient use of microcomputers by most scientists depends on the provision of suitable applications programs. As a result maintenance and improvement of existing programs become important and included a revision of the utility programs providing software tools for USCD Pascal programming; enhancements to various balance programs; the revisions of the culture collection labelling and listing program; and the transfer of a non-linear regression program for nucleic acid kinetics to the 2988 mainframe to allow use of the graph plotter.

Studies of crop environment were supported by writing a program to estimate accumulated natural evaporation using the Penman formula and another to transfer data from a Freeman Enercon temperature and humidity recorder, graph selected periods and calculate various summary statistics; both programs used Pascal for an Apple.

To support studies of the phytoalexin rishitin programs were written for a BBC microcomputer to monitor bacterial respiration using paired oxygen electrodes. In this system, the digital noise on the BBC's analogue to digital converter is reduced by averaging and the trace of oxygen against time is displayed on a screen using high resolution graphics. Data are stored on disk and transferred to EMAS for analysis. The system allows the operator to validate the initial experimental conditions before committing valuable rishitin. It replaced an earlier system using a chart recorder and subsequent digitisation which was less accurate and more laborious.

(J. W. McNicol, J. B. Cowan, R. Kidger)

Statistics

Much of the work consisted of support for routine analyses carried out by research workers. More substantial involvement is indicated by items in the reports of the Physiology and Crop Production and the Zoology Departments.

The use of principal components was developed extensively with the Chemistry Department in the statistical analysis of the near infra-red spectra produced by the Neotec 6350 scanning infra-red composition analyser. A sample spectrum consists of reflectance energy measurements at each of 700 wavelengths. Principal components provide a valuable aid in the examination of a set of spectra. Plots of the principal component weights often reveal much more clearly than the original spectral graphs those areas of the spectrum at which there is relatively high variation. By matching these areas with known absorbance bands it is sometimes possible to identify the cause of the variation. The generation of a calibration equation by multiple regression relating a constituent of interest to reflectance energies at a small number of wavelengths is made difficult both by the very high correlations between the reflectance energy

scores, and by the large number of wavelengths involved. The use of the principal components rather than the wavelength energies as the independent variables in the calibration equations is operationally simpler. However neither method has yet been shown to be clearly superior in predictive ability. Identification of outliers in the spectral data is also simplified by examining plots of scores on one principal component against those on another. The programs which provide the statistical analysis of the spectral data are based on software supplied by AFRCUS. They are written for the 2988 mainframe using both GENSTAT and FORTRAN 77. Three main facilities are provided: the generation of sample spectra principal components; the generation and validation of regression models (calibration equations) using either wavelength energies or principal components; the detection of outliers.

Forecasting the date of crop maturity is important for the efficient running of farm operations and for meeting the requirements of processors for a continuous supply. Records of calabrese in four years were related to meteorological variables using multiple regression techniques; these equations were then evaluated by comparing their forecasts with the maturity dates of another, commercially grown crop.

(P. B. Topham, J. W. McNicol, J. B. Cowan, P. Smith)

Data management

Several new bibliographic and other catalogues were begun by users and required considerable support in the early stages; these included the potato physiology literature collection and records of nematology electron micrographs. The computerised catalogues of raspberry reprints and black currant literature references were continued, but that referring to the photograph and slide collection was discontinued due to lack of use.

HORTIHERB (see Physiology and Crop Production) was established using VIEW, a generally available view-data facility which is the basis of various ERCC information systems. A special process was set up by the ERCC allowing restricted access by non-accredited users limited to inspecting data and leaving messages. The facility was reviewed with ERCC system design staff to ensure that as HORTIHERB expands it remains fast and easy to use. Some text handling routines were written to assist in maintaining and extending HORTIHERB, to tabulate data for checking, to cross reference it and to check spelling.

(R. J. Clark)

VIROLOGY

B. D. HARRISON

One result of the rapid increase in number and sophistication of the molecular biological techniques that have important applications in plant virology is the increase in collaboration with other research groups both in Britain and overseas. This report provides some examples of the advantages gained from this type of collaboration. Newer techniques have also made it possible to assess the similarity in nucleotide sequence of the genetic material of different viruses. The results of such comparisons in three groups of viruses that have contrasting types of bipartite genome indicate that a different pattern of variation occurs in each group. In two tobraviruses, tobacco rattle and pea early-browning viruses, the larger genome segment is strongly conserved whereas the smaller segment, which contains the particle protein gene, is very variable. In contrast, in the geminiviruses the nucleic acid species containing the particle protein gene seems the more strongly conserved of the two genome segments, and in the nepoviruses our previous work showed that the two genome parts are more or less equally variable. These different patterns presumably represent responses to different sets of selection pressures but they may also reflect the limitations imposed by different kinds of genome organisation on the ways in which viruses can adapt to new environmental conditions, hosts or vectors.

Other noteworthy results described below include the first steps towards a serological detection method for a previously intractable but common aphid-borne virus infecting raspberry, characterisation of two contrasting mechanisms of virus resistance in potato, maintenance of virus freedom in the scheme for field propagation of virus-tested narcissus, discovery of a series of serological relationships among geminiviruses and evidence that the small circular RNA in cultures of solanum nodiflorum mottle virus is a satellite nucleic acid and not, as suggested by work elsewhere, an essential part of the virus genome.

PU 1(j) Study molecular aspects of the biological properties of viruses especially nepoviruses and tobraviruses

Relationships between pea early-browning virus (PEBV) strains

Hybridization experiments using complementary DNA copies of genome RNA preparations showed RNA-1 of an isolate of the Dutch serotype of pea early-browning virus (PEBV-D)* has extensive sequence homology

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with RNA-1 of isolates of the English serotype (PEBV-E) and of broad bean yellow band virus (BBYBV)*, a recently described virus received from G. P. Martelli[1]. However the RNA-2 species of PEBV-D, PEBV-E and BBYBV have little or no sequence homology with one another. The pattern of variation in the genome RNA species of these isolates is therefore similar to that found previously among serotype I/II strains of tobacco rattle virus (TRV).

In immunosorbent electron microscopy (ISEM) tests, BBYBV proved to be serologically related to PEBV-D and PEBV-E, but not closely; it was less distantly related to PEBV-D than to PEBV-E. BBYBV particles were also trapped by antiserum to the CAM isolate of TRV although no reaction was detected in reciprocal tests. This reaction was unexpected (see p.93) and may be an artifact.

In attempts to produce pseudo-recombinants, isolates containing BBYBV RNA-1 + PEBV-D RNA-2, PEBV-E RNA-1 + BBYBV RNA-2 and PEBV-E RNA-1 + PEBV-D RNA-2 were obtained, the last two apparently having novel combinations of biological properties. There seem to be no barriers to the free interchange of genome segments between these strains. In contrast, attempts to produce a pseudo-recombinant isolate containing RNA-1 of TRV and RNA-2 of BBYBV were unsuccessful. It is concluded that BBYBV is a new serological form of PEBV, and the designation PEBV-BBYB is proposed.

(D. J. Robinson, B. D. Harrison, I. M. Roberts)

Putative naturally occurring pseudo-recombinant isolates of tobraviruses

Nucleic acid hybridization tests described in last year's report indicated that isolate Italy 6* has a RNA-1 species consisting largely or completely of nucleotide sequences typical of RNA-1 of TRV serotype I/II, and a RNA-2 species similar to that of PEBV-E.

In further tests, pseudo-recombinant isolates containing RNA-1 of TRV strain SYM and RNA-2 of Italy 6 were obtained readily, and had properties similar to those of Italy 6. A pseudo-recombinant isolate containing PEBV-E RNA-1 + Italy 6 RNA-2 also was obtained, but few of its nucleoprotein particles contained RNA-1. It induced symptoms typical of Italy 6 in *Phaseolus vulgaris,* a character which is determined by RNA-1 in some other tobravirus isolates.

A second isolate, NAR5, originally obtained from narcissus, was found to have nucleotide sequences typical of the RNA-1 of TRV serotype I/II and of the RNA-2 of PEBV-D. As predicted from this observation, serological tests showed that NAR5 is related to PEBV-D. However, the RNA-2 of NAR5 readily formed particle-producing pseudo-recombinant

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[1]Istituto di Patologia Vegetale, Bari, Italy

isolates when added to the RNA-1 of TRV serotype I/II. Initial indications are, therefore, that both Italy 6 and NAR5 are naturally occurring pseudo-recombinants of TRV and PEBV, and that in their biological properties they are closer to TRV than to PEBV.

(D. J. Robinson, B. D. Harrison, W. P. Mowat)

*Relationship between tomato black ring virus (TBRV) and artichoke Italian latent virus (AILV)**

In hybridization experiments using complementary DNA, about 20% sequence homology was detected between AILV RNA and RNA-1 from TBRV strains belonging to both Scottish and German* serotypes. In contrast, AILV RNA was found to contain about 30% of the sequences of RNA-2 from the Scottish serotype of TBRV, but a smaller proportion of sequences of RNA-2 from the German serotype. These amounts of homology suggest that AILV is more closely related to TBRV than are either cocoa necrosis virus* or grapevine chrome mosaic virus,* both of which are serologically related to TBRV.

A previously undetected distant serological relationship between AILV and TBRV was found using ISEM and this relationship was confirmed in gel diffusion precipitin tests. Together with the similar vector specificity and biophysical properties of AILV and TBRV, these results indicate that AILV should be included in the same nepovirus sub-group as TBRV.

(S. M. Dodd, D. J. Robinson)

Genome and serological relationships among geminiviruses

The number of members of this recently described group of plant viruses is increasing rapidly but information on their inter-relationships is fragmentary. The generous co-operation of colleagues in many countries has now enabled nucleic acid hybridization and serological tests for relationships to be done. In the nucleic acid hybridization tests, probes prepared by nick-translation of DNA clones (provided by J. Stanley[1]) representing each of the two DNA genome segments of a Kenyan isolate of African cassava mosaic virus, previously called cassava latent virus, were used to search for homologous nucleotide sequences in nucleic acid extracted from imported leaf material infected with a range of other geminiviruses. No reaction was detected, in spot hybridization tests, between the DNA-2 probe and any of the extracted nucleic acids. In contrast, the DNA-1 probe reacted with the nucleic acids of bean golden mosaic (Puerto Rico)†, honeysuckle yellow vein mosaic (UK), tobacco leaf curl (Japan)†, tomato golden mosaic (Brazil)†, tomato leaf curl (Egypt)† and tomato yellow leaf curl (Lebanon)† viruses, all of which are

[1] JII

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reported to be transmitted by the whitefly, *Bemisia tabaci*. However, no reaction was obtained between the DNA-1 probe and nucleic acid extracted from leaves infected with beet curly top (USA)†, maize streak (Nigeria)†, wheat dwarf (Sweden)† or solanum atypical leaf curling (Peru)† viruses, the first three of which have leafhopper vectors. The nucleotide sequence relationships were detected only when non-stringent conditions were used for hybridization, indicating that the homologies were imperfect.

The DNA-2 of African cassava mosaic virus contains the virus particle protein gene, and ISEM tests provided evidence for a pattern of relationships similar to that obtained by nucleic acid hybridization. Using a range of antisera, relationships were found between five whitefly-transmitted viruses: African cassava mosaic*, bean golden mosaic, euphorbia mosaic (USA)†, squash leaf curl (USA) and tomato golden mosaic. In contrast, five leafhopper-transmitted viruses, namely beet curly top, chloris striate mosaic (Australia), maize streak, tobacco yellow dwarf (Australia) and wheat dwarf were apparently serologically unrelated, either to the whitefly-transmitted viruses or, with one exception, to one another. However, a distant relationship was found between beet curly top and tobacco yellow dwarf viruses. This pattern of relationships would be readily understandable if the particle proteins of geminiviruses are adapted for transmission by their specific vectors.

(D. J. Robinson, I. M. Roberts, B. D. Harrison)

Effects of temperature on the behaviour of African cassava mosaic virus (ACMV) in plants

The greatest concentrations of the West Kenyan type isolate of ACMV* in *Nicotiana benthamiana* were reached 14 to 17 days after inoculation in plants kept at 20 or 25°C. Much less virus antigen, estimated by ELISA, was produced at 30°C. At 15°C, ACMV multiplied slowly but eventually attained a peak concentration, assessed by ELISA, ISEM or DNA hybridization tests, only slightly lower than that reached at 20 or 25°C. However, the specific infectivity of virus particles produced at 15°C was only 2-4% of that of particles produced at 20-25°C. Moreover, five out of six attempts to purify ACMV particles from systemically-infected leaves of *N. benthamiana* kept at 15 or 17°C were unsuccessful, and in the remaining experiment the yield of particles was only 5% of that from plants kept at 23°C. When examined in the electron microscope, such virus particles as were purified from plants at 15°C appeared normal but DNA extracted from these particles was found to be more fragmented than DNA from virus cultured at 23°C. Most virus particles produced at 15°C therefore contain fragmented DNA, have a low specific infectivity

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and probably are fragile. These seemingly related features may represent a lack of adaptation of this tropical virus for survival in cooler environments.

ACMV-C*, a serologically distinctive strain from the east coast of Kenya, reached only low concentrations in *N. benthamiana* and, in spot hybridization tests, its nucleic acid reacted with probes prepared from only one of the genome DNA species of the type strain. It is adapted to even higher temperatures than the type strain, 30°C being the optimum temperature for infection and accumulation of virus DNA, and the temperature at which systemic symptoms were most severe.

At 30°C, ACMV isolates in mosaic-affected cassava plants from Angola* behaved more like the type isolates than like ACMV-C. Symptom intensity diminished, until after 10 weeks the new growth was symptomless. Spot hybridization tests on these symptomless leaves did not detect ACMV DNA, whereas equivalent leaves of plants kept at 22°C showed symptoms and contained ACMV DNA. Similar results were obtained with both particle-containing and particle-lacking plants of mosaic-affected cassava.

(D. J. Robinson, J. C. Sequeira, B. D. Harrison, I. M. Roberts, G. H. Duncan)

Small circular RNA molecules in sobemovirus cultures

Last year's report indicated that small circular RNA species (RNA-2) associated with each of two putative sobemoviruses, lucerne transient streak* (LTSV) and solanum nodiflorum mottle* (SNMV) viruses, behaved as satellite RNA species in association with genome RNA (RNA-1) of LTSV. Work in Australia, however, had indicated that SNMV RNA-2 is part of the SNMV genome and is necessary for SNMV infectivity. In further work, a particle-producing isolate of SNMV was cultured which synthesized RNA-1 but remained free from RNA-2 after three passages in *N. clevelandii*. Addition of SNMV RNA-2 had no appreciable effect on the infectivity of this culture for *N. debneyi* but led to the occurrence of SNMV RNA-2 in SNMV particles. Thus, contrary to the evidence from the Australian work, only the RNA-1 of SNMV is genomic, and RNA-2 seems to be a satellite RNA.

Of 14 viruses (representing 12 plant virus groups) tested, only LTSV and turnip rosette virus (TRosV) were shown to support the replication both of LTSV RNA-2 and of SNMV RNA-2: SNMV did not support the replication of LTSV RNA-2. However, the amounts of LTSV RNA-2 and SNMV RNA-2 detected in TRosV particles purified from plants inoculated with the appropriate RNA mixtures were much less than that in particles of the virus donating the RNA-2. Some RNA-2 activity was also detected in extracts made up to 15 days after inoculation from leaves

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inoculated with LTSV RNA-2 or SNMV RNA-2, either with or without viruses in the other groups. It is not known whether such activity merely reflects the stability of these small RNA molecules that is caused by their extensive secondary structure or whether they replicate in inoculated cells and fail to spread to other cells without the aid of a helper virus. Whatever the reason, the ability of these RNA-2 molecules to be packaged in the particle protein of a helper virus would seem likely to facilitate their transmission from plant to plant by vectors of the helper virus, and their ability to use different helper viruses would exploit this advantage further. Nevertheless, some specificity exists and all the viruses found to have helper ability are members or putative members of the sobemovirus group. The reason for this specificity is not clear, but it is noteworthy that the particles of sobemoviruses, unlike those of most plant viruses, are commonly found in the nuclei of infected cells, as too are viroids, which closely resemble the satellite RNA species in size and structure.

(A. T. Jones, M. A. Mayo)

Bioassays for small RNA molecules

The ability of LTSV* RNA-2 and SNMV* RNA-2 to change the type of lesion caused by LTSV RNA-1 from chlorotic to necrotic formed the basis of an extremely sensitive bioassay, capable of detecting as little as 0.001 μg RNA-2/ml. To test the possibility that similar bioassays could be used for other small RNA molecules, potato spindle tuber viroid (tests at the DAFS Plant Quarantine Unit in collaboration with P. Harris), and satellite RNA species from cucumber mosaic and tobacco ringspot viruses*, were added to inocula of LTSV RNA-1. However, no change in lesion type was observed.

(A. T. Jones, M. A. Mayo)

Translation products and RNA species of potato leafroll virus (PLRV)

Previous work (Ann. Rep. 1981) showed that PLRV RNA acts as a messenger RNA when added to rabbit reticulocyte lysates. Further translation tests, using the wheat germ system, confirmed the synthesis of polypeptides of approximate mol.wt. 7.1×10^4 and $1.2\text{-}1.4 \times 10^5$, in larger and smaller amounts, respectively. A polypeptide of $2.8\text{-}3 \times 10^4$ mol.wt. was also produced in substantial amounts; this was probably obscured by an endogenous product in analyses of the products of translation in reticulocyte lysate. Neither of the two smaller products reacted with antiserum to PLRV. In contrast, PLRV particle protein, which reacted with PLRV antiserum, was the only virus-specific polypeptide found when inoculated tobacco protoplasts were supplied with ^{35}S-methionine and the proteins in protoplast extracts were

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analysed by gel electrophoresis and autoradiography. The particle protein mainly accumulated in the second day after inoculation

(M. A. Mayo, H. Barker)

A DNA clone about 1 kb long, copied from PLRV RNA by D. Baulcombe[1], was used as a probe for PLRV RNA in extracts prepared from tobacco protoplasts 2 days after inoculation. The extracts were treated with formaldehyde, and the RNA was separated by electrophoresis in 1% agarose, then blotted to nitrocellose and PLRV-specific sequences were located by hybridization with ^{32}P-labelled DNA. Two relatively abundant species were detected of *c.* 6.4 and 3.4 kb, together with two less abundant species of 4.9 and 2.1 kb. RNA from virus particles contained a main component of 6.4 kb but no species of 3.4 kb was detected. It seems likely that the largest RNA species is the PLRV genome and that subgenomic RNA species are generated during virus multiplication.

(M. A. Mayo, D. J. Robinson, H. Barker)

Molecular biology of raspberry bushy dwarf virus (RBDV)

The discovery of a strain of RBDV* able to infect raspberry cultivars immune to Scottish isolates of the virus (see p.196) has increased the need for more detailed information on the virus and provided the impetus for a resumption of work on its molecular biological properties. The nucleic acid composition of RBDV is unique: particle preparations contain three single-stranded RNA species of about 6.4 kb (RNA-1), 2.5 kb (RNA-2) and 1.0 kb (RNA-3), determined by electrophoresis of glyoxal-denatured RNA in agarose gels. The proportions of molecules of these three species differ greatly: about 2% are RNA-1, 10% RNA-2 and 88% RNA-3. RBDV particles are *c.* 33 nm in diameter and have $s^{\circ}_{20,w} =$ 115*S*. They sediment as a single, rather broad, zone in sucrose density gradients but no evidence was found for a separation of particles of different RNA composition, although it seems unlikely that all three RNA species can be packaged within the same particle. Isopycnic centrifugation of formaldehyde-fixed particles in CsCl, Cs_2SO_4 or RbBr also failed to reveal evidence of particle heterogenicity. However, electrophoresis of preparations of intact particles in 2.4% polyacrylamide gels resulted in multiple bands, suggesting that the preparations in fact contain many kinds of particle, differing in the number of their protein sub-units and also presumably in the amount of RNA they contain. The particles dissociated in as little as 0.01% sodium dodecyl sulphate and in 1 M $CaCl_2$, although not in 1 M NaCl, and so presumably are stabilised by protein-RNA linkages.

(A. F. Murant, J. H. Raschké)

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[1]PBI

The addition of unfractionated RBDV RNA to suitable wheat germ extracts induced the synthesis of several polypeptides, the most abundant having a mol.wt. of 3×10^4 and the largest having a mol.wt. of about 1.8×10^5. The translation products of RNA from the Scottish strain were indistinguishable from those of RNA from the resistance-breaking strain. A proportion of the 1.0 kb RNA failed to precipitate following overnight treatment with 2 M LiCl at 4°C and this RNA induced synthesis of the 3×10^4 mol.wt. polypeptide and small amounts of lower mol.wt. polypeptides. The 3×10^4 mol.wt. polypeptide co-migrated with protein from RBDV particles and reacted specifically with RBDV antiserum.

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

Biological activity of DNA copies of virus RNA genes

Work was started in collaboration with D. Baulcombe[1] and M. Bevan[1] to determine the biological activity of cloned DNA copies of plant virus RNA and, in particular, to see whether cross-protection between virus strains can be simulated by incorporating virus genes into the plant genome. If the transformed plants have enhanced virus resistance, the way would be open to a new, generally applicable, approach to controlling virus diseases in crop plants.

Genome RNA species of cucumber mosaic and tobacco rattle viruses were prepared for cloning, and procedures established for detecting nucleic acid species and determining their biological activity.

(B. D. Harrison, M. A. Mayo, D. J. Robinson)

PU 1(i) Study mechanisms of virus transmission by aphids

Heracleum latent virus (HLV) and heracleum virus 6 (HV6)

Previous studies showed that transmission by the aphid *Cavariella theobaldii* of HLV, a closterovirus with filamentous particles *c.* 730 nm long, depends on the presence, in the same source plant, of HV6, a serologically unrelated closterovirus with longer particles. In further work, HV6 particles were partially purified from infected coriander by clarification of extracts with bentonite followed by differential centrifugation and isopycnic centrifugation in Cs_2SO_4. An antiserum, made by injecting a rabbit intramuscularly with formaldehyde-fixed virus, had a titre of 1/400 to HV6 as determined in the electron microscope by the coating of particles with antibody. Particles of HLV and HV6 of characteristic modal length were readily found in extracts from singly infected coriander plants or in mixtures of the two kinds of extract. The modal length of HV6 particles, not previously determined accurately, was found to be 1650 ±45 nm (95 particles measured) in 2% sodium phosphotungstate, pH 6. In contrast, the particles in extracts from

[1] PBI

majority of them became coated with antibody when exposed to HV6 antiserum and therefore contained HV6 protein. However, a few particles were coated along only part of their length and some particles remained uncoated with HV6 antibody. Conversely, in tests with HLV antiserum, a few particles from doubly infected plants were coated along only part of their length with HLV antibody. Further work is required to show whether this phenomenon can be attributed to phenotypic mixing, and whether it is involved in the aphid transmission of HLV.

(A. F. Murant, G. H. Duncan, J. H. Raschké)

The possibility that other closteroviruses might exhibit helper-dependence was investigated in experiments in which mixed infections of beet yellows virus (BYV) with either HLV or apple chlorotic leaf spot virus were established in *Chenopodium quinoa* and sugar beet, and the plants used as sources of virus for *Myzus persicae*. However, the aphids transmitted only BYV.

(A. F. Murant)

A new helper virus for parsnip yellow fleck virus (PYFV) in hogweed (Heracleum sphondylium)

Transmissibility of PYFV by the aphid *Cavariella aegopodii* was shown previously to be mediated by anthriscus yellows virus (AYV), which occurs naturally in cow parsley (*Anthriscus sylvestris*) and readily infects chervil (*Anthriscus cerefolium*) but seems not to infect hogweed. However, PYFV was readily transmitted by *C. aegopodii* from naturally infected hogweed (*Heracleum sphondylium*) to chervil test plants, although not from chervil to chervil unless AYV was used to aid transmission. These observations suggest there is a helper virus for PYFV transmission in hogweed and that it differs from AYV in host range.

(A. F. Murant)

The groundnut rosette complex

Studies were begun on the aphid-transmitted complex of groundnut rosette virus (GRV) and groundnut rosette assistor virus (GRAV), obtained from Nigeria*, together with its vector *Aphis craccivora**.

Aphid-inoculated groundnut plants contained a few *c.* 25 nm isometric particles which were detected by ISEM with the aid of antisera to the following luteoviruses: bean leaf roll, beet western yellows and potato leafroll viruses. One component of the complex, presumably GRAV, therefore is a member of this group.

Groundnut plants developed symptoms resembling those of the complex when inoculated manually with extracts from aphid-inoculated plants, but these plants could no longer act as sources for transmission of

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the virus by aphids. The sap-transmissible component, presumed to be GRV, also infected several species in the families Chenopodiaceae, Leguminosae and Solanaceae, and gave characteristic symptoms in *Nicotiana clevelandii* and in *Phaseolus vulgaris* cultivars Pinto, The Prince and Top Crop. No satisfactory local lesion host was found, although a few local lesions were usually produced in *Chenopodium murale* and *C. quinoa*.

The infectivity of bentonite-containing extracts of symptom-bearing *N. clevelandii* leaves survived for several days at 4°C and pH 8.0, and was almost completely sedimented when extracts were centrifuged at 36,000 rev./min for 2 h. However, no virus-like particles were detected in sedimented material by conventional electron microscopy, or by ISEM with the aid of PLRV antiserum. Phenol/SDS extracts of leaves of manually inoculated *N. clevelandii* or aphid-inoculated groundnut were very infective when assayed by manual inoculation, but no virus-specific nucleic acid bands were detected by polyacrylamide gel electrophoresis. These results closely resemble those obtained with carrot mottle virus, another dependent virus, which was studied previously in some detail.

(D. V. R. Reddy, A. F. Murant, G. H. Duncan)

The tobacco rosette complex

Preliminary studies were made of the tobacco rosette complex*, in which tobacco mottle virus depends on tobacco vein distorting virus for transmission by *Myzus persicae*. Aphid-inoculated plants contained small numbers of *c.* 25 nm isometric particles resembling those of luteoviruses but these particles only gave weak reactions in ISEM with antisera to bean leaf roll, beet mild yellowing, potato leafroll and tobacco necrotic dwarf viruses, and no reaction with antisera to beet western yellows or carrot red leaf viruses. It is therefore not clear whether the helper virus in this complex is a luteovirus.

(A. F. Murant, G. H. Duncan)

Double-stranded RNA in Nicotiana clevelandii *infected with carrot mottle virus (CMotV)*

Previous work showed that CMotV is transmitted by aphids when its single-stranded RNA, which is about 4.4 kb, is incorporated in virus particles that contain the coat protein of its helper, carrot red leaf virus. In further work, preparations of double-stranded RNA from CMotV-infected *N. clevelandii* were found to contain two main components when electrophoresed in 2.4% polyacrylamide gels. The larger (*c.* 4.4 kbp) one is presumably the double-stranded form of the infective RNA found previously but the function of the smaller component (*c.* 1.2 kbp), which occurred in the greater amount, is not known.

(A. F. Murant, J. H. Raschké)

*Held under DAFS licence

PU 1(l) Devise methods for detecting viruses and virus strains

A seed-borne virus-like particle in coriander (Coriandrum sativum)

Coriander is used extensively as a test plant in work with viruses of umbelliferous plants, and short rod-shaped virus-like particles (VLP) have been seen infrequently by electron microscopy of coriander leaf extracts, though usually not more than one particle per 20-30 grid holes. However, preparations of heracleum virus 6 purified from coriander tissue (see p.188) contained numerous contaminating VLP. When such preparations were fixed with formaldehyde and injected into a rabbit, an antiserum was obtained with a titre of 1/1000, as determined in the electron microscope by the coating of VLP with antibody. In ISEM tests the VLP were detected reproducibly in coriander roots and leaves, and in extracts of dry coriander seed. The VLP were straight to slightly flexuous rods 220-260 nm long and *c.* 21 nm wide, and had an obvious axial periodicity of *c.* 4.5 nm; many of the VLP were partially disrupted. Tests by ISEM and ELISA showed that the particles occurred in 12-100% of the seedlings raised from seed from Australia (two samples), Bulgaria (three samples), England, India, Morocco and Rumania (each one sample), as well as in two commercial seed samples. Only one sample, from China, was entirely free from the VLP. The VLP were not transmitted by inoculating seedlings of the Chinese stock with sap from seedlings of the Bulgarian stock.

(A. F. Murant, G. H. Duncan)

New virus from lucerne*

A virus with isometric particles, obtained from naturally infected lucerne in Australia (isolate SM), resembled lucerne Australian latent virus (LALV) in host range and *in vitro* properties. Unlike LALV, however, purified particles of isolate SM sedimented as a single component of *c.* 130*S*, and contained two protein species with estimated mol.wt. of 26,000 and 40,000. Isolate SM was seed-borne in pea and *C. quinoa*. It reacted with homologous antiserum but not with antiserum to LALV, strawberry latent ringspot virus, broad bean wilt virus or five comoviruses. The virus seems not to have been described previously.

(A. Remah, A. T. Jones, M. J. Cannon)

Broad bean stain virus (BBSV)

A high incidence of seed-borne BBSV was again detected in tick bean plants grown in field experiments at the Institute. The highest incidence (18%) was in plants grown from two seed stocks produced in England. No infection with Echtes Ackerbohnenmosaik virus was detected.

(A. T. Jones, A. Remah)

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*Held under DAFS licence

Virus in hogweed (Heracleum sphondylium)
Carrot mottle, carrot red leaf and tomato bushy stunt viruses were found in hogweed plants. This brings to 10 the number of viruses found, in a range of combinations, in apparently symptomless plants of this species.
(A. F. Murant)

PU 1(k) Devise methods for the electron microscopy of viruses

Detection of geminiviruses in leaf extracts
A method was devised of protecting leaf samples from deterioration during transit from abroad. Leaves infected with geminiviruses were individually sandwiched between filter paper soaked in 50% glycerol, and sealed in polythene bags from which air had been excluded. Samples treated in this way were mostly in good condition, and virus particles could be detected in them even after storage for several weeks. The leaves were washed overnight in extraction buffer, then two 8 mm disks were cut and ground in the buffer using the micro-mortar technique (Ann. Rep. 1979, 108). Geminivirus particles are fragile and the choice of extraction buffer was critical. Particle stability was greatest in 0.01 M tris adjusted to pH 8.0 with 0.01 M EDTA. However, particles of maize streak virus (MSV)† seemed more stable in 0.07 M phosphate buffer at pH 6.5.

Of the negative stains tested, phosphotungstic acid, ammonium molybdate and methylamine tungstate at pH 4-8 damaged most of the particles, although ammonium molybdate gave better results with particles fixed with 0.2% osmium tetroxide. Uranyl acetate and uranyl formate damaged fewest of the particles, but often formed precipitates on the grids, making the particles difficult to detect. Best results were achieved by washing particles on grids, first with distilled water and then with uranyl formate adjusted to pH 4.5 with sodium hydroxide.

Using these methods, the following geminiviruses were detected in ISEM tests with homologous antisera: African cassava mosaic*, bean golden mosaic†, beet curly top†, maize streak†, wheat dwarf† and, probably, tobacco leaf curl†. The numbers of particles trapped per 1000 μm^2 grid area ranged from about 150,000 (African cassava mosaic virus, to *c.* 100 (tobacco leaf curl virus). Particles of bean golden mosaic virus were particularly fragile whereas those of maize streak and wheat dwarf viruses were preserved best.
(I. M. Roberts, B. D. Harrison, D. J. Robinson)

Immunoelectron microscopy of tobraviruses
At SCRI, ISEM has been successful with more than 50 plant viruses, and considerable reliance has been placed on the results of such tests.

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However, some difficulties and anomalies have also been encountered, most recently in work with PEBV-BBYB* (see p.182). Particles of this virus unexpectedly were trapped on grids treated with antiserum to tobacco rattle virus (TRV) strain CAM*, although no reaction occurred in reciprocal tests. The same result was obtained with several bleeds of TRV-CAM antiserum, and with virus taken from systemically infected leaves of either *Nicotiana clevelandii* or *Phaseolus vulgaris*. To test the possibility that the trapping was caused by a reaction of plant proteins adhering to the virus particles with trace amounts of antibody to these proteins, antiserum-coated grids were exposed to extracts from healthy plants before they were floated on virus-containing extracts. However, this did not prevent the trapping of PEBV-BBYB particles. A further oddity was that when PEBV-BBYB particles from *N. clevelandii* or *P. vulgaris* were trapped by TRV-CAM antiserum, and then treated with additional TRV-CAM antiserum, only a proportion of the particles became coated with antibody. Further work is needed to find the explanation for these observations.

(I. M. Roberts, D. J. Robinson, B. D. Harrison)

PU 4(e) Study virus diseases of forage brassica crops and devise methods of control

Turnip mosaic virus was detected in several fodder rape plants in a group of families grown at Pentlandfield.

(W. P. Mowat, A. B. Wills[1])

PU 9(m) Study mechanisms of virus resistance in potato

Extreme resistance to potato virus Y

The behaviour of potato virus Y (PVY) was studied in plants and mesophyll protoplasts of potato cultivars Corine and Pirola, known to possess extreme resistance controlled by the Ry gene derived from *Solanum stoloniferum*. When glasshouse-grown plants were manually inoculated with a PVYo isolate, Corine remained symptomless and Pirola developed only a few small necrotic streaks in the veins of inoculated leaves and only very limited and sporadic systemic necrotic symptoms. Graft-inoculated plants gave the same systemic reactions as manually inoculated ones.

When protoplasts of Corine and Pirola were inoculated with PVY RNA, typically only about 0.1% became infected whereas up to 11% of protoplasts of the susceptible cultivar, Kerr's Pink, were infected as judged by fluorescent antibody staining. The few Corine and Pirola protoplasts that became infected were as intensely stained by fluorescent

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[1]Forage Brassica Breeding Department

antibody as were Kerr's Pink protoplasts. In contrast, many Corine and Pirola protoplasts were infected by inoculation with tobacco mosaic virus. Thus the virus-specific resistance to PVY infection expressed by intact plants of cultivars carrying the Ry gene is also evident in isolated protoplasts. This conclusion differs from that reached by testing the behaviour of protoplasts of potato clones whose leaves develop numerous necrotic lesions after inoculation with PVY. This type of resistance, as reported last year, is not expressed by isolated protoplasts. The results obtained with Corine and Pirola more closely parallel those obtained elsewhere with virus-resistant tomato and cowpea, where virus replication in plants and protoplasts either is not detected or is very limited.

(H. Barker, B. D. Harrison)

Polygenic resistance to potato leafroll virus (PLRV)

The behaviour of potato leafroll virus (PLRV) was studied in glasshouse-grown plants of potato clones and cultivars known to differ in polygenically controlled resistance to infection in field trials. Their reaction to primary infection was assessed by grafting with scions from susceptible potato plants with secondary infection. PLRV antigen was detected by ELISA in plants of all genotypes within 20 days of grafting. Plants of resistant genotypes did not escape infection. However, the concentration of antigen decreased with increase in resistance rating and the most resistant genotypes contained only about 1% of the antigen found in susceptible genotypes.

Similar differences in antigen concentration were found in leaves of plants with secondary infection. When graft-transmitted from a resistant clone (G7445(1)) to a susceptible cultivar, PLRV multiplied to the usual extent in the susceptible cultivar, and there was no evidence that the resistant clone had selected a virus variant from the original virus culture.

When plants of four genotypes differing in resistance rating were inoculated with PLRV-carrying aphids (*Myzus persicae*), the proportion of plants infected was directly related to the field resistance rating. For example, tubers from less than 20% of G7445(1) plants (the genotype with the highest field resistance rating) inoculated with three aphids contained detectable amounts of PLRV compared with 100% of tubers of Kerr's Pink, a very susceptible cultivar. The concentration of virus antigen produced in foliage of the infected plants was similar to that in plants of the same genotype inoculated by grafting.

(H. Barker, B. D. Harrison)

To investigate the possibility that PLRV antigen synthesis might be suppressed in resistant genotypes without a comparable diminution of PLRV RNA synthesis, a nick-translated cloned DNA probe was used to assess the virus RNA content of leaf extracts. However, virus-specific

RNA was barely detectable in leaves of cv. Pentland Crown (resistant) although species of mol.wt. *c.* 6 and 3 kb were readily found in leaves of cv. Maris Piper (susceptible).

(H. Barker, M. A. Mayo, D. J. Robinson)

Chlorogenic acid and resistance to PLRV

American workers have reported that the concentration of chlorogenic acid in potato leaves of different cultivars is correlated with resistance to infection with PLRV. Such a correlation, if reliable, would offer the opportunity of screening potato clones for PLRV resistance by a rapid chemical assay. An improved method for measuring chlorogenic acid (5-caffeoylquinic acid) concentration in potato leaf extracts was developed using high performance liquid chromotography. Good separation of chlorogenic acid was achieved by using 100 mM acetate buffer, pH 4.2, with an acetonitrile gradient of 25 to 35 % in 20 min, and recording absorbance at 325 nm. Concentrations of chlorogenic acid were in the range 50-330 μg/g fresh weight and varied with leaf position and leaf age. However, chlorogenic acid concentration in different genotypes was not correlated with resistance to infection with potato leafroll virus, measured in field trials. Thus a sound basis for a screening test was not found.

(H. Barker, G. D. Lyon[1])

PU 9(n) Study detection methods, properties, transmission and spread of potato viruses

Relationship between potato leafroll (PLRV), beet mild yellowing and beet western yellows viruses

In ISEM tests, all three viruses reacted with antisera to each of the other two, and the beet viruses behaved like one another. PLRV reacted less strongly with antisera to the beet viruses than did the beet viruses with antiserum to the Scottish stock culture of PLRV. The possibility that the PLRV culture might contain a mixture of viruses was examined by trapping particles with the homologous antiserum and testing the ability of beet mild yellowing virus antibody to coat them. All the trapped particles became uniformly coated, and the PLRV culture therefore seemed not to be a mixture. These results indicate that the two beet viruses are antigenically very similar, and that they are moderately closely related to PLRV.

In ELISA and ISEM tests, two monoclonal antibodies received from R. Martin[2], to a Canadian isolate of PLRV, reacted with the Scottish stock culture, but less strongly than did a Scottish polyclonal antiserum. Both monoclonal antibodies also reacted with beet mild yellowing virus in ISEM tests, but only weakly.

(B. D. Harrison, I. M. Roberts)

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[1] Mycology and Bacteriology Department

[2] Agriculture Canada Research Station, Vancouver

PU 10(i) Study the properties, spread, and control of *Rubus* viruses

Raspberry bushy dwarf virus (RBDV)

Further studies with the resistance-breaking isolate of RBDV (RBDV-RB) found at EMRS and mentioned in last year's report, showed that it infected by grafting all the British raspberry and blackberry cultivars tested, including several known to be resistant to infection with the Scottish type isolate of RBDV. However, of the four North American red raspberry cultivars tested, two (Haida and Heritage) did not become infected and will therefore be studied further as possible sources of resistance to isolates of the RB type.

Although RB isolates of RBDV are known to occur in British raspberry crops only in plantations at EMRS, similar isolates were found in loganberry from the east and west of England in 1981 and 1982. A survey was therefore started to assess the incidence of RBDV in commercial loganberry plantations. No Loganberry is propagated in Scotland and little is grown commercially, so the survey was made in England with the help of ADAS officers. RBDV-infected plants were found at eight out of 26 sites and in graft-inoculation tests to cv. Glen Clova raspberry all the isolates were found to be of the RB type. The incidence of infection at these eight sites ranged from 15 to 100%, and at one site there was evidence of spread from loganberry to blackberry.

(A. T. Jones, M. J. Cannon)

Serological detection of black raspberry necrosis virus (BRNV)

Previous work on this common aphid-borne virus has been hindered by the very low concentration of virus particles in herbaceous test plants and the extreme difficulty in serially transmitting the virus by mechanical inoculation. In tests in summer 1983, mechanical inoculation of sap from some raspberry plants induced symptoms typical of BRNV in *Chenopodium quinoa* and in addition caused faint systemic vein clearing in *Nicotiana clevelandii*. Tests in which dilution end-points were estimated by assays in *C. quinoa* indicated that the BRNV concentration in the *N. clevelandii* sap was, in contrast to experience with other BRNV isolates, about a thousandfold more than that in *C. quinoa* sap, and no difficulty was experienced in maintaining the virus culture in *N. clevelandii*. However, further tests showed that this culture also contained a second agent, which could be separated from BRNV by using very dilute inocula, and which did not infect *C. quinoa* systemically. Because of the relatively large concentration of BRNV in doubly infected *N. clevelandii,* virus particles were purified from such plants and an antiserum prepared which had a gel-diffusion titre of at least 1/128 to BRNV and about 1/512 to the second virus. When $F(ab')_2$ fragments

[1]Mycology and Bacteriology Department

were prepared from this antiserum and used in indirect ELISA, strong reactions occurred with sap from raspberry and *Rubus* spp known to be infected with BRNV but not with sap from healthy raspberry plants or from raspberry infected with other viruses. Although further work is needed to identify the second virus in the mixed culture, these findings bring close the prospect of a means of screening *Rubus* plants for infection with BRNV that is more rapid than graft inoculation to *Rubus* indicator plants.

(A. T. Jones, M. J. Cannon)

Host range of rubus yellow net virus (RYNV)

Raspberry veinbanding mosaic disease is reported to be caused by dual infection with RYNV and BRNV. Only a few currently grown raspberry cultivars, such as Glen Isla and Malling Jewel, are known to be subject to this disease although all cultivars tested are susceptible to infection with BRNV. The finding, noted in last year's report, that *R. macraei* is a suitable indicator for RYNV, provided an opportunity to study the *Rubus* host range and effects of this virus. Following graft inoculation with RYNV, symptomless infection occurred in Glen Clova, Malling Delight, Malling Landmark, Malling Orion and Norfolk Giant. The absence of veinbanding mosaic disease in field plantings of these cultivars is therefore not a consequence of immunity to RYNV.

(A. T. Jones)

Outbreaks of raspberry ringspot virus (RRV)

Although RRV was first found in field plantings of the widely grown raspberry cv. Glen Clova in 1981, it was detected in many samples of this cultivar received from different parts of eastern Scotland in 1983. Infected leaves typically had chlorotic blotches or ringspots and/or pronounced yellowing of the veins. It is not known whether this widespread occurrence and increased incidence of RRV in raspberry reflects a relaxation of crop hygiene or the spread of a new virus strain. However, all the isolates tested were indistinguishable serologically from the Scottish type isolate of RRV. By 1983, the plantation of Glen Clova raspberry found to be infected in 1981 contained large areas of severely stunted plants, indicating that RRV infection of this cultivar can be debilitating.

(A. T. Jones)

Cucumber mosaic virus (CMV) in an aphid-resistant raspberry

CMV was obtained from several plants of EMRS raspberry selection 3655/56 growing in the National Fruit Trial at SCRI and with leaves showing interveinal chlorosis and chlorotic ringspots. This is yet another example of CMV infection in a raspberry genotype resistant to *Amphorophora idaei,* the main aphid vector of raspberry viruses. The

new CMV isolates reacted only weakly with antisera either to a CMV isolate from *Rubus phoenicolasius* or to strain W. *Rubus* plants therefore seem to be susceptible to a range of CMV strains.

(A. T. Jones)

PU 10(j) Produce virus-free stocks of raspberry and other *Rubus* crops and assess virus resistance of new genotypes

Virus indexing and heat therapy

During the year, 16 imported *Rubus* species and selections* and 26 selections from the SCRI *Rubus* breeding programme were indexed for virus infection. In addition, 22 imported *Ribes* species and selections*, and two selections from the SCRI *Ribes* breeding programme, were indexed for mechanically transmissible viruses. Of the imported material, only one raspberry selection was found to be virus infected; this plant, which came from Canada, contained raspberry bushy dwarf virus and was destroyed. Three advanced *Rubus* selections from the SCRI breeding programme were heat treated in attempts to free them from virus infection.

(M. J. Cannon, A. T. Jones)

Susceptibility of newer raspberry cultivars to nepoviruses

In graft inoculation tests, cv. Glen Moy became infected with arabis mosaic (AMV), raspberry ringspot (RRV) and tomato black ring (TBRV) viruses, cv. Glen Prosen was infected by RRV and TBRV, and cv. Joy was infected with AMV and strawberry latent ringspot virus.

(A. T. Jones, M. J. Cannon)

PU 16(a) Study the detection, properties and epidemiology of narcissus and tulip viruses

Detection of nepoviruses in narcissus

Experience with the method currently used for detecting nepoviruses in narcissus, infectivity assay on *Chenopodium amaranticolor* and *C. quinoa,* has shown that the tests may need to be repeated in successive years before a plant can be considered virus-free. For example, infectivity tests detected tomato black ring virus for the first time in 1983 (in seven of 30 3-year old plants) in two clones of cv. Fortune in stage 1 propagation at SCRI. However, ELISA detected the virus in all 68 plants tested of one clone and in 66 of 68 plants of the second clone. The greater sensitivity of ELISA suggests it will be a more reliable method of detection than the infectivity test.

(W. P. Mowat)

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Diagnosis of tobacco rattle virus (TRV) in narcissus

Previous results (Ann. Rep. 1982, 187) showed that the direct form of ELISA, using antibodies to TRV strain PRN, detected only four of the 16 isolates of TRV obtained from field infected narcissus. In an attempt to increase the range of isolates detected, an indirect form of ELISA was tested, in which a horseradish peroxidase-protein A conjugate, and $F(ab')_2$ fragments of antibody to strain PRN and to strain NAR5, a serologically distinctive narcissus isolate, were used. Of four isolates from narcissus that were not detected by direct ELISA, one was detected by indirect ELISA with PRN antibody molecules and another by indirect ELISA with NAR5 antibody. NAR5 particles also reacted weakly with PRN antibody although PRN particles did not react with NAR5 antibody. These results indicate that the range of antigenic variation of narcissus isolates exceeds the difference between strains PRN and NAR5, and that the prospect for a serodiagnostic method of identifying all field isolates of TRV is poor.

(W. P. Mowat)

Incidence of viruses in commercial narcissus stocks

The incidence of narcissus tip necrosis virus (NTNV) and narcissus mosaic virus (NMV) in Scottish grown commercial stocks of the cultivars Carlton (10 stocks), Golden Harvest (8 stocks) and Yellow Cheerfulness (3 stocks) was assessed by indexing 30 plants from each stock by ELISA. NTNV was detected in all stocks of Carlton (maximum incidence = 40%) and of Yellow Cheerfulness (maximum incidence = 10%) but was not found in Golden Harvest. NMV was detected in all plants of Yellow Cheerfulness and its incidence in stocks of Carlton ranged from 27-80% whereas infected plants were detected in only four stocks of Golden Harvest (maximum incidence = 10%). These results contradict the prevailing view that the incidence of virus infection in commercial stocks of Carlton is so slight that little improvement can be expected from virus-tested (VT) clones. The results also underline the need to consider the incidence of virus infection when choosing commercial stocks for agronomic comparisons with VT clones.

Because antigenic variation is known among isolates of NTNV, it seems possible that the standard double antibody sandwich form of ELISA might not detect all field isolates of this virus. However, no additional infections were detected in eight narcissus stocks by a form of $F(ab')_2$ ELISA that has a broader spectrum of reactivity.

(W. P. Mowat)

Control of spread of narcissus yellow stripe virus by oil emulsion sprays

In a trial at Mylnefield in 1982, 1050 l/ha of an 0.75% emulsion of SC811 oil (British Sun Oil Co. Ltd.) was applied at 3 megapascals to narcissus plots each separated by 6 metres and each containing narcissus

yellow stripe virus infector plants. Plots received either five, seven or 11 sprays applied from 20 May to 8, 23 and 29 July, respectively, or were unsprayed. The incidence of yellow stripe increased from 30% at planting in 1982 to about 40% in 1983, irrespective of the treatment applied. However, these results are inconclusive because of drifting of the sprays applied at such a high pressure. Interestingly, leaves on most plants in each plot remained green into September, and further work is in progress to explore this potentially useful effect.

(W. P. Mowat, J. A. T. Woodford[1], S. C. Gordon[1])

PU 16(b) Produce and maintain virus-free stocks of narcissus

In 1983, the eighth annual batch of virus-free clones was released by SCRI to SNSA (F.B.) Ltd. for further rapid multiplication by ESCA and NSCA. The issue comprised 40 kg of bulbs of the cultivars Carlton and Corinthian. In addition, exchanges began between SCRI and GCRI of small numbers of bulbs of VT clones, to ensure their availability to the bulb industry throughout the UK. In this first exchange, SCRI provided 20 VT clones representing eight cultivars and GCRI provided 27 VT clones representing six cultivars.

Virus-indexing of virus-tested clones

In 1983, as in previous years, no infection with narcissus mosaic or narcissus tip necrosis viruses was found in plants released by ESCA and NSCA to SNSA (F.B.) Ltd. for field propagation. Likewise no infection was found in similar tests on 500 plants of the first issue of VT clones, now in its fourth year of field propagation, and no virus-like symptoms were found by visual inspection. In addition, plants of a VT clone of cv. Carlton were tested, 2 years after planting a trial to compare this clone with two commercial stocks of Carlton; remarkably, none of the eight viruses commonly occurring in commercial narcissus stocks in Scotland was found. This result has special importance because not only were plants of the VT and commercial stocks grown in adjacent rows but the trial was situated within a 4 ha commercial planting of narcissus.

(W. P. Mowat)

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[1]Zoology Department

ESTATE

F. J. W. ENGLAND
W. I. A. JACK

Mylnefield

The formalities for the SCRI to take tenancy of Gourdie and Menzieshill farms were completed at Martinmas adding an extra 78.8 ha at the disposal of the Institute. The objective of having land in a uniform status for field trials has continued to be pursued; to date all except 25 ha are in a state of readiness (Ann. Rep. 1982, 197).

As the meteorological records show the period from March to the end of June was dull, cold and wet, July and August were extremely dry and warm, and followed by a cold and wet September. The extremes of weather resulted in a season not without its problems although in most instances crops grew well, but not outstandingly so, resulting in yields slightly better on average than last year; the most notable exceptions were soft fruit crops where yields were well below average for the Institute.

In summary, despite the use of modern machinery and technology, and management systems, the prevailing weather conditions remain the predominate influence on crop production.

Farm crops and field experiments

Farm crops increased by 84.1 ha this year due to the additional land at Gourdie and Menzieshill farms, and included 80.9 ha barley, 30 ha winter wheat, 26.1 ha grass, 2 ha field bean, 0.8 ha potato and 8.7 ha fallow.

Golden Promise remained the standard barley cultivar. Sowing started on 9 March into ideal seedbed conditions and continued until the 14 March when adverse weather intervened, sowing was resumed on 25 March and was completed on the 4 April although seedbed conditions had then deteriorated. Germination and the establishment of correct plant populations were satisfactory but, subsequent growth was poor in the dull wet and cool growing conditions as was to be expected; mildew (*Erysiphe gramminis*) was evident in late May requiring an application of triadimeton (Bayleton) fungicide. Harvesting started on 10 August and was completed under excellent conditions on the 30 August. The yield of 4.9 t/ha was up 0.1 t/ha on the previous year, the grain samples in

general were of good quality and with a moisture content averaging 16.9%; the nitrogen content was such that 91% of the crop was sold for malting.

Winter wheat cultivars Avalon and Brigand which were sown in the autumn of 1982 overwintered well and plant populations were satisfactory in the spring. The judicious use of nitrogen, a fungicide and a growth regulator maximised yield of milling quality grain. Harvesting started under excellent conditions on 29 August at a grain moisture content of 15%, but conditions deteriorated thereafter and harvesting was completed on 20 September with the grain moisture content above 20%. The yield of 7.1 t/ha was less than expected, but with a protein value of 11.5% all was sold for milling, the first time this has been achieved at Mylnefield.

Grass grew slowly in the cool wet conditions of the early part of the spring but made rapid progress in June, cutting started on 20 June and baling was completed by the 28 June. Hay was secured under fine conditions, and was of excellent quality. The entire crop was sold directly from the field, and yield of 6.6 t/ha was up 0.6 t/ha compared to the previous year. A second cut was taken on 29 July but this was of inferior quality.

Field bean cv. Herz Freya was sown on the 8 March into excellent seedbed conditions; the plant population was satisfactory, and although the crop suffered from drought conditions in July and August pod number per plant was good. The crop ripened rapidly and was combined on 6 September giving an excellent sample of beans at 17% moisture content; the yield of 2.8 t/ha was up 0.7 t/ha compared with the previous year.

Soil conditions were not good at planting time for potato cv. Maris Piper, and although subsequent growth was slow the crop progressed satisfactorily. Sprays were applied fortnightly against pests and diseases and the crop was irrigated throughout the drought period of July and August. Lifting which was started on 13 September, lasted until 9 November with frequent interruptions through heavy rain and hampered by difficult ground conditions. Tuber quality, size and yield of the harvested crop was variable ranging between 17.3 t/ha for non-irrigated and 64 t/ha for irrigated.

There was a total of 234 field experiments and off-station trials, an increase of 38 compared with 1982. Thirty different crop species were grown, using 54 management regimes requiring many special requirements involving the use of 25 fertiliser formulations, 45 herbicides, 25 insecticides, 15 fungicides and 10 experimental chemicals supplied by sponsor's of field trials. The crops grown included 11 ha raspberries, 9.5 ha brassicas, 7.6 ha potatoes, 5.5 ha black currants, 1.7 ha strawberries, 1.1 ha black- and hybrid berries, 0.6 ha cereals, 0.6 ha field beans and

peas, 0.2 ha bulbs and 1.4 ha other crops. This is an increase of 8.5 ha on the previous year resulting from the transfer of the forage brassica breeding trials from The Murray's farm and the increase in potato trials from Physiology and Crop Production Department.

Fruit picking started with strawberries on 12 July followed by raspberries 21 July, Tayberries 22 July, black currants 26 July, blackberries 13 August and finally blueberries 29 August. The omens for the fruit crop were as bad up to the end of June as they were auspicious throughout the harvesting season with little time lost through wet weather; however, crops never recovered from the early setbacks and yields were well down on previous years. The fruit crops sold included 15.6 t raspberries, 3.8 t strawberries, 0.8 t black currants and 0.5 t other fruit showing a decrease of 24.9 t compared with 1982.

Following harvest, the routine programme of plot clearance, stubble cleaning and liming was practiced. Ploughing was done when conditions were suitable and was almost completed by the end of the year. Thirty ha of winter wheat Avalon were sown between 22 September and 14 October; a good plant stand was produced.

New farm equipment acquired during the year included a mower, potato digger and rotary ridger. Also, following investigations into computerising the estate records, and to make the administration of experiments less labour intensive, an Apple microprocessor unit and program was purchased.

Estate work was confined to Gourdie farm, where a further 1600 m of security and vermin proof fencing was erected on the north, east and west boundaries of the farm and drainage problems in Gowrie East field were rectified.

Glasshouses

The area of heated glass was increased by some 770 sq.m with the completion of the new range for the Zoology Department and is progressively being brought into use. Additional Filclair gauze tunnels and polythene tunnels were constucted on the South Bullionfield site to provide additional space for the production of bulbs, raspberry and brassica stocks.

The production and maintenance of plant material for use by the scientific departments increased this year due mainly to the transfer of the forage brassica breeding programme from Pentlandfield. Plant production of 124,000 units was up 5,751 compared with 1982; Departmental totals were 51,116 for Virology, 32,073 for soft fruit and forage brassica breeding, 19,185 for Estate, 10,957 for Mycology and Bacteriology, 6,469 for Zoology and 4,200 for Physiology and Crop Production. Black currant plants raised from hard and soft wood cuttings and from seed totalled 16,500; raspberry pot plants raised

totalled 14,000 from 70 cultivars, and raspberry and hybrid berry plants from seed totalled 10,000; between 7-8,000 narcissus bulblets and sowings of seed produced plants for field trial of brassica, raspberry root was despatched to NSDO of 12 cultivars to produce 16,260 pot canes.

An observation trial continued comparing different soil-less compost mixtures, and different containers, for the production of raspberry root. Results have confirmed that no one soil-less compost formulation offers advantages in the quantity and quality of roots produced; with the seven raspberry cultivars in the trial over 80% of the cuttings taken produced plants. However, it was found that the most economical and practical container size was 30 cm square × 30 cm deep.

Pentlandfield

Murrays Farm

The weather in 1983 was notable for a cold, very wet winter and spring which seriously delayed sowing and planting, followed by a very dry summer. The total rainfall was the highest since records began in 1972.

Spring cereal sowing started on 9 March and was completed on 2 April. Forty-one ha of spring barley cv. Golden Promise treated with triadimenol (Baytan) were drilled into a moderately good seedbed; a further 12.1 ha were drilled with spring barley cv. Tweed treated with mercurial dressing only. Cereal experimental plots, cultivar multiplication and surrounds occupied a further 17.0 ha. Fertiliser was applied to the seedbed at the rate of 439 kg/ha to all the spring barley. Growth was slow until the drier, warmer weather in June. Foliar diseases began to appear in July and the crop was sprayed with propiconazole (Tilt 250 EC) in the middle of that month. The crop of Tweed remained healthy apart from some *Rhynchosporium*, and no sprays were applied. All barley crops received a top dressing of nitrogen (Nitram) at the rate of 188.4 kg/ha in May. Harvesting started on 26 August and was completed on 13 September. Despite the poor season, the average yield of Golden Promise was 4.70 t/ha and of Tweed 4.41 t/ha; the grain of both cultivars was sold for malting.

The winter wheat was top dressed with fertiliser in March at the rate of 377 kg/ha, and with nitrogen (Nitram) in April at 190 kg/ha. The crop grew well but *Septoria* and eye spot attacked the crop later in the season. Propiconazole (Tilt 250 EC) was applied at the end of June. Harvesting took place between 20 and 26 September. The cultivars Mardler and Norman showed aborted heads and the yields were disappointing, averaging 5.13 t/ha.

Potatoes occupied 10 ha in Sunnyside field, the remainder being sown to brassica trials. Fertiliser was broadcast at 1255 kg/ha before final cultivations. Early potato trials were planted in early April and the main crop was planted in late May and early June; thiofanox (Dacamox 5G)

aphicide granules being applied for weed control. Emergence was slow and irregular due to the dry conditions. There was little aphid activity but precautionary insecticide sprays were applied. The early material was uplifted in August, and the main crop material during October.

Swede, kale and rape trials grown in Sunnyside were for pre-cultivar assessments. The inclement conditions produced very erratic germination and very slow early season growth in the kale and swede crops; the rape, drilled in June, established very poorly. High levels of mildew occurred on the swede trials. The trials were harvested in November and yields were disappointing.

The grass crops in Wall field and in Reserves A and B were top-dressed at the beginning of April, and the average yield was 6.2 t/ha; and the hay was sold to ESCA. The aftermath was grazed by lambs belonging to ESCA until mid November.

Reserve A was sprayed with glyphosate (Roundup) in August in preparation for sowing winter cereal trials. Winter barley and winter wheat plots were drilled in September and October with a commercial crop surround of cv. Armada winter wheat. Folly and Crow fields were sown with commercial winter wheats Norman and Longbow, in October.

A Bamlett Tive Jet fertiliser distributor and a front loader were purchased new during the year.

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

INFORMATION SERVICES

R. J. A. EXLEY

A policy decision that the date of publication of the Annual Report be advanced by almost 5 months to August, required a major change in the work routine. The presentation of the Report to the Governing Body, was followed by an afternoon Press Meeting at which information about relevant areas of the Institute's work was discussed.

Commencing this year DAFS displayed in their Pavilion at Ingliston, for the duration of the annual RHAS Show, an exhibit showing representative aspects of the work of the seven SARIs which it finances. Information Services have co-ordinated and produced the exhibit, and are to be responsible for initiating reviews of its content.

LIBRARY

Mylnefield

In 1983, loans remained at the same level as in previous years; of a total of 2013 loans, 651 were internal and 1362 were external. Seventeen translations and 18 literature searches were made, and current awareness services continued to be provided for six members of staff or groups.

The library was provided with a VDU and a line to EMAS, and this has facilitated literature searching and other library services. Among these is the updating of the Raspberry Literature Collection and of the Mylnefield and Pentlandfield libraries' mailing lists which are being unified.

The periodicals circulation system was extended by the introduction of a microcomputer program to generate circulation lists. At present it is used for periodicals whose contents pages only are circulated. Problems connected with generating lists for journals whose whole parts are circulated remain to be solved.

Meetings of the Scottish Agricultural Librarians' Group were attended by U. M. McKean and a meeting on Interlibrary loans at the National Library of Scotland was attended by U. M. McKean and M. Mitchell.

(U. M. McKean)

Pentlandfield

Use of the Pentlandfield library began to decline during 1983 reflecting the beginning of the transfer of staff to Mylnefield. Literature searches were conducted on 33 different topics, and 48 other detailed enquiries

were handled. The book stock received 69 new acquisitions. Subscriptions were taken out for the new *Journal of Cereal Science* and for *Agricultural Supply Industry* but subscriptions to the journals *Byte* and *Animal Feed Science & Technology* were cancelled. While internal library loans showed a slight increase rising to a total of 898 items, external borrowing fell to 399. Five translations were undertaken by the Librarian.

A Hazeltine Esprit II VDU and Newberry Printer were acquired for the library facilitating online literature searching and the production of the fortnightly current awareness lists. The first stage of the rationalization of housekeeping routines began with automation of the internal loans system. A union list of periodical holdings at Mylnefield and Pentlandfield was produced by the two libraries.

During the year the Librarian attended meetings held by the CAB, Aslib, the Institute of Information Scientists, National Library of Scotland, and the Scottish Agricultural Librarians' Group.

(B. E. Asher)

VISUAL AIDS

The following are the first combined figures for photographic and graphic work at Mylnefield and Pentlandfield. Display material for conferences, exhibitions and poster sessions accounts for a larger proportion of the work than in previous years.

PHOTOGRAPHY					GRAPHICS	
Jobs	Colour	Monochrome	Diazo	E.M./Prints	Jobs	Graphics
1931	6365	8933	617	2437	146	485

It is worthy of note although a 'job' may require as much as 5% of a persons annual time to plan and produce, as occurred this year, the job total is only increased by one, which highlights the difficulty in quantifying some visual aid tasks.

The DAFS SARI exhibit at Ingliston required a new display system to be purchased, with eight 6×6 ft panels being required to accommodate the material, which for 1983 comprised 41 colour prints, 5 graphics and 58 items of titling.

A Hasselblad camera system was bought to enable larger format photographs to be taken, especially for display purposes, where the size requirement of the finished print is usually beyond the resolution capability of 35 mm.

Air-brush work is now available at both Mylnefield and Pentlandfield; this technique can improve the impact of graphics, particularly for display purposes and enhance their visual appearance. However it must be remembered that the technique is very labour intensive and therefore adequate time must be available in order to achieve an acceptable result.

(T. G. Geoghegan)

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The Society is a specially authorised Society under the provisions of the Friendly Societies Act, 1974. Its objects are the promotion of agriculture, arboriculture, or horticulture and the operations of the Society in carrying out these objects shall be exclusively scientific, and shall be limited to experimental and other research for the improvement of plants and crops in Scotland, investigating conditions affecting their production, and by maintaining an association with the Scottish Crop Research Institute.

The Society was formerly known as the Scottish Society for Research in Plant Breeding which acted as managing agent for the Scottish Plant Breeding Station. After the amalgamation of the latter with the former Scottish Horticultural Research Institute to form the Scottish Crop Research Institute during 1981, the Society adopted its new name and its membership was expanded by the welcome inclusion of the members of the former Scottish Horticultural Research Institute Association.

During 1983 the Society held a meeting on the topic of 'Cereal Requirements for Northern Britain.' The proceedings of this meeting have been published in Society Bulletin No. 3, the contents of which are noted at the end of this section. Copies of the Bulletin are available from the Secretary of the Society.

The 1983 Society Lecture was given on 3rd March by Dr K. Dexter, C.B., the then Director General, Agricultural Development & Advisory Service, Ministry of Agriculture, Fisheries and Food. Dr Dexter's theme was 'A View of the way ahead for Agricultural Research and Development.' The text of the lecture has been circulated to members of the Society.

The Society gratefully acknowledges the assistance and help given by the Director and staff at Scottish Crop Research Institute in arranging and presenting these meetings.

SSCR Bulletin No. 3 (March 1984)

Cereal Requirements for Northern Britain

[1]NSDO £1·50

Mylnefield

Two features of the weather in 1983 were striking, the cold wet spring and the warm dry summer.

While the wet conditions delayed planting for many crops, low temperatures meant that those already in the ground grew only slowly. As a result, for many crops growth was less than average by early summer.

The fairly rapid transition to warm temperatures quickly brought on growth but the associated drought meant that crops grown on light land and without irrigation soon were checked in growth.

Wind

January and October were each the windiest of these months since our records of wind began, in 1959, and November was the least windy in that period. During the growing season, however, winds were generally close to or a little below average.

Rainfall

Over the year, rainfall was 95% of the 30-year average but its distribution was very erratic. The period April to June was the wettest since 1969 with 140% of the average rainfall for the period. Then July and August gave the driest mid-summer on record with only 26% of average rainfall. In September rainfall was again high, 146% of average.

Temperature

The year began and ended with mild weather. January had the equal highest mean maximum temperatures for that month and December was equally clement. In April and May temperatures were about 1.5°C below average, then in July and August they were about 2°C above average.

Sunshine and Solar radiation

During April and May the duration of bright sunshine was only 61% of average, the lowest since our records began. It is worth noting that despite the low rainfall during July and August, neither the duration of bright sunshine nor the total solar radiation was much above average.

(D. K. L. MacKerron)

MYLNEFIELD

Month	Temperature: Daily Air Maxima Mean °C	Daily Air Maxima DFA *	Daily Air Minima Mean °C	Daily Air Minima DFA *	0.1m Soil Mean °C	0.1m Soil DFA *	0.3m Earth Mean °C	0.3m Earth DFA *	Accumulated Day Degrees Above 6°C	Accumulated Day Degrees Below 6°C	Days Ground Frost	Potential Evap-oration mm	Rainfall Total mm	Rainfall DFA *	Bright Sunshine hours Total h	Bright Sunshine hours DFA *	Mean Daily Solar Radiation mWh/cm²	Windspeed Mean km/h	Windspeed DFA †
January	8·0	+2·5	2·0	+2·0	3·3	+1·8	4·2	+1·7	26	55	17	19·5	65·6	+ 2·8	61·8	+ 8·7	53	23·6	+10·7
February	4·1	−1·4	−1·0	−1·0	1·0	−0·6	2·9	+0·3	0	125	27	9·7	16·1	−31·9	65·5	− 6·1	106	10·3	− 1·9
March	9·1	+1·2	3·1	+1·4	4·5	+1·2	5·4	+1·1	45	42	16	34·6	56·0	+ 7·1	105·4	+ 0·1	198	16·1	+ 1·3
April	9·0	−2·0	2·3	−1·0	5·2	−1·1	6·3	−0·6	34	44	18	50·0	62·3	+22·2	120·2	−37·2	315	12·3	− 1·9
May	11·1	−2·6	6·2	+0·4	9·2	−1·0	9·5	−0·6	86	3	3	56·2	80·2	+24·6	89·2	−93·0	318	11·5	− 1·0
June	15·8	−1·1	8·7	0·0	13·6	−0·3	12·5	−1·0	188	1	0	87·9	63·2	+12·9	171·3	− 7·1	477	12·2	+ 0·4
July	20·7	+2·2	12·4	+2·2	18·0	+2·7	15·7	+0·6	327	0	0	93·9	9·9	−51·6	183·5	+ 8·6	467	10·0	− 0·7
August	20·4	+2·1	11·9	+1·8	17·2	+2·8	16·2	+1·3	314	0	0	80·3	23·0	−42·6	178·6	+24·8	396	8·4	− 1·4
September	14·7	−1·2	8·2	−0·4	10·9	−0·6	12·4	−0·3	168	3	4	47·8	92·2	+29·1	108·5	− 9·6	216	13·8	+ 2·5
October	12·3	−0·2	5·6	−0·6	7·2	−0·9	9·7	0·0	107	16	6	23·5	61·6	− 0·1	91·7	+ 1·0	125‡	16·8	+ 5·2
November	9·2	+0·9	3·5	+1·3	5·2	+1·1	7·4	+1·5	52	42	14	0·1	15·4	−40·6	73·8	+ 6·8	71	6·4	− 5·7
December	8·1	+1·8	1·9	+1·1	4·1	+1·8	5·5	+1·9	30	58	18	8·7	107·1	+37·3	29·2	−14·7	27	15·7	+ 3·0

*DFA Deviation from 1954-1983 average

†DFA Deviation from 1959-1983 average

‡ includes estimated values

Month	Mean Air temperature °C		Mean Soil temperature °C		Number of Days air temperature 0°C		Total rainfall	Number of wet days
	Max.	Min.	5 cm	10 cm	Air	Grass	mm	>1·0mm
January	7·9	2·2	3·0	3·3	7	13	51·5	14
February	3·6	−1·2	0·6	1·2	19	25	34·3	11
March	8·2	2·9	4·5	4·4	4	12	64·0	14
April	8·4	1·5	5·1	4·8	10	17	66·3	13
May	11·2	5·1	9·9	9·2	0	0	160·5	20
June	15·7	7·7	13·5	12·7	0	1	53·1	8
July	20·7	11·5	17·8	16·9	0	0	7·7	4
August	20·5	11·0	16·8	16·2	0	0	31·5	5
September	14·9	8·3	11·2	11·3	0	1	102·7	15
October	12·0	5·7	7·3	7·7	2	5	65·0	16
November	9·1	3·2	5·2	5·8	8	12	18·5	5
December	8·1	2·2	4·1	4·4	9	13	59·7	15
Annual total	—	—	—	—	59	99	714·8	140
Annual mean (365 Days)	11·7	5·0	8·3	8·2	—	—	—	—

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INSTITUTES FOR AGRICULTURAL AND FOOD RESEARCH IN GREAT BRITAIN

The research programmes of all the institutes supported from public funds are co-ordinated by the Agricultural and Food Research Council. Most publish a report annually and details are obtainable from the Secretary of the Institute concerned.

AFRC Institutes

Animal Breeding Research Organisation	King's Buildings, West Mains Road, Edinburgh, EH9 3JQ
Food Research Institute	Colney Lane, Norwich, NR4 7UA
Institute of Animal Physiology	Babraham, Cambridge, CB2 4AT
Institute for Research on Animal Diseases	Compton, Newbury, Berks., RG16 0NN
Letcombe Laboratory	Wantage, Berks., OX12 9JT
Meat Research Institute	Langford, Bristol, BS18 7DY
Poultry Research Centre	Roslin, Midlothian, EH25 9PS
Weed Research Organisation	Begbroke Hill, Yarnton, Oxford, OX5 1PF

State-aided Institutes in England and Wales

Animal Virus Research Institute	Pirbright, Woking, Surrey, GU24 0NF
East Malling Research Station	East Malling, Maidstone, Kent, ME19 6BJ
Glasshouse Crops Research Institute	Rustington, Littlehampton, Sussex, BN16 3PU
Grassland Research Institute	Hurley, Maidenhead, Berks., SL6 5LR
Houghton Poultry Research Station	Houghton, Huntingdon, PE17 2DA
John Innes Institute	Colney Lane, Norwich, NR4 7UH
Long Ashton Research Station	Long Ashton, Bristol, BS18 9AF
National Institute of Agricultural Engineering	Wrest Park, Silsoe, Bedford, MK45 4HS
National Institute for Research in Dairying	Shinfield, Reading, RG2 9AT
National Vegetable Research Station	Wellesbourne, Warwick, CV35 9EF
Plant Breeding Institute	Maris Lane, Trumpington, Cambridge, CB2 2LQ
Rothamsted Experimental Station	Harpenden, Herts., AL5 2JQ
Welsh Plant Breeding Station	Plas Gogerddan, Aberystwyth, Dyfed, SY23 3EB
Wye College, Department of Hop Research	Ashford, Kent, TN25 5AH

State-aided Institutes in Scotland

Hannah Research Institute	Ayr, Scotland, KA6 5HL
Hill Farming Research Organisation	Bush Estate, Penicuik, Midlothian, EH26 0PY
Macaulay Institute for Soil Research	Craigiebuckler, Aberdeen, AB9 2QJ
Moredun Institute (ADRA)	408 Gilmerton Road, Edinburgh, EH17 7JH
Rowett Research Institute	Bucksburn, Aberdeen, AB2 9SB
Scottish Crop Research Institute	Invergowrie, Dundee, DD2 5DA
	Pentlandfield, Roslin, Midlothian, EH25 9RF
Scottish Institute of Agricultural Engineering	Bush Estate, Penicuik, Midlothian, EH26 0PH

LIST OF ABBREVIATIONS

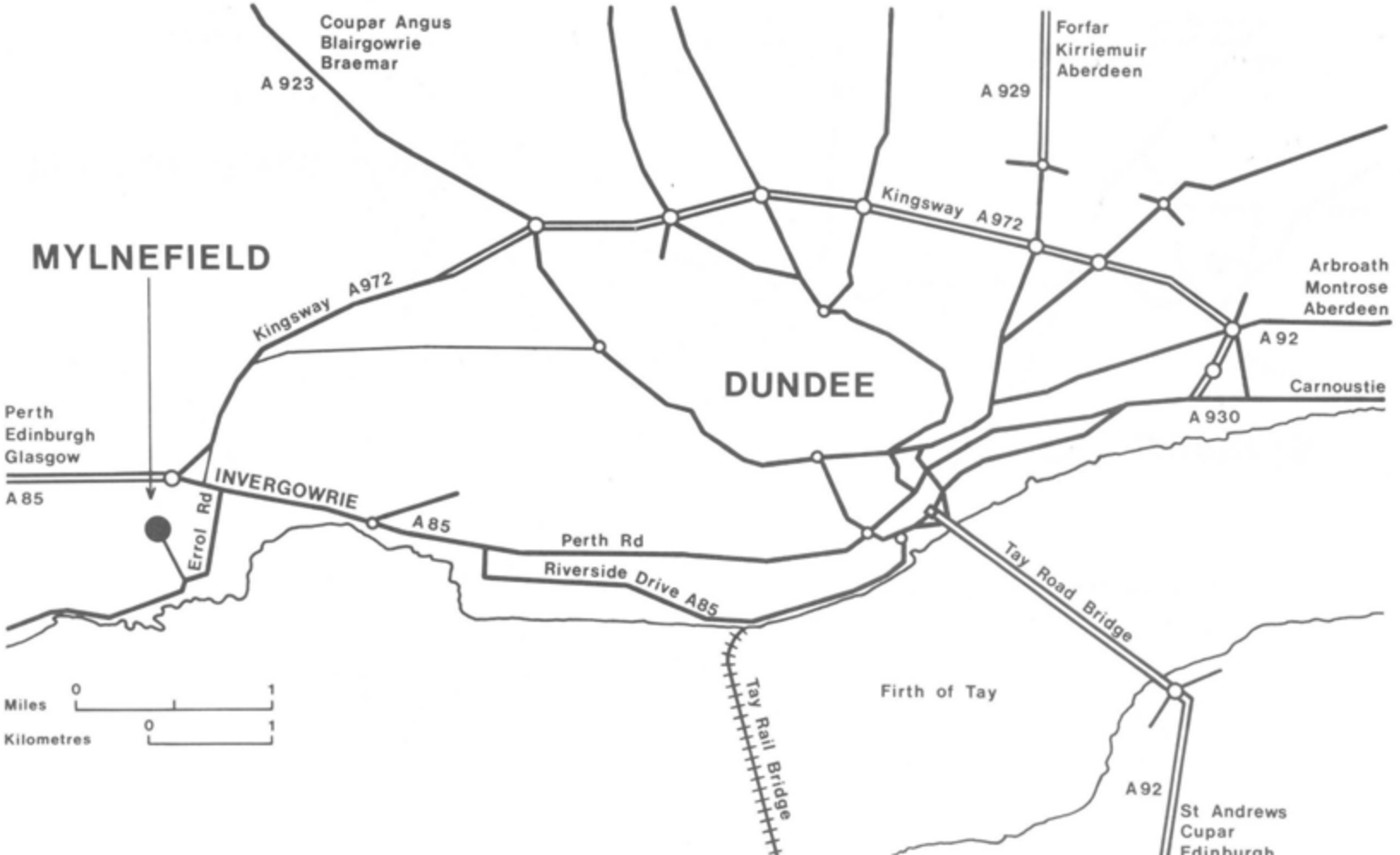
Countries and Organisations

AAB	Association of Applied Biologists
ADAS	Agricultural Development and Advisory Service
AFRC	Agricultural and Food Research Council
ATB	Agricultural Training Board
BA	British Association
BAPB	British Association of Plant Breeders
BBC	British Broadcasting Corporation
BC	British Columbia
BMS	British Mycological Society
BSPP	British Society of Plant Pathology
COSAC	Council for Scottish Agricultural Colleges
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFS	Department of Agriculture and Fisheries for Scotland
DANI	Department of Agriculture for Northern Ireland
DSIR	Department of Scientific and Industrial Research
EAPR	European Association for Potato Research
EMRS	East Malling Research Station
ERCC	Edinburgh Regional Computing Centre
ESCA	East of Scotland College of Agriculture
ESN	European Society of Nematologists
FAO	Food and Agricultural Organisation
FBPP	Federation of British Plant Pathologists
FRI	Food Research Institute
HEA	Horticultural Education Association
HFRO	Hill Farming Research Organisation
IRAD	Institute for Research on Animal Diseases
ISHS	International Society of Horticultural Science
ISPP	International Society of Plant Pathology
ISTA	International Seed Testing Association
JCO	Joint Consultative Organisation
JII	John Innes Institute
MAFF	Ministry of Agriculture, Fisheries and Food
MISR	Macaulay Institute for Soil Research
NATO	North Atlantic Treaty Organisation
NIAB	National Institute of Agricultural Botany
NIAE	National Institute of Agricultural Engineering
NSCA	North of Scotland College of Agriculture
NSDO	National Seed Development Organisation
NVRS	National Vegetable Research Station
PBI	Plant Breeding Institute
PMB	Potato Marketing Board
RHAS	Royal Highland and Agricultural Society
SARI	Scottish Agricultural Research Institutes
SEB	Society for Experimental Biology
SERC	Science and Engineering Research Council
SHRI	Scottish Horticultural Research Institute
SIAE	Scottish Institute of Agricultural Engineering
SIO	Scottish Information Office
SNSA	Scottish Nuclear Stock Association
SPBS	Scottish Plant Breeding Station
SRC	Science Research Council

SSRPB	Scottish Society for Research in Plant Breeding
STV	Scottish Television
UC	University of California
UK	United Kingdom
USA	United States of America
USDA	United States Department of Agriculture
USSR	Union of Soviet Socialist Republics
WPBS	Welsh Plant Breeding Station
WRO	Weed Research Organisation
WSAC	West of Scotland Agricultural College

Others

ACAS	Agricultural Chemicals Approval Scheme
AFRS	Agricultural and Food Research Service
Cv.	cultivar
CVT	Co-ordinated Variety Trials
DOMD	Digestible organic matter in dry weight
DM	dry matter
EEC	European Economic Community
EHF	Experimental Husbandry Farm
EHS	Experimental Horticultural Station
ELISA	enzyme-linked immunosorbent assay
EM	Electron microscope
EMAS	Edinburgh Multiple Access (Computer) System
JMT	joint main trial
NFT	National Fruit Trials
NIR	near infra-red
NLT	National List Trial
PCN	potato cyst nematode
RCCA	Research Council Co-operative Award
SDI	Selective Dissemination of Information
SMCO	S-methyl cysteine sulphoxide
TLC	thin layer chromatography
TGA	Total glycalkaloid
VTSC	virus tested stem cutting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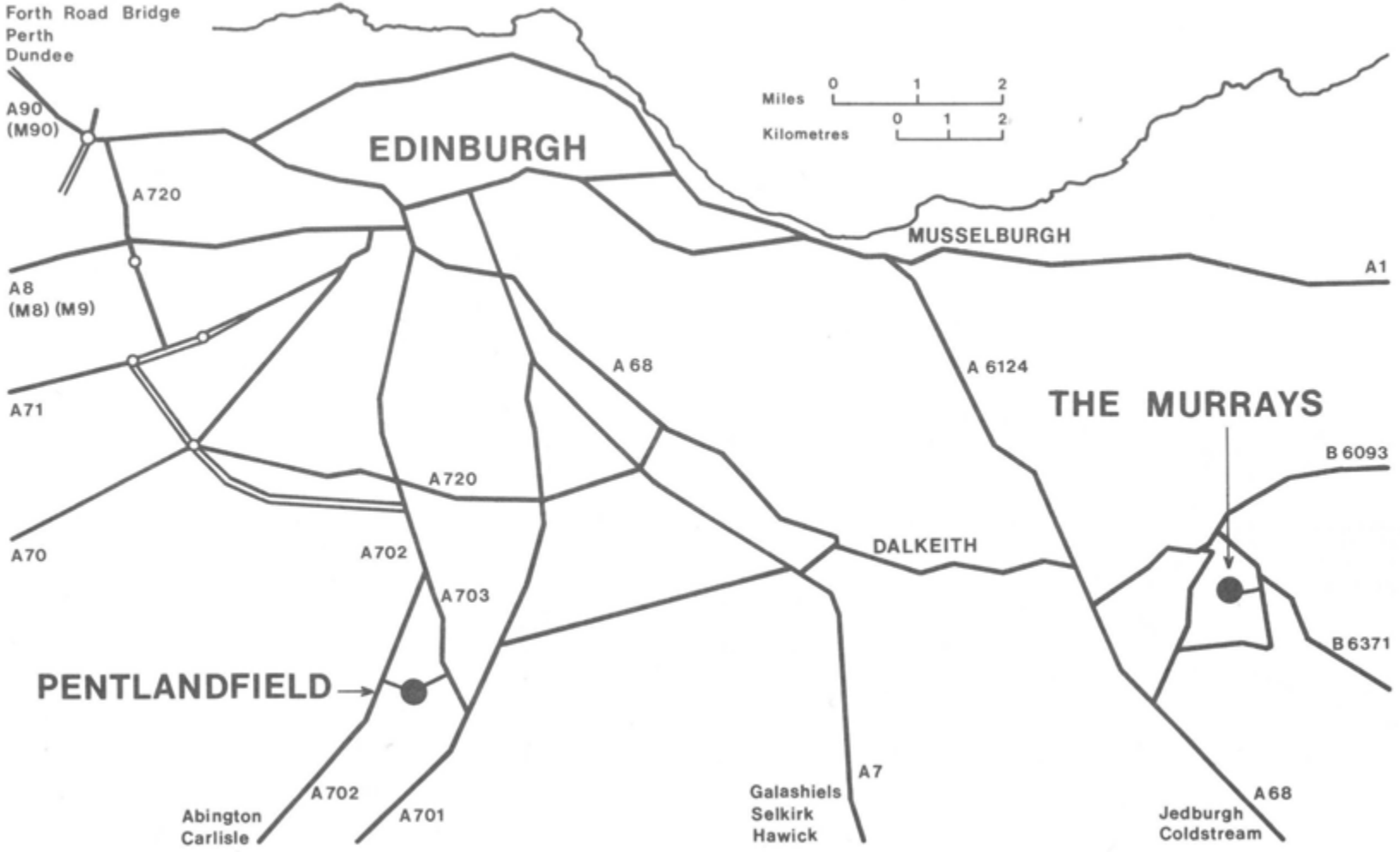
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