SCOTTISH CROP RESEARCH INSTITUTE

FOURTH ANNUAL REPORT

1984

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

GENERAL REPORT

C. E. TAYLOR

The Institute welcomed its first AFRC Visiting Group from 9 – 11 May inclusive. Visiting Groups had last reviewed the research programmes of SHRI and SPBS as independent institutes in 1973 and 1975 respectively. In 1980, soon after the Secretary of State for Scotland had approved the amalgamation of these two institutes, an ARC Programme Review Group provided advice on the content of the research programmes of the new Institute. The 1984 Visiting Group provided the first opportunity for the AFRC to re-assess these plans, and to examine proposals for the next 6 years. The Group consisted of: –

Professor D. C. Smith, F.R.S. (Chairman)
Professor J. F. Elston
Professor J. Friend
Professor J. D. Hayes
Professor D. L. Lee
Mr Maitland Mackie
Professor P. Wildy

It was supported by senior staff of the AFRC secretariat and of DAFS. The Secretary of the AFRC, Professor (now Sir) Ralph Riley, attended for the first day. The occasion provided an opportunity for discussion and exchange of views on the progress, structure and intentions of the Institute, and the Group is thanked for its helpful advice and constructive criticism. The research programme generally met with the approval of the Visiting Group. The proposed expansion of work in tissue culture and cell biology was welcomed, but the Institute's capacity to breed potato cultivars for overseas markets was doubted. However, this latter issue was resolved when the Group's Report was presented to the AFRC Council on 9 October and SCRI is now encouraged to continue and expand the breeding of cultivars for overseas markets in support of the Scottish seed potato industry.

The Institute's work was further examined in the course of two DAFS Commodity Reviews. The Grass and Fodder Crops Review was held on 28 March and the Horticultural Crops Review on 22 November. The outcome of these was to recommission most of the Institute's work in these areas. However, a decision was made to terminate the fodder cabbage breeding programme and to reduce the kale breeding effort and thus to concentrate brassica work on swede, forage rape and turnip together with associated research work.

At the end of the year papers were submitted to DAFS for the Cereals Review which is scheduled for early 1985.

The appointment in July of Dr N. L. Innes as Head of Plant Breeding Division enabled the divisional management of the research activities to be implemented. Three members of staff transferred to Mylnefield from Pentlandfield, and the posts of Officer-in-Charge and Director's Secretary at Pentlandfield were terminated. The nematologists in the Potato Breeding Department were re-assigned to the Zoology Department thus rationalising the organisation of their work. The movement of more staff from Pentlandfield is dependent upon progress with buildings at Mylnefield; it is expected that 1985 will see a significant migration which will facilitate further integration of personnel and programmes. The closure of at least some of the buildings and glasshouses at Pentlandfield should also result in fuel economies.

Building work continued at Mylnefield. A new car park, 960 m^2 in area, was built to the east of the existing buildings. A farm building of 630 m^2 was completed. It will be used for the storage of grain and farm machinery. A chemical store was built to house all potentially dangerous materials in full conformity with health and safety regulations. A new central store was opened in December; it provides enlarged, secure and improved facilities and enables the several unsatisfactory satellite stores dispersed about the site to be dispensed with. Conversion began of the old main store into an extension for the workshop. Work on the new propagation glasshouse and headerhouse complex began in January and continued throughout the year. It will provide 1314 m^2 of space to replace the dilapidated accommodation at Mylnefield and meet the additional requirement of staff moving from Pentlandfield.

Construction began of a new boiler house which will provide all the heating requirements of the site. Two new gas-fired boilers will be incorporated and the existing two boilers, which are oil-fired, will be converted to burn gas, or be replaced. Gas was provided to the site during the year. The central service project of providing a 'ring main' of water, electricity, telephone cables etc. in underground ducts was well advanced by the end of the year.

In August, building commenced of the crop handling building for the cereal breeders. It will provide reception and storage for their crops with modern and efficient facilities for drying, threshing and weighing. The area will be approximately the same as currently exists at Pentlandfield where the accommodation is scattered over several locations. Extension began of administration accommodation by adding a new storey to the Library. Among the new rooms will be one to house the terminal for the administrative computer; SCRI is the only institute lacking a terminal because at present there is no secure housing for it. Inevitably all this building work created some inconvenience for the staff at Mylnefield and this will continue for the next 2 or 3 years.

Distinguished visitors to the Institute included Lord Selborne, Chairman of AFRC accompanied by Dr J. Ingle; Sir William Fraser, Permanent Under Secretary of State for Scotland, and Lady Fraser; Mr A. Hitchcock, Chairman of the PMB and Mr S. R. Kingsley, Chief Executive of NSDO. Many other individuals and groups from home and overseas visited the Institute and expressed an interest in its work. It was a pleasure to receive them. The Annual Report for 1983 was released at a Press Day held on 1 August at which selected aspects of the work were discussed with the press, Governing Body and some invited guests.

The Institute frequently depends upon the help and co-operation of others, either individuals or organisations, without whose assistance the work would be greatly handicapped. The assistance may be from scientists with other organisations working on collaborative ventures, from farmers who generously make their land available for trials, from commercial companies undertaking testing work free of charge or from donations of finance or equipment. The Institute is most grateful to all its collaborators and very appreciative of the help that they give.

At the end of the year contact was established with the British Technology Group over a possible patent application; as reductions in government funding begin to take effect similar sources of finance will have to be investigated.

It has not been possible for financial reasons for the Institute to accept as many sandwich students for their industrial training as might have been wished; the number of research students has also had to be restricted. Nevertheless we did take a certain number of students (including several Dutch students from Wageningen) and recognise the valuable contribution that they make to the work of the Institute. In November six young people began their training at Mylnefield under the Youth Training Scheme.

It was with great regret that the Institute learned of the death on 10 April of Dr A. R. Wilson. Dr Wilson joined the SHRI in 1956 as Head of the Mycology Section and was Deputy Director from 1965 until his retirement in 1969. His first work at SHRI was on tomato diseases but he then returned to his principal interest of potato pathology and built a team investigating gangrene and the blackleg/soft rot complex; he was thus in the vanguard of the broadening of the SHRI remit. Today the protection of the potato crop is a major component of the SCRI programme.

Governing Body

Mr J. A. Inverarity was welcomed as a member of the Governing Body.

Financial assistance

An Foras Talúntais	£300
BASF United Kingdom Limited, Agrochemical Division	£575

Overseas Development Administration	£33,012
Potato Marketing Board	£8,417
Scotlab Instrument Sales Limited	£2,100
Scottish Agricultural Industries plc	£550
Scottish Society for Crop Research	£425
United Biscuits Agriculture	£1,856

Appointments

M. M. Aiton	SO	Virology Department
N. Anderson	Craftsman	Engineering and Maintenance Division
H. Bain	HSO	Chemistry Department
E. M. Bennett	EW	Forage Brassica Breeding Department
A. L. Craig	ASO	Virology Department
A. Cross	ASO	Chemistry Department
S. Cunningham	Craftsman	Engineering and Maintenance Division
S. R. Foote	ASO	Physiology and Crop Production Dept
D. W. Griffiths	HSO	Chemistry Department
E. Hall	CA	Administration Division
T. Hopton	P & TO I	Engineering and Maintenance Division
N. L. Innes	DCSO	Plant Breeding Division
Y. Jorgensen	ASO	Forage Brassica Breeding Department
A. M. Lennon	HSO	Virology Department
R. A. Macleod	ASO	Cereal Breeding Department
F. M. McGill	ASO	Zoology Department
P. R. Massalski	HSO	Virology Department
G. Menzies	EW 2	Information Services Division
C. Muir	ASO	Chemistry Department
L. M. Pitcher	ASO	Forage Brassica Breeding Department
T. Purves	Craftsman	Engineering and Maintenance Division
D. L. Richardson	HSO	Physiology and Crop Production Dept
C. W. Tymkewycz	ASO	Potato Breeding Department
E. W. Vandome	Asst Librarian	Information Services Division
K. Watson	ASO	Potato Breeding Department

Promotions

P. D. S. Caligari	PSO	Potato Breeding Department
D. M. Farrer	SO	Cereal Breeding Department
G. W. Pollock	P & TO IV	Engineering and Maintenance Division
P. Smith	HSO	Data Processing Department
K. Taylor	SO	Chemistry Department
C. E. Thomas	SO	Cereal Breeding Department
W. T. B. Thomas	SSO	Cereal Breeding Department
Y. White	CO	Administration Division

Awards

C. E. Taylor	Commander of the British Empire
E. Baird	SCOTEC Ordinary Certificate in Biological Sciences
D. M. Farrer	Cereal Crop Inspector, DAFS
A. E. Grant	ATB Certificate of Craftsmanship in Horticulture
R. Keith	ATB Certificate of Craftsmanship in Horticulture
A. Jenkins	SCOTEC Ordinary Certificate in Biological Sciences
A. Jolly	SCOTEC Ordinary Certificate in Biological Sciences
A. M. Lennon	Ph.D., University of Manchester
P. R. Massalski	D.Phil., University of Oxford
F. M. McGill	Higher National Diploma in Biology
A. J. Sim	SCOTEC Ordinary Certificate in Biological Sciences
P. J. Stewart	Scottish National Certificate in Computer Data Processing
G. W. Swinney	SCOTEC Certificate in Applicable Mathematics

Resignations

B. E. Asher	Asst Librarian	Information Services Division
M. J. C. Asher	SSO	Cereal Breeding Department
D. J. Hall	ASO	Potato Breeding Department
D. I. McGrath	Craftsman	Engineering and Maintenance Division
G. Reilly	Handyman/Caretaker	Engineering and Maintenance Division
J. Reilly	CO	Administration Division
G. A. Ritchie	ASO	Virology Department
A. M. Young	ASO	Physiology and Crop Production Department

Retirements

A. E. Cochrane, Driver/Groundsman in the Estate Division (Pentlandfield) retired on 1 November after 9 years service.

J. H. Couttie, Head of the Engineering and Maintenance Department at Mylnefield retired on 21 December after 28 years' service.

I. M. Hayes, Director's Secretary (Pentlandfield) retired on 22 June after 15 years service.

Redundancies

F. J. W. England, Officer in Charge, Pentlandfield was made redundant after 35 years service.

C. J. McDougall, Printer, Information Services Division was made redundant on 31 August.

Visiting Workers

M. A. Abou-Elnasr (Ain Shams University, Egypt) arrived in July to spend 10 months studying plant virological techniques (Virology Department).

O. Ansa (Ahmadu Bello University, Nigeria) spent 4 weeks in March studying the properties of groundnut rosette viruses (Virology Department).

P. R. Bristow (Washington State University, Puyallup, Washington, USA), spent 9 months working on the infection of strawberry flowers and fruits by *Botrytis cinerea* (Mycology & Bacteriology Department).

M. Coiro (Istituto di Nematologia Agraria del CNR, Bari, Italy) spent 1 month examining the taxonomy and biology of virus vector nematodes (Zoology Department).

A. El Hassan Shaaban (Sudan) spent 2 months working on barley malting quality under the auspices of the British Council (Cereal Breeding Department).

F. Faoro (Istituto di Patologia Vegetale, Milan, Italy) spent 8 weeks in June – July studying the infection of plant protoplasts with viruses (Virology Department).

B. Flis (Potato Research Institute, Mlochów, Poland) visited from 1 August to 26 September to work on potato breeding and associated research studies (Potato Breeding Department).

A. Kerr (Department of Plant Pathology, Waite Agricultural Research Institute, University of Adelaide, Australia) worked for a 4 week period from 26 November on opine catabolic functions of strains of *Agrobacterium* spp. pathogenic to *Rubus* spp. (Mycology & Bacteriology Department).

B. E. L. Lockhart (Institut Agronomique et Vétérinaire Hassan II, Agadir, Morocco) spent 1 week in October characterising new plant viruses by electron microscopy (Virology Department).

M. Pelsmaeker (University of Ghent, Belgium) spent 10 days in June discussing nematological techniques (Zoology Department).

D.V.R. Reddy (ICRISAT, Hyderabad, India) departed in April, having spent 6 months studying groundnut viruses (Virology Department).

G. S. Shekhawat (Division of Plant Pathology, Central Potato Research Institute, Simla, India) commenced an 8 month period working on bacterial soft rot of potato (Mycology & Bacteriology Department).

J. Solomon (Central Plantation Crops Research Institute, Kerala, India) spent 1 week in November studying techniques of electron microscopy of viruses (Virology Department).

Y. Speigel (Nematology Division, Volcani Center, Israel) spent 5 days in September, discussing and conducting experiments on host recognition in nematodes (Zoology Department).

R. E. Thornton (Washington State University) visited for 6 months to exchange information on potato growth and development (Physiology and Crop Production Department).

Research Assistants

R. A. Bain (PMB Research Assistant) continued studies of infection of potato by soft rot erwinias (Mycology & Bacteriology Department).

M. R. Groom (MAFF Research Assistant, jointly with University of Dundee), continued studies on the causes of cavity spot of carrot (Mycology & Bacteriology Department).

T. D. Heilbronn (PMB Research Assistant) continued for a second year to study the gap between farm yields and potential yields of potato (Physiology and Crop Production Department).

Research Students

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

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

M. J. Farmer (AFRC post-graduate student) began her studies on nepovirus proteins (Virology Department).

S. K. Hemida (Post-graduate student funded by University of Assiut, Egypt) began studies on virus properties and transmission by aphids (Virology 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 & Bacteriology Department).

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

L. V. Lopez-Llorca (Spanish post-graduate student) started studies on nematode/fungi interactions (Zoology Department).

V. M. Lumb (PMB post-graduate student), completed his studies on the effects of climate in Scotland and Israel on blackleg development (Mycology & Bacteriology Department).

L. A. Perryman (AFRC post-graduate student) continued studies on irradiated pollen as a means of gene transfer in plant breeding (Potato Breeding Department).

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

Sandwich Course Students

B. N. M. van Adrichem (Agricultural University Wageningen) worked on late blight (Potato Breeding Department).

O. C. R. Carter (Coventry Polytechnic) worked on the screening of potato for late blight and bacterial soft rot (Potato Breeding Department).

P. Degreef (Agricultural University, Wageningen) studied barley breeding methodology (Cereal Breeding Department).

P. Goudappel (Agricultural University, Wageningen) studied competition and selection in barley (Cereal Breeding Department).

M. Jones (Sheffield City Polytechnic) developed computer programs for the European Mapping of Plant Parasitic Nematodes and analysis of EPPNS data (Zoology Department).

F. de Langen (Agricultural University, Wageningen) investigated the morphology of aneuploid plants of *Brassica oleracea* (Forage Brassica Breeding Department). He also worked for 3 months on plant breeding problems in *Ribes* and *Rubus* (Soft Fruit Breeding Department).

R. Lindsay (Dundee College of Technology) worked on investigations into the causes of growth cracking in potato tubers (Physiology and Crop Production Department).

G. MacDonald (North East London Polytechnic) gained work experience of potato breeding (Potato Breeding Department).

C. Rijnders (Agricultural University, Wageningen) worked on isozymes of *Brassica campestris* (Forage Brassica Breeding Department). He also worked for 3 months on plant breeding problems in *Ribes* and *Rubus* (Soft Fruit Breeding Department).

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

A. J. Wilshin (Dundee College of Technology) studied elicitation of phytoalexins in potato by *Erwinia carotovora* (Mycology & Bacteriology Department).

Sabbatical Leave

D. L. Jennings commenced a 4 month visit to the Horticultural Research Institute, Victoria, Australia to study aspects of raspberry development.

Visits Abroad

T. J. W. Alphey visited INRA, Antibes, France, 11 – 16 December to attend the first meeting of the Steering Committee for the 18th International Symposium of the European Society of Nematologists.

J. Brown and P. D. S. Caligari visited Israel, 12 – 22 June, to harvest and assess potato clones in commercial assessment, *Verticillium* and *Alternaria* resistance trials.

R. A. Fox attended Council Meetings of the EAPR in Wageningen, Netherlands 23 – 26 February and in Interlaken, Switzerland 30 June – 1 July where he also attended a meeting of the EAPR Disease Assessment Committee and, from 2 – 7 July, the 9th Triennial Conference of the EAPR. He visited the Volcani Institute and Gilat Experimental Station in Israel 8 – 14 October, and the Institute for Agricultural Plant Breeding, Wageningen on 29 – 30 October to work on the EAPR Technical Dictionary and on 22 – 23 November for an EAPR Editors' Meeting.

B. D. Harrison spent 20 May – 3 June in Colombia examining virus diseases of cassava and discussing future research plans at Centro Internacional de Agricultura Tropical, Cali, in connection with ODA-funded work at SCRI. In September he paid brief visits to several centres of plant virus research in Japan.

J. R. T. Hodgkin spent 23 – 25 August in Holland visiting the Agricultural University, Wageningen and breeding centres to discuss current developments in brassica breeding.

N. L. Innes attended a Governing Board meeting of the ICRISAT at Hyderabad, India, from 11 – 16 September.

V. M. Lumb and R. A. Bain worked at the Volcani Center, Israel for 4 weeks in May and R. A. Bain for 4 weeks in November on the joint project on potato blackleg between SCRI and the Volcani Center. The visits were supported by the PMB and the Volcani Center.

W. H. Macfarlane Smith visited breeding establishments in Sweden, Denmark and Holland for 5 days in August to discuss work in progress on forage brassica crops.

G. R. Mackay visited Cyprus, 26 April – 2 May, to harvest potato trials and discuss collaborative arrangements with members of Cyprus Agricultural Research Institute. With P. D. S. Caligari he visited Spain and Algeria 23 – 30 May to harvest potato trials at Valencia and Staoueli respectively, and to assess the performance of SCRI potato clones. He attended the 9th Triennial Conference of the EAPR at Interlaken 2 – 7 July. With M. F. B. Dale he visited Rioja, northern Spain, 19 – 23 September, to harvest and assess potato clones in trial. He visited Portugal, 23 – 28 September, as a member of the SSPDC lecture tour of Portuguese farming co-operatives.

A. F. Murant visited the Institute of Plant Protection, Bet Dagan, Israel from 1 – 6 April, supported by a grant from the British Council.

M. C. M. Pérombelon visited Valencia, Spain, 26 – 28 March and 26 – 28 September in connection with the joint project between SCRI and Luis Matutano S.A. and INIA – CRIDA07 on blanking problems in crops caused by soft rot erwinias. The visits were supported by Luis Matutano S.A. and the SSPDC. He also visited the Volcani Center, Israel 13 – 20 May in connection with the joint project between SCRI and the Volcani Center on a comparative study of potato blackleg development in Scotland and Israel and attended an EMBO Workshop on Genetics of Soft Rot Erwiniae, Marseille, France 23 – 27 July.

W. M. Robertson visited the Volcani Center, Israel, 7 – 13 February, to discuss joint projects on nematode recognition.

D. J. Robinson attended the Sixth International Congress of Virology at Sendai, Japan, 1 – 7 September.

J. S. Swanston visited Gore, New Zealand, from 7 January to 6 April to select and harvest material from the SCRI barley nursery.

C. E. Taylor attended two meetings as a member of the Scientific Council of the Istituto di Nematologia Agraria, CNR, Bari, Italy from 11 – 13 June and 10 – 12 December. He attended the first International Congress of Nematology in Guelph, Canada from 5 – 11 August.

J. A. T. Woodford visited Frankfurt, Germany, 6 – 8 June to discuss the development and trialling of insecticides.

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

20 – 22 March	Crop Protection in Northern Britain 1984, University of Dundee	
	T. J. W. Alphey (S. C. Gordon)	The use of a side-banding machine to apply granular nematicides for the control of spraing in potatoes
	B. Boag	The effect of pesticides on *Longidorus elongatus* and the yield of a grass/clover sward
	S. C. Gordon	Pests of Tayberry and their control
	H. M. Lawson (B. Boag)	A review of weed control practices in swede crops in Scotland in 1982
	H. M. Lawson (J. S. Wiseman)	Evaluation of crop tolerance to herbicides for the control of annual weeds in raspberry
	H. M. Lawson (J. S. Wiseman) (M. E. Halford[1])	Evaluation of crop tolerance to herbicides for perennial weed control in raspberry and black currant
	D. A. Perry	Recent advances in control of cavity spot of carrots
	B. Williamson	Problems of diagnosis and control of raspberry cane blight and midge blight in Scotland
	J. A. T. Woodford (S. C. Gordon) (G. N. Foster[2]) (R. G. McKinley[1]) (M. W. Shaw[3])	Trials with granular insecticides for the control of aphids and potato leafroll virus disease in Scotland, 1980 – 82
2 – 3 April	Royal Institute of Chemistry, East Anglian Branch, Cambridge	
	I. A. Cowe (J. W. McNicol)	A suite of programs for the structural analysis of near infra-red spectra and prediction of chemical composition

[1] Crop Division ESCA
[2] Biological Sciences Division WSAC
[3] Zoology Division NSCA

3 – 5 April	Society for Experimental Biology, Environmental Physiology Group, Cardiff	
	W. W. Kirk (B. Marshall)	Temperature and potato leaf development
3 – 4 April	Society for Experimental Biology, Nucleic Acids and Protein Group, Cardiff	
	D. J. Robinson (I. M. Roberts) (J. C. Sequeira[1]) (B. D. Harrison)	African cassava mosaic virus: relationships to other gemini-viruses, and effects of temperature
4 – 5 April	F. E. Nitzany Workshop on Epidemiology and Diagnosis of Plant Viruses, Bet Dagan, Israel	
	A. F. Murant	The nature of plant virus satellites
	A. F. Murant	Helper-dependence among persistent and semi-persistent aphid-borne viruses
12 April	Society for General Microbiology, Clinical Virology Group, Warwick	
	I. M. Roberts	Technical aspects of immuno-sorbent electron microscopy
22 May	AAB, Cambridge, Novel Techniques in Plant Breeding	
	W. Powell (P. D. S. Caligari)	Irradiated pollen as a means of limited gene transfer
26 – 28 June	European and Mediterranean Plant Protection Organisation Workshop on Cyst Nematodes, Münster, West Germany	
	M. F. B. Dale	Field performance of potato cultivars resistant and partially resistant to *Globodera pallida* (Stone)
	M. S. Phillips	The effect of environmental factors on the expression of resistance particularly with regard to initial population density
	M. S. Phillips (D. L. Trudgill)	Variation in virulence in British populations of *Globodera pallida*
	D. L. Trudgill	Potato cyst nematode : pathotyping problems

[1]Estacio Agronómica Nacional, Oeiras, Portugal

26 – 29 June	International Erwinia Conference, Edinburgh	
	M. C. M. Pérombelon	Blackleg: the disease, its symptoms, pathology and terminology
	M. C. M. Pérombelon	The blackleg problem as it affects seed potato exports
	M. C. M. Pérombelon	Outline of advice to growers to minimise disease spread and development
	M. C. M. Pérombelon	Assessment of how present knowledge might reflect the standards of blackleg freedom required in certification schemes
	M. C. M. Pérombelon	Research and development and international co-operation: proposals for discussion
2 – 7 July	9th Triennial Conference of the EAPR, Interlaken, Switzerland	
	H. Barker	Studies on mechanism of resistance in potato to potato leafroll virus
	J. Brown (P. D. S. Caligari) (G. R. Mackay) (G. E. L. Swan)	The efficiency of selection in the early generations of a potato breeding programme
	M. F. B. Dale	Resistance to *G. pallida* within *Solanum tuberosum*
	M. J. De, Maine	Effect of doubling the chromosome number of dihaploids on characters affecting tuber yield
	R. A. Fox	Observations on root pathogens of potato and the effects of different lengths of rotations
	D. K. L. MacKerron	Potato sprout emergence in soil as a function of temperature and time from planting
	B. Marshall (T. D. Heilbronn[1]) (D. K. L. MacKerron) (P. D. Waister)	Modelling potential dry matter production

[1] Research Assistant

	P. D. Waister (P. A. Gill) (H. A. Ross)	The phasing of stem-to-stem and plant-to-plant competition in the potato crop
17 – 19 July	EMBO Workshop on Plant Viruses, Satellites and Viroids: Genome Structure, Expression and Replication, Strasbourg, France	
	M. A. Mayo (D. V. R. Reddy[1]) D. J. Robinson	Translation *in vitro* of RNA from Indian peanut clump virus Genome sequence relationships and variability among tobraviruses
5 – 10 August	First International Congress of Nematology, Guelph, Canada	
	T. J. W. Alphey (R. Bromilow[2])	Studies on the production of nematicidal root exudate following foliar applications of oxamyl
	B. Boag (T. J. W. Alphey)	The influence of competition on migratory ectoparasitic nematodes with r and K survival strategies
	D. J. F. Brown	Groups of *Longidorus* species (Nematoda : Longidoridae) present in European and Mediterranean countries
	J. M. S. Forrest (W. M. Robertson) (D. L. Trudgill)	Mass re-emergence of potato cyst nematode juveniles from roots of resistant potatoes—are surface sugar moieties involved?
	D. L. Trudgill	The effect of reciprocal grafting between two potato cultivars on tolerance to *Globodera pallida*
13 – 18 August	Eighth European Congress on Electron Microscopy, Budapest, Hungary	
	I. M. Roberts	Freeze-drying and high resolution shadowing of plant virus particles for structural studies

[1] Visiting Worker
[2] RES

20 – 22 August	8th International Symposium on Sexual Reproduction in Seed Plants, Ferns and Mosses, Wageningen, The Netherlands	
	J. R. T. Hodgkin (G. D. Lyon)	Pollen germination inhibitors associated with the self-incompatible response of *Brassica oleracea* L.
27 – 29 August	Pre-congress Symposium of the Sixth International Congress of Virology, Taipei, Taiwan	
	B. D. Harrison	Involvement of virus-specified proteins in transmission of plant viruses by vectors
1 – 7 September	Sixth International Congress of Virology, Sendai, Japan	
	B. D. Harrison	Usefulness and limitations of the species concept for plant viruses
	B. D. Harrison (D. J. Robinson) (I. M. Roberts)	Genome and serological relationships among geminiviruses
	A. F. Murant (G. H. Duncan)	Nature of the dependence of heracleum latent virus on heracleum virus 6 for transmission by the aphid *Cavariella theobaldi*
	A. F. Murant (D. V. R. Reddy[1]) (G. H. Duncan) (J. H. Raschké) (O. Ansa[1]) (M. A. Mayo)	Properties of the aphid-transmitted complex of groundnut rosette virus and its helper, groundnut rosette assistor virus
11 – 12 September	International Symposium on Transmission of Plant and Animal Viruses by Vectors, Fukuoka, Japan	
	B. D. Harrison	Keynote address: Impact of molecular biology on research on vector transmission and ecology of plant viruses
	A. F. Murant	Comparison of viruses dependent on luteoviruses for transmission by aphids

[1] Visiting Worker

17 – 20 September	Workshop on Computers in Biogeography, Johannes Kepler Universität, Linz, Austria	
	P. B. Topham (T. J. W. Alphey) (C. E. Taylor)	European Plant Parasitic Nematode Survey: NEMA-National European Mapping Approaches
18 – 20 September	Better Brassicas '84 Conference, St. Andrews	
	M. J. Allison	The use of infra-red reflectance analysis to estimate kale digestibility
	J. E. Bradshaw	Kale breeding at SCRI: population improvement and cultivar production
	I. A. Cowe (R. C. McDonald[5])	Effect of tissue type on near infra-red reflectance prediction of nitrogen in kale
	S. Gowers	Swede breeding at SCRI
	J. R. T. Hodgkin	The potential for pollen selection in brassicas
	J. R. T. Hodgkin (I. H. McNaughton)	A preliminary report on the use of irradiated pollen for interspecific, intergeneric and intraspecific gene transfer in the brassicas
	N. L. Innes	Concluding remarks
	W. H. Macfarlane Smith	Forage rape breeding at the SCRI
	W. H. Macfarlane Smith (V. A. F. Heppel[1]) (J. Wood[2]) (W. D. Gill[3]) (K. C. Walker[4])	Husbandry practices in forage rape growing
	C. E. Taylor	Introductory remarks
	C. J. Williamson	Resistance to *Plasmodiophora brassicae* in *Brassica napus*
	C. J. Williamson	Yield losses due to powdery mildew in swede and forage rape

[1] Advisory and Development Division WSAC
[2] AFRC Unit of Statistics
[3] Crop Division ESCA
[4] Crop Husbandry Division NSCA
[5] Woodlands Agricultural Research Institute, Invercargill, New Zealand

	C. J. Williamson (G. R. Dixon[1])	The combination of host resistance and calcium cyanamide for control of *Plasmodiophora brassicae* (clubroot) in swede
25 – 27 September	AAB, Reading	
	H. Barker	New aspects of the resistance of potato to potato leafroll virus
	J. M. S. Forrest (W. M. Robertson) (D. L. Trudgill)	Mass re-emergence of potato cyst nematode juveniles from roots of resistant potatoes—possible involvement of surface sugar moieties
	B. D. Harrison	Effects of agricultural change on virus diseases: new problems and opportunities
	B. D. Harrison (D. J. Robinson) (I. M. Roberts)	Genome and serological relationships among geminiviruses
	A. T. Jones (A. Remah[2]) (M. J. Cannon)	Properties of another new virus infecting lucerne in Australia
	A. T. Jones (M. J. Cannon)	New and old virus disease problems in *Rubus* in Britain
	P. R. Massalski (J. I. Cooper[3])	Seed and pollen transmission of cherry leaf roll virus in birch and other trees
	P. R. Massalski (J. I. Cooper[3])	Cherry leaf roll virus: cDNA hybridisation, relationships and RNA homology
	W. P. Mowat	Prevalence and prospects for control of narcissus mosaic and narcissus tip necrosis viruses
	A. F. Murant (G. H. Duncan)	Possible mechanism of the dependence of heracleum latent virus on heracleum virus 6 for transmission by aphids
	C. E. Taylor	Highlights of the First International Congress of Nematology
16 – 17 October	Australian Association of Cereal Chemists: Near Infra-red 1984 Melbourne, Australia	
	I. A. Cowe (J. W. McNicol)	Some Techniques for the Interpretation of Near Infra-red Reflectance Data

[1] Horticulture Division NSCA
[2] Institut Agronomique et Vétérinaire, Agadir, Morocco
[3] NERC, Oxford

19 – 20 October	Australian Association of Cereal Chemists: Annual Conference, Melbourne, Australia	
	I. A. Cowe (J. W. McNicol)	The assessment of malting quality in a barley breeding programme at the Scottish Crop Research Institute
10 – 12 December	Marketable Yield of Cereals, NAC Course, University of Warwick	
	D. A. Perry	Seed requirements for germination and crop establishment
11 December	AAB/ISHS Symposium on Weed Control in Fruit Crops, Oxford	
	H. M. Lawson	Volunteer crops as weeds of soft fruit crops
	H. M. Lawson	The contribution of soil partial sterilants to weed control in soft fruit crops
	H. M. Lawson	Herbicide recommendations for fruit crops
17 – 19 December	British Society for Plant Pathology, Control of Plant Diseases; Costs and Benefits, Manchester	
	R. L. Wastie (R. M. Solomon)	The value of resistant cultivars of potato to disease control

Conferences Organised

R. A. Fox served on the management committee for the Third Triennial Conference on Crop Protection in Northern Britain, 1984, held at the University of Dundee, 20 – 22 March.

H. M. Lawson served on the organising committee of the Conference on Crop Protection in Northern Britain, 1984, held at the University of Dundee, 20 – 22 March. He also served on the organising committee and chaired a session of the BCPC Symposium on Soils and Crop Protection Chemicals, at Wye College, Kent, 11 – 12 July.

W. H. Macfarlane Smith, J. R. T. Hodgkin and A. B. Wills organised Better Brassicas '84, a UK Conference on the improvement of brassicas, held at St. Andrews, 18 – 20 September.

C. E. Taylor was a member of the organising committee for the First International Congress of Nematology held in Guelph, Canada from 5 – 11 August. In this connection he attended an organising seminar at the University of Florida, Gainesville from 23 – 27 April.

Courses Organised or Contributed to

B. Boag organised a Workshop sponsored by the Nematology Group of the AAB held at RES on the identification and biology of ring, sheath and pin nematodes in the British Isles on 29 March.

D. J. F. Brown gave a lecture on soil-borne virus diseases of potatoes in Britain as part of the Seed Potato Production in Scotland, International Course, ESCA on 15 June.

G. H. Duncan was one of the organisers of the Scottish Symposium on Electron Microscope Techniques held in Dundee on 21 November.

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 basic training course on Crop Protection at WSAC on 26 January and 25 October.

G. R. Mackay lectured on potato breeding in the UK to the Seed Potato Production in Scotland, International Course, ESCA on 15 June.

I. M. Roberts (with M. J. W. Webb[1] and G. J. Hills[2]) organised and was an instructor at two electron microscopy workshops at the JII from 2 – 4 and 5 – 6 April.

D. L. Trudgill gave a lecture on the biology and control of potato cyst nematodes in seed potato land as part of the Seed Potato Production in Scotland, International Course, ESCA on 15 June.

R. L. Wastie lectured on bacterial soft rot of potatoes at Coventry Polytechnic on 9 February. He also lectured to students on blight and blackleg at the Seed Potato Production in Scotland, International Course, ESCA, on 15 June.

A 3-week course of lectures on crop physiology, weeds, fungal pathogens and plant viruses was repeated at the University of Dundee, with 12 members of staff from four departments acting as lecturers.

Courses Attended

H. Bain attended a course on capillary gas chromatography at Leeds University from September 24 – 29.

E. Baird and A. Young attended a course for Cereal Disease Recorders at NIAB, Cambridge on 12 June.

R. J. Clark attended a course on The Data Protection Act 1984, Dundee on 11 December, sponsored by the British Computer Society and British Telecom.

P. A. Gill attended an ERCC course on Computer Graphics, Edinburgh 14 – 18 May 1984.

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[1] NVRS
[2] JII.

P. A. Gill attended the 12th Scottish Symposium on Electron Microscope Techniques, Dundee, 21 November 1984.

C. E. Henry attended an RMS Principles of Light Microscopy Course at Brunel University, London, 15 – 20 July.

W. W. Kirk and B. Marshall attended a series of tutorials on Biometry at the University of Dundee, autumn and spring terms.

R. Lowe, N. A. Williams and J. Ross attended a course Separations for Biotechnology and Biochemistry, 26 – 30 March at Loughborough University of Technology.

M. C. M. Pérombelon attended a workshop on Techniques in Molecular Biology at the Hatfield Polytechnic, 10 – 14 September.

W. M. Robertson attended an AFRC Electron Microscope Immunochemistry Workshop at the JII, 5 – 6 April.

P. Smith attended a Quantimet Advanced Training Course, Cambridge Instruments, 2 – 6 February.

K. Taylor attended an ERCC-organised course on Fortran Programming held at Edinburgh University, 15 – 19 October.

R. L. Wastie, T. G. Archibald and C. P. Carroll attended a Lift Truck Safety Course, The Murrays farm, organised by ROSPA, 17 February.

J. D. Watson attended a Graphics Facilities Workshop at ERCC, 19 June.

Invited Lectures

P. D. S. Caligari lectured on Plant Breeding and Future Developments, at the Edinburgh Biotechnology Forum, University of Edinburgh on 21 November. He lectured on the Use of Irradiated Pollen as a Means of Gene Transfer in Plant Breeding at the Department of Plant Biology and Ecology, St. Andrews University on 7 February.

B. D. Harrison gave lectures on Geminivirology and Cassava at the CIAT, Cali, Colombia on 29 May, and Relationships Among Geminiviruses, Nepoviruses and Tobraviruses at the National Agriculture Research Center, Tsukuba, Japan on 24 August.

N. L. Innes gave the Masters Memorial lecture on The Work of the NVRS in Conservation and Breeding of Vegetables to the RHS in London on 9 October.

D. L. Jennings gave a lecture on Soft Fruit Breeding to students at the Royal Botanic Gardens, Edinburgh on 12 June.

A. T. Jones gave a lecture and led a discussion on Viruses in Soft Fruit on 11 October at Forfar to a group of growers and Agricultural College Advisers.

H. M. Lawson gave a talk on Weed Control in Soft Fruit to a meeting of growers organised by WSAC at Paisley, on 28 February.

G. D. Lyon gave a lecture to the Microbiology Department at Birmingham University on Phytoalexins: A Defence Against Attack? on 29 October.

D. K. L. MacKerron gave a lecture on the effects of water supply on quality and yield in potato at a seminar on irrigation organised by Wright Rain Ltd. on 27 March. He also gave a lecture on the importance of timing irrigation and the effect on yield and quality of potatoes at a seminar organised by Norsk Hydro Fertilisers Ltd. on 21 November.

M. A. Mayo gave a seminar on Satellites to the Microbiology Department, Birmingham University on 15 October.

M. C. M. Pérombelon gave a lecture on 23 July at the EMBO Workshop on Genetics of Soft Rot Erwiniae in Marseille, France entitled Pathogenicity of Soft Rot Erwinias.

I. M. Roberts gave a lecture entitled Antigen/Antibody Reactions in the Electron Microscopy of Viruses to the Microbiology Society, University of Dundee on 1 November.

C. E. Taylor gave a lecture on Scientific Pathways in Agricultural Research to the University of Dundee Biochemistry Society on 16 January. He gave a lecture on Horticultural Production and Improvements at the Institute of Biology's meeting Food for the 90s held in Glasgow on 7 April.

P. D. Waister lectured on the Physiological Basis of Yield at the RASE course: Yield of Potatoes, 8 – 10 February, Peterborough, and 12 – 14 December, Warwick. He also gave a lecture on Raspberry Growth and Development to the Biological Science Department, University of Bath, on 21 February.

Students from St. Andrews University and WSAC received a series of 16 lectures together with demonstrations on plant viruses, fungal and bacterial pathogens and crop pests by the Director, and the staff of the Mycology & Bacteriology, Virology, and Zoology Departments.

Editorial Duties

P. D. S. Caligari	Member of Editorial Board of *Heredity*
R. A. Fox	Executive Editor of *Potato Research*
B. D. Harrison	Editor of *Commonwealth Mycological Institute/ Association of Applied Biologists, Descriptions of Plant Viruses*
	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*

M. A. Mayo	Joint Editor of *Journal of General Virology*
I. H. McNaughton	Joint Editor of *Eucarpia Cruciferae Newsletter*
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 of *Crop Research*
D. L. Trudgill	Consulting Editor of *Plant and Soil*
P. D. Waister	Associate Editor of *Journal of Horticultural Science* Associate Editor of *Crop Research*
A. B. Wills	Member of Editorial Board of *Crop Research* Joint Editor of *Eucarpia Cruciferae Newsletter*

Service on Committees

T. J. W. Alphey	Co-ordinator and UK representative of the European Plant Parasitic Nematode Society Member of the Steering Committee of the 18th International Symposium of the European Society of Nematologists
M. M. Anderson	NFT Black Currant Panel
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
I. A. Cowe	Vice-Chairman of the ICC study group (D)—Infrared techniques
M. F. B. Dale	AAB Member of the Plant Breeding Group Committee
R. P. Ellis	Institute Representative BAPB, Cereal Crop Group BAPB Representative on COSAC Recommended List Consultative Committee 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

S. C. Gordon	Member of the AFRC Pesticide Application Research Discussion Group
	AAB Member of the Pesticide Application Group Committee
B. D. Harrison	Institute of Virology, Oxford, Advisory Committee
	Sixth International Congress of Virology, Programme Committee
	AFRC/SERC/DTI Plant Biotechnology Steering Group on Pathogenesis and Symbiosis
N. L. Innes	Board European Association of Plant Breeders (EUCARPIA)
	Governing Board International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India
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
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
	Plant Variety Development Panel
	SCRI/ASS/COSAC Forage Brassica Working Group
G. R. Mackay	BAPB Member of Main Committee and Convener of Potato Crop Group
D. K. L. MacKerron	Chairman EAPR Working Group on Water Relations
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
	Maximum Yields/Yield Constraints of Cereals Working Group
M. A. Mayo	XIV International Congress of Microbiology, Member of Virology Programme Sub-Committee of the Scientific Programme Committee
W. P. Mowat	Convener of SNSA Bulb Technical Committee
	Member of the AAB Virology Group 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
M. C. M. Pérombelon	ISPP Member, Bacteriology Section Committee
	Chairman International *Erwinia* (Soft Rot) Group
I. M. Roberts	Chairman AFRC Electron Microscope Advisory Group
W. M. Robertson	AAB Member of the Nematology Group Committee
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
R. D. Taylor	ATB Horticultural Training South of Scotland Committee
	Scottish Association of Young Farmers' Clubs Proficiency Tests, Council for Agriculture: Horticultural Panel
R. Thompson	MAFF Research Consultative Committee; Other Arable Crops, Technical Secretary
	Secretary DAFS Maximum Yield/Yield Constraints of Potatoes Working Group
	SCRI/COSAC Liaison Group
P. B. Topham	ERCC member of Research Councils' Users' Committee
P. D. Waister	Tayside and Fife Branch Committee of BA
	HEA Scottish Branch Committee
	Dundee University Botanic Garden Committee
	Elmwood Agricultural and Technical College Horticultural Advisory Committee
	Chairman DAFS Maximum Yield/Yield Constraints of Potatoes Working Group

	Chairman SNSA VT Narcissus Evaluation Panel Co-Chairman EAPR Working Group on Tuber Numbers AFRC/DAFS/MAFF Fruit Committee
R. L. Wastie	Member of Council British Society for Plant Pathology
A. B. Wills	BAPB Vegetable Crop Group AAB Member of Plant Breeding Group Committee SCRI/ASS/COSAC Forage Brassica Working Group
J. A. T. Woodford	AAB Member of the Entomology Group Committee

Exhibitions and Poster Sessions

21 – 23 February	*British Growers Look Ahead, Harrogate* Display featuring information on new soft fruits bred at SCRI
20 – 22 March	*Crop Protection in Northern Britain 1984, University of Dundee* The HORTIHERB information retrieval system Snow rot in winter barley
9 – 10 April	*Society for General Microbiology, Virus Group, Warwick* Satellite nature of 'virusoid' RNA Naturally occurring tobravirus pseudo-recombinants
16 May – 6 June	*Liverpool Garden Festival : Information Technology in Horticulture* Demonstration of HORTIHERB program
17 May	*British Society for Research into Agricultural Engineering, Edinburgh : Spraying Technology* Cross-flow fan assisted spraying of raspberries
19 – 24 June	*10th Eucarpia Congress, Wageningen, Netherlands* Irradiated pollen in barley breeding
2 – 5 July	*The Royal Show, Warwick. AFRC Science Into Practice* New black currants for the 80's
1 – 2 August	*Fruit Focus, Rochester* Air-assisted spraying of raspberries
5 – 10 August	*First International Congress of Nematology, Guelph, Canada* Advances in the use of the computer for the identification of nematodes

	The European Plant Parasitic Nematode Survey Groups of *Longidorus* species (Nematoda : Longidoridae) present in European and Mediterranean countries *Pratylenchus penetrans* and soil fungi as causes of replanting problems in Scottish raspberries
17 – 18 August	*Perth Horticultural Show* Tayberry and Tummelberry
21 – 23 August	*Ayr Flower Show* Tayberry and Tummelberry
20 – 24 August	*8th International Symposium on Sexual Reproduction in Seeds, Plants, Ferns and Mosses, Wageningen* Pollen germination inhibitors associated with the self-incompatible response of *Brassica oleracea* L.
1 – 7 September	*Sixth International Congress of Virology, Sendai, Japan* The biochemical and genetic bases of variation between tobravirus isolates
12 September	*HEA Scottish Branch Conference: Computers in Horticulture* The HORTIHERB information retrieval system The use of computers for calabrese maturity prediction
17 – 19 September	*The Sixth John Innes Symposium on The Cell Surface in Plant Growth and Development* Pollen germination inhibitors associated with the self-incompatible response of *Brassica oleracea* L. Do phytoalexins modify recognition sites on *Erwinia carotovora?* Saccharide residues on potato cyst nematode—a role in host recognition Surface carbohydrates involved in virus/plant/nematode interactions The cell surface in plant growth and development
17 – 20 September	*Workshop: Computers in Biogeography, Linz, Austria* European Plant Parasitic Nematode Survey : NEMA—National European Mapping Approaches
18 – 20 September	*Better Brassicas '84 Conference, St. Andrews* Fodder radish, a crop with potential? Seedling test for resistance to *Plasmodiophora brassicae* SCRI method for estimation of SMCO in brassicas

19 – 22 November *British Crop Protection Conference : Pests and Diseases, Brighton*
Alternatives to DDT for the control of clay-coloured weevils in raspberry

12 – 14 December *RASE course: Yield of Potatoes, NAC Warwick*
Displays on the differences between farm yields of potato and potentials, and on factors affecting size grade distribution of tubers

Radio and Television

D. L. Jennings, 26 April, The Tayberry, *Radio Tay.*

C. E. Taylor, 10 April, Outlook for Horticulture, *Radio Tay.*

C. E. Taylor, 30 July, Prospects for Research, *BBC Radio Scotland.*

D. L. Trudgill, 13 April, Plant Nematology, *Radio Tay.*

P. D. Waister, 18 April, Research at SCRI, *Radio Tay.*

D. L. Jennings, 20 December, Country Hour. Impressions of Raspberries in Tasmania, *Australian Broadcasting Corporation* (Tasmania).

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CEREAL BREEDING

R. P. ELLIS

The spring barley cultivars Tweed and Heriot performed well in 1984 Scottish Agricultural Colleges' Recommended List Trials and both have been recommended for general use in Scotland. Spring barley cultivars Ayr and Esk were two of the highest yielding lines in 1984 first year National List Trials (NLT 1) and both continue in trial in 1985, as does cv. Forth. Six new submissions to NLT 1 in 1985 were made, five of the erectoid habit and one of the semi-prostrate habit.

Alterations were made to the spring barley breeding scheme to try to reduce the occurrence of non-uniform stocks and increase overall efficiency. The most advanced material in the winter barley breeding programme is being trialled at several sites and more material is being generated and assessed at earlier stages in the programme.

The analysis of data from the Triple Test Cross experiment in spring barley was extended to an examination of phenotypic, genetic and environmental correlations. Work continues on the development of cross prediction by the use of random F_3 lines and doubled haploid families. Good estimates of relative cross performance were achieved with both techniques.

Studies of random inbred lines produced by both single seed descent and doubled haploidy showed associations between the *erectoides* dwarfing gene and a number of agronomic and yield characters which did not diminish following rounds of recombination whereas association between the *denso* dwarfing gene and a daylength response gene did disappear.

Collaboration between SCRI, WPBS and PBI was extended; the WPBS pathology work was integrated with the breeding programmes at SCRI and PBI.

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

Cv. Tweed continued to perform well in the Scottish Agricultural Colleges' Recommended List trials and will continue to have a general recommendation for growing in Scotland in 1985. Its mildew resistance remained very good and its 'good' malting quality was confirmed. Certified seed of Tweed is available for sowing in 1985.

Cv. Heriot was entered in the Scottish Colleges' trials for the first time in 1984. It performed well and received a provisional general recommendation for growing in Scotland in 1985. Heriot has good resistance to powdery mildew but its diversification group has yet to be established. For a further description of Heriot (*Ann. Rep. 1983,* 46). Its sister line, cv. Nairn, performed rather poorly in the Scottish Agricultural Colleges' Recommended List Trials in 1984 and was withdrawn from further trials. As both Heriot and Nairn possess winter cultivars in their pedigree, their suitability for use as winter barley(s) is being assessed in an autumn sown trial together with standard winter barley control cultivars.

Cultivars Ayr (SCRI 8310) and Esk (SCRI 8313) performed well in NLT 1. They were amongst the highest yielding lines in both the NL and BAPB series of trials, and also have good all round disease resistance and early maturity. Both continue into second year Value for Cultivation and Use (VCU) trials in 1985. Cv. Forth (SCRI 836) performed adequately in NLT 1 and proceeds to the second year of trials but cv. Teviot (SCRI 8318) was withdrawn.

Six new submissions for NLT 1 in 1985 were made from the 20 stocks in secondary progeny trials and multiplication in 1984. SCRI 843 and SCRI 844 were both derived from the cross (cv. Goldmarker × cv. Athos) × (Goldmarker × cv. Magnum) and were third and second highest yielders in the 1984 Joint Main Trial (JMT). Both are early maturing erectoid lines and possess good all round disease resistance. SCRI 8410 and SCRI 8413 were derived from the cross ((cv. Akka × cv. Midas) × cv. Aramir) × cv. Ingot and yielded very well in the 1984 JMT. They are late heading erectoid lines and possess good resistance to powdery mildew and yellow rust. SCRI 845, derived from the cross (MM47 × Guinness 377/1) × Heriot, is a late heading *denso* line which also performed well in the 1984 JMT. SCRI 8418 is a medium heading erectoid line derived from the cross ((Akka × Midas) × Aramir) × cv. Yamina which performed well in an SCRI trial series.

Eighteen selections, representing the *erectoides, denso* and *nutans* growth habits, were made from the 206 stocks in primary progeny trials and multiplication in 1984. These are entered into secondary progeny multiplication and the Joint Main Trial in 1985. Pure-breeding lines were selected from several high yielding, but non-uniform, stocks from the 1984 primary trials and these have been re-entered into primary progeny trials and multiplication.

Over the last few years the standard procedure in the SCRI spring barley breeding programme was to trial selected F_4 bulks of F_2 single plants whilst raising a separate nursery of head rows associated with each trial bulk. The best ear rows related to the best bulks were then entered into a primary progeny multiplication and trial scheme, but as much of

the material was found to be non-uniform at this stage, the breeding scheme was altered to irradicate the problem. Firstly, selections for primary progeny trial and multiplication were grown in the spring barley nursery at DSIR Gore, New Zealand enabling further observation and elimination of non-uniform lines. The system has been applied to all the potential 1985 primary stocks, with the exception of the recycled stocks mentioned above. Secondly, an extra year of trialling was included, so that selections from the first bulk yield trials are then entered into a second year of yield trials at a number of sites. Single plant progenies from selected bulks are then multiplied to provide seed for primary progeny trials and multiplication. Consequently, head rows associated with the entries into the first bulk trials are no longer raised. Some 700 selections were in the first bulk yield trials in 1984 and 180 were kept for second bulk yield trials at a number of sites in 1985.

The breeding scheme was altered so that there is no selection of single plants at the F_2 generation—a process which was ineffective and inefficient. Instead, random samples from selected crosses are advanced to be raised as rows in the field at the F_4 generation. This allows further opportunities for recombination and segregation and further advancement towards homozygosity before selection begins.

Approximately 9,000 F_4 rows were assessed in two nurseries. The larger, c. 5,500 rows, was of lines derived by single seed descent from F_2 bulks harvested in 1983 (*Ann. Rep. 1983,* 39). Fairly widespread infections of both mildew and yellow rust occurred in this nursery, facilitating selection. It was also possible to eliminate lines with weak straw. Five hundred and sixty five selections were sent to New Zealand for further assessment and multiplication, including an additional 20 random selections from each of the crosses selected by cross prediction for their likelihood of producing high yielding lines.

The other nursery, comprising progeny rows from individual F_3 plants, selected in 1983, was affected by drought, which limited the spread of disease and made maturity assessment difficult; selection pressure was therefore reduced. Approximately 400 selections were retained for first bulk yield trials in 1985. As part of the F_4 exchange, 57 selections were made amongst 1,200 rows from PBI and 22 selections were made amongst 600 rows from WPBS. These selections were also entered into first bulk yield trials in 1985.

One hundred and thirty two crosses were multiplied in New Zealand in 1983/84 and grown in the F_2 bulk plot trial in 1984. Random F_3 lines from 40 of these crosses were also grown in the 1984 cross prediction material. Before harvest, a random sample was taken from each plot and a sample of 200 seeds from the bulk plots of the 40 crosses was sown in New Zealand. The F_3 prediction technique was used to identify the most promising crosses and all the lines from these were returned for

assessment as single plant progeny rows at The Murrays farm in 1985. The best of the other 92 crosses were grown under single seed descent conditions during the winter for sowing as rows in 1985.

Fifteen entries in a cultivar × nitrogen level trial were SCRI entries in 1984 NLT, with eight controls plus Heriot, Nairn and Tweed. The trial was sown on 12 April and topdressed on 23 May giving three nitrogen levels of 100, 125 and 150 Kg/ha. No lodging occurred in the trial and Ayr and Esk were the highest yielding entries, followed by cv. Klaxon. No significant cultivar × nitrogen interactions were detected but SCRI cultivars were more responsive to fertiliser levels than were the controls.

Facilitates were provided for a 60 entry three replicate trial of less advanced lines from PBI with possible potential for Scotland.

A widespread epidemic of powdery mildew developed in most of the breeding material in 1984 allowing effective selection for resistance. Apart from the special nursery, development of yellow rust was sporadic and some selection against susceptibility was possible. A heavy infection of brown rust developed in July and selection against susceptibility was possible amongst the later sown breeding material. Most of the spring barley entries in the *Rhynchosporium* nursery were autumn sown and this proved effective in allowing infection to develop on the susceptible lines but the remaining spring sown entries showed very little development of infection, even amongst those expected to be susceptible. There were no problems due to a lack of winter hardiness in the spring material. Some trials and nurseries suffered from drought stress during the hot dry weather.

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

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

Approximately 200 selections, mainly from material originating from the PBI winter barley programme, were raised in single site yield trials in 1983/84. Selection was mainly for yield, disease resistance and maturity. Twenty seven lines were selected from the PBI material and nine from the SCRI material which should allow a preliminary assessment of the use of the dwarfing genes in a winter barley breeding programme. All the selections and six controls were sown in a 42 entry trial at three Scottish sites—The Murrays farm, Invergowrie and Turriff, Aberdeenshire (the latter in collaboration with MISR). These sites provide the basis of a regional testing scheme. Twenty five ear rows associated with each selection in the trial were sown in a separate nursery at The Murrays farm to provide stocks for primary progeny trial and multiplication.

Some 1,000 F_4 selections were received from PBI and raised in a nursery in 1983/84 to assess their suitability for growing in Scotland.

Useful epidemics of powdery mildew and *Rhynchosporium* developed, allowing effective selection against susceptibility. Coupled with selection for other agronomic characters, 124 lines were retained for yield trial at The Murrays farm in 1984/85.

Material from the SCRI breeding programme started in 1982 is now being assessed in the field. A number of lines were advanced by single seed descent for assessment as observation plots at the F_4 generation in 1984/85. Some 1,000 F_3 lines representing ten crosses were also sown for assessment to identify crosses with the greatest potential to produce superior recombinant inbred lines.

In order to enlarge the gene pool in winter barley, a wide range of parental material has been used in the crossing programme. In particular, spring × winter and two-row × six-row crosses should provide a broad genetic base.

Two winter barley trials were carried out for the PBI in 1983/84 to assess the adaptability of 40 new cultivars to Scottish conditions. Both trials consisted of six replications, three of which received a routine fungicide spraying programme.

(W. Powell, A. Young)

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

Two genetic factors have been shown to affect β-amylase activity and, therefore, diastatic power, in crosses between six-row and two-row cultivars (*Ann. Rep. 1982,* 49). As such crosses generally produce large amounts of unadapted material, the use of limited gene transfer, by irradiated pollen, is being investigated as a means of producing agronomically acceptable lines with high enzyme activity. Three levels of radiation (5, 10 and 15 Gy) were given to seven pollen parents known to have high levels of α and/or β-amylase activity. The highest dose of radiation had a notably deleterious effect on seed set. In crosses where a lower dose was used, preliminary field observations indicated that the proportion of lines resembling the maternal phenotype did not differ significantly from that observed in crosses between the same parents without radiation. Further assessment is necessary but, although the method may have considerable potential, there appear to be several practical difficulties to overcome.

Results from an initial screening of material from a cross, between cv. Ark Royal and a multiple genetic marker stock, suggested a possible location for one for the factors affecting β-glucan content. A further series of crosses has been designed to enable the investigation of other factors contributing to malting quality.

Analysis of the data accumulated on the Triple Test Cross experiment carried out with J. L. Jinks[1] (*Ann. Rep. 1981,* 164) was resumed. The

[1]Genetics Department, Birmingham University.

data were used to compute phenotypic, genetic and environmental correlations between characters. Phenotypic correlations were mainly less than the additive genetic correlations and sometimes of different sign. Large dominance correlations were of the same sign as their respective additive genetic correlations so that production of F_1 hybrids from these crosses will not lead to alternative character combinations from those found in inbred lines. Additive and dominance genetic correlations showed that there was an association between the *erectoides* dwarfing gene with low thousand grain weight and plant yield.

The evaluation of the use of random F_3 lines for cross prediction (*Ann. Rep. 1983,* 40) continued. The lines from the three crosses in the unreplicated trials were regrown in replicated generalised lattice trials in 1984. As in the 1983 trials, five single plants were sampled from the plots prior to harvest and scored in the laboratory for height and the components of yield. The parents of the six crosses and cv. Golden Promise were grown in the original prediction experiment and in all the assessment trials. Univariate and bivariate predictions were made on the basis of the mean of the parents of all six crosses compared with those observed in the assessment trials. Results so far show good agreement between predicted and observed rankings of the crosses. A computer program to produce univariate and bivariate probabilities of exceeding user supplied standards of characters has been written incorporating subroutines developed by J. W. McNicol[1].

Studies continued with J. L. Jinks[2] on the use of random inbred lines in barley breeding. Doubled haploid systems offer the quickest method of advancing heterozygous breeding lines to homozygosity. Currently the *Hordeum bulbosum* technique is the most efficient method of haploid production in barley. However, the efficiency of this system is reduced by the suggested need for a multiplication phase following colchicine treatment of haploid plants prior to agronomic assessment. It has been demonstrated that the rankings of the H_1 (the first selfed generation after colchicine treatment) and H_2 (second generation) generations remain unaltered. The production of variation following a tissue culture phase (somaclonal variation) has been reported in barley. The *H. bulbosum* doubled haploid system shows no evidence of generating such variation. Estimates of the genetical parameters necessary for univariate cross prediction were obtained from F_3 and doubled haploid (DH) families. Both methods gave satisfactory results for a range of characters but the DH method provided the most accurate method of ranking crosses.

Random inbred material derived by both doubled haploidy and single seed descent for studies on cross prediction with J. L. Jinks[2] was used to

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[1] Data Processing Department

[2] Genetics Department, Birmingham University

examine the effects of three major agronomic genes used in the breeding programme. Comparison of *erectoides* and *nutans* populations of random inbred lines showed that the means for a number of agronomic and yield characters of the *erectoides* population were generally lower than those for the *nutans* population. These associations did not disappear following several rounds of recombination. Variation at the *erectoides* locus of Golden Promise contributes largely to the additive genetic variation for a number of characters, particularly thousand grain weight. Associations were also found between the *denso* dwarfing gene, a daylength response gene and the agronomic and yield characters studied. However, these associations disappeared following several rounds of recombination, suggesting that they were the result of linkage disequilibria.

Field experiments involving Golden Promise lines regenerated from embryo-derived callus indicated that the variation produced in this way was greater than that observed in seed-derived material. Thus somaclonal variation does appear to be produced from immature embryo-derived callus in barley.

M_5 material originating from an irradiated pollen cross (Golden Promise × cv. Magnum) was examined in a replicated yield trial in 1984. Twelve genotypes which showed high levels of resistance to mildew combined with high yield were retained for growing in yield trials at a number of sites.

Two experiments on methodology within the breeding programme were carried out. The first compared the performance of an F_5 bulk derived from an F_2 single plant with 10 random selections from the bulk. Results showed that at least 10 progenies from an F_2 single plant bulk should be trialled to obtain at least one progeny exceeding the performance of the bulk. The second experiment compared two alternative plot shapes for first bulk and primary progeny yield trials with that used in subsequent yield trials. For semi-prostrate selections, small square-shaped plots gave results more similar to those from the plots used in advanced trials than did long thin plots.

The effects of competition on the selection process in barley were investigated. In general barley breeders attempt to identify superior genotypes in heterogeneous populations but the same genotypes are then grown in monoculture. In the early generations of a breeding programme both intra- and inter-genotypic competition effects are operative but the finished cultivar will only be subjected to intra-genotypic effects. It is therefore essential to establish the extent of intra- and inter-genotypic competition on characters of importance to breeders. A substitution design was used for the experiment which consisted of a series of six monocultures and six binary mixtures of duocultures. Preliminary results indicate the presence of significant levels of intra- and inter-genotypic effects for a range of characters including height and the components of yield.

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

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

Microspore derived lines from the F_1 of cv. Golden Promise × cv. Mazurka were screened for their reaction to isolates of powdery mildew. The segregation ratios so obtained provide information on the segregation of major genes in microspore derived lines of barley.

A genetical study was undertaken of a further two cultivars exhibiting partial mildew resistance. Estimation of the genetical components of the means of the basic generations (i.e. parents, F_1, F_2 and first backcrosses) showed the possible presence of a partially effective major resistance gene in one cultivar, but there was no evidence of such a gene in the other. There was little correlation of height and percentage of leaf area infected with powdery mildew.

The *H. spontaneum* lines identified as possessing single dominant genes for resistance to powdery mildew were crossed to the spring barley cv. Midas to determine whether the genes found are alleles at the Ml-a locus.

Following discussions between SCRI, WPBS and PBI, the WPBS cereal pathology and nematology work was integrated with the cereal breeding programmes at SCRI and PBI. WPBS will continue to identify new sources of resistance to foliar diseases and pests and release these for exploitation in the other public sector breeding programmes. These sources of resistance will be screened as they come through the breeding programme, in an extension of the screening work that WPBS already undertake for SCRI and PBI. Using computer links, information can be passed rapidly between the three stations.

(M. J. C. Asher, C. E. Thomas, W. T. B. Thomas, W. Powell)

PU 2(g) Trial extension crops (spring oats, winter wheat, etc.) in collaboration with other organisations

This Department was a major participant in the BAPB system to test new cultivars of winter barley, winter wheat, spring barley and spring oats. Four trials of spring oat lines, bred by the WPBS, were grown to evaluate their suitability for Scottish conditions.

Some interest has been expressed in triticale and its potential for Scotland. In 1982/83 a small number of observation plots of PBI breeding lines was grown and this was extended to a replicated yield trial in 1983/84, which included PBI's current NLT submissions, Newton, Torrs and Warren and a winter wheat. The yields of the triticale lines were disappointing compared to that of the winter wheat; a further trial is being grown in 1984/85.

(A. Young)

FORAGE BRASSICA BREEDING

A. B. WILLS

Following the DAFS Grass and Fodder Crop Review in March, it was decided that less emphasis will be placed on the production of new cultivars of forage brassicas. Consequently, the fodder cabbage breeding programme will be discontinued, and the kale breeding programme will be substantially reduced. This reduction in breeding *per se* emphasises the importance of the Department's research work. By enforcing a reconsideration of all current work the reduction in breeding effort has also highlighted the need to enhance links with other organisations carrying out relevant work on brassicas. This was partly achieved by a multidisciplinary brassica meeting organised by staff of the Department and by the setting up of a Forage Brassica Working Party under the aegis of the SCRI/ASS/COSAC Liaison Group.

Continued research on the inhibitors of pollen germination extracted from stigmas of *Brassica oleracea* has now shown, by using HPLC fractionation prior to bioassay, that some inhibitors affect both *Brassica* and *Petunia* pollens equally. It is intended now to ascertain whether these compounds have useful biological applications. The finding that pollen rescued from a liquid medium will germinate on decapitated styles has removed a major barrier to successfully utilising pollen from liquid treatments for seed production. Procedures for exposing pollen to some selective media to obtain plant improvement, and for using pollen as a vector of alien DNA, can now be investigated.

In a more immediately applied context, a promising start has been made towards devising an objective measure of stem hardness in rape as a means of selecting for greater palatability. Materials derived from interspecific crosses are now beginning to figure prominently in the swede and rape breeding programmes. Their main value will be in the introduction of superior disease resistances to both crops and in increased palatability of rape stems. It is apparent, though, that the use of some species material has incurred severe penalties of poor quality and adaptation which may not easily be overcome.

The Stocks and Trials Unit envisaged in the Annual Report for 1983 was instituted within the Department. It indertakes the multiplication, purification and maintenance of potential new cultivars and carries out trials of advanced breeding material at a number of sites in Scotland and the north of England. Although it was not possible to transfer all stock multiplication from Pentlandfield before flowering commenced, most of

the work was done at Mylnefield. In future years all multiplications should be at Mylnefield in polythene tunnels so as to obtain better environmental conditions and isolation from flowering brassica crops than can be achieved in unprotected isolation plots. A full programme of trials of advanced materials was undertaken with some initial problems of management at distant sites.

Two hybrid savoy cultivars, Lundie and Lussa, bred during the now discontinued culinary cabbage breeding programme, were entered on the National List. There are no further candidates in the pipeline, so the remaining commitments to the breeding of culinary brassicas are for the maintenance of parent lines involved in the production of those cultivars which continue on the National List and for the appropriate disposal of seed stocks.

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

F_1 hybrid breeding

Twelve self-incompatible lines derived from interspecific crosses were tested against eight strong S-alleles previously isolated. It was inferred that six additional S-alleles were present in these lines, bringing the number of different S-alleles obtained in *Brassica napus* to 15.

The extent of outcrossing among parent lines was determined from the progenies produced in an experiment to test various methods of hybrid production (*Ann. Rep. 1982,* 61). Generally, slightly lower levels of outcrossing occurred in polythene tunnels with blow-flies as pollinators than in isolation plots with naturally occurring pollinators, except for crosses involving different flower colours (buff and bright-yellow). When there were differences between lines in flowering time, as well as flower colour, outcrossing decreased from 84% in polythene tunnels to 61% in isolation plots, where the plants flowered less quickly and evenly. When parent lines had the same flower colour and good coincidence of flowering, up to 99% hybrid seed was produced with single crosses and up to 97% with double-crosses, even when modified by using self-incompatible and self-compatible lines.

Although the modified double-cross method reduces the number of self-incompatible lines required, the total amount of inbred seed needed is not reduced. Production of seed from self-incompatible lines by bud pollination is laborious, and an alternative method of using open flowers was examined. Pollinations were carried out by applying pollen to the end of the style after the stigma had been pinched off with pollination forceps, and the seed set was compared with that from open flower pollination and bud pollination. Open flower pollination produced only four seeds from 146 pollinations, whereas 713 seeds were obtained from 147 pollinations with the stigma removed. Stigma-removed pollination was faster than green-bud pollination (4.8 and 3.6 pollinations per minute, respectively), but more seeds per pollination were produced by bud

pollination. The overall rates of seed set obtained by an experienced pollinator were similar at 22 seeds per minute for bud pollination and 23.5 seeds per minute for stigma-removed pollination. Bud-pollination requires considerable skill and dexterity, but stigma-removed pollination does not and this may therefore be more suitable if unskilled labour has to be used to multiply self-incompatible lines for commercial production.

Pedigree breeding

A major breeding objective is the incorporation of high levels of clubroot resistance and this has been introgressed into swede from Dutch stubble-turnips, particularly ECD 04. These plants have been outcrossed and their progenies selfed to produce F_2 lines for the pedigree programme. Sixty-four F_2 lines from 23 different outcrosses were sown in the field for selection. The clubroot resistant lines were also intercrossed and F_1 plants were grown overwinter in the glasshouse and bag-selfed to provide a further set of F_2 lines.

The most advanced line with some clubroot resistance was also used in the crosses from which the F_3 lines in trial were derived. The other parents were mainly selections from commercial cultivars, including Angus and Melfort, but the breeding line K21 was also used.

Four adjacent α – design trials were sown, with 74 lines and four common controls in each trial.

The F_4 trial was sown with material derived from crossing turnip and swede, followed by three generations of selfing after restoration of the swede chromosome number ($2n = 38$). These lines are theoretically more inbred than F_4 but they displayed considerable within-line variation, and were mostly low yielding and poorly adapted.

The F_5 lines in trial were derived from crosses between swede cultivars. Some were high yielding and agronomically desirable lines, although lacking in clubroot resistance. The two best lines had dry weight yields 15% higher than the mean of the controls, and also had good shape and mildew resistance, while another three lines had yields over 10% higher than the mean of the controls.

(S. Gowers, D. J. Gemmell)

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

Kale polycross improvement programme

The fifth generation of the kale polycross improvement programme, which started in 1971, was assessed at Mylnefield in 1984. The mean dry matter yield of the 180 half-sib families represented was 9.51 t/ha compared with 9.16 t/ha for the mean of the seven control cultivars Canson, Giganta, Greendale, Kestrel, Midas, Proteor and Vulcan. As the mean dry matter yield (104%) relative to these control cultivars was the same as the third (105%) and fourth (104%) generation populations no

additional generations will be produced. It is intended to assess the fifth generation families for clubroot resistance and chemical composition and to select the best six families for evaluation as potential cultivars.

Selection for high and low thiocyanate ion content
Kale leaves have a relatively high content of the indole glucosinolates which release the goitrogenic thiocyanate ion (SCN^-) on hydrolysis by the enzyme myrosinase. Therefore in 1978 it was decided to select populations with high and low contents from the third generation of the kale polycross improvement programme. After one generation of half-sib family selection their mean contents were 51.9 and 41.5 mg SCN^-/100 g DM respectively, and after a further generation 54.6 and 37.8 mg respectively. Hence selection has been effective and will be continued to provide contrasting populations for further research projects.

New marrow-stem kale population
One hundred and fifty three half-sib families of the second generation were assessed for clubroot resistance in seedling tests. The 32 most resistant families were selected to produce third generation seed in 1985. The intention is to assess this and subsequent generations for SMCO, SCN^-, dry matter yield, digestibility and for clubroot resistance.

(J. E. Bradshaw)

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

A trial was grown for assessment of second generation material for dry matter yield and content. The mean whole plant dry matter yield of 120 half-sib families was 8.33 t/ha. The two Dutch Winter White control cultivars, Amager Høj Green and Holland Late Winter, yielded 9.03 and 8.37 t/ha respectively. The mean whole plant dry matter content of the breeding population was 10.83%. The contents of the two January King control cultivars, January King No. 3 and January Prince, were 12.23 and 12.31% respectively. Sixteen families which combined high dry matter yields (average 9.49 t/ha) and high dry matter contents (average 12.41%) were chosen to produce the third generation in 1985. This will end the programme as it has been decided to redirect the breeding effort.

(J. E. Bradshaw)

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

Turnip cultivars for the Scottish uplands
Twenty-three lines, from selections made in 1982 (*Ann. Rep. 1982,* 66), were sown in trials at two sites to assess yield. As in 1983, the mean dry weight yield of the upland site at Couston/Henderston farm (3.20 t/ha) exceeded that of the low lying site at Mylnefield (2.93 t/ha). Infection

by mildew at both sites was severe. Selections were made from eight lines which outyielded the mean of the controls at both sites.

The backcrossing series to transfer clubroot resistance from stubble turnip ECD04 into cultivars of traditional turnips was continued. Fourth backcrosses were made using cv. Green Top Yellow as a recurrent parent, and fifth backcrosses using cv. Foll. S_2 seed was produced from lines of the backcrossing series (ECD04 × cv. Green Top Scotch) and S_1 seed from (ECD04 × cv. Green Top Yellow) in order to obtain lines homozygous for clubroot resistance. Lines from (ECD04 × cv. Hvit Mainepe), true breeding for clubroot resistance, were multiplied.

(S. Gowers, D. J. Gemmell)

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

Cultivar breeding

Forage rape breeding objectives were re-examined in the light of the responses obtained in the forage rape farm survey made in 1983 (*Ann. Rep. 1983,* 54) and extended in 1984, and it was decided to increase emphasis on stem structure and edibility. The selection criteria also include: improved resistance to mildew *(Erysiphe cruciferarum)* and clubroot *(Plasmodiophora brassicae)*; increased leafiness; winter hardiness; better leaf retention; resistance to stem and petiole breaking; and freedom from bolting. Materials displaying differences in plant height and in levels of the potentially toxic chemicals, S-methyl cysteine sulphoxide and the glucosinolates, are also sought for future experimental work.

Satisfactory yields were obtained in breeding trials at Mylnefield, despite the dry conditions over most of the growing season. The average dry matter yield in all trials for the control cultivars, Barsica, Crack, Emerald and Nevin, was equivalent to 4.92 t/ha (cf. 3.82 t/ha in 1983). Germination and establishment were assisted by light rain prior to sowing in June. In late summer plants suffered leaf loss from a moderately severe attack of powdery mildew, and drought stress. Rain in late September considerably increased growth and some growth continued until the delayed harvest in late November and early December. Three hundred and forty-two plants were selected from 147 F_2 populations using the criteria listed, except clubroot resistance, chemical content and stem hardness, which cannot be tested at this stage of the breeding programme. The parents of these populations included cultivars, resynthesised *Brassica napus* and clubroot resistant materials from breeding lines.

The F_3 trial, which was limited to two replications due to poor seed production in 1983, compared 70 lines and the control cultivars Emerald and Nevin. The best F_3 line had a fresh weight yield 41% higher than the mean of the controls and 30 others out-yielded this mean. Twenty-one lines had a higher dry matter content and 27 a higher dry matter yield, than the mean of the controls. The 70 lines were assessed in glasshouse

tests for resistance to clubroot. Several were very resistant. However, none had better mildew resistance than Emerald, which is one of the more mildew resistant cultivars on the NIAB Recommended List.

The F_4 trial comprised 15 lines and five control cultivars (Barsica, Crack, Emerald, Lair and Nevin) with four replications. The mean fresh weight yield of the controls was exceeded by nine lines, in one case by 15%. Only three lines had a better dry matter content but eight had a better dry matter yield than the mean of the controls. These last eight and two other lines were selected for multiplication and further trials.

The F_5 trial had four lines and four control cultivars, (Crack, Emerald, Lair and Nevin). The fresh weight yields of three lines equalled that of Lair, the best control cultivar, but their dry matter contents and yields were lower than those of the controls. The low dry matter contents almost certainly resulted from using re-synthesised *B. napus* as one of the parents of these lines. Particularly good resistances to mildew, stem and petiole breaking and bolting were recorded for two lines, but further assessment is needed before deciding whether they should be entered for National List Trials.

Effects of plant spacing

A further trial was grown to study the effect of plant spacing on yield and other characters, using Lair and the breeding line SC57. Seed size (grade 2.00 – 2.25 mm) and inter-row spacing (0.5 m) were the same as in previous years but inter-plant spacings were changed to 5.1, 12.7, 30.5 and 50.8 cm. These wider spacings were chosen to obtain a clear effect on yield and other characters. For both Lair and SC57, the maximum fresh weight and dry matter yields were obtained at spacings of 5.1 or 12.7 cm. Dry matter content was at a maximum at 5.1 cm for Lair and 12.7 cm for SC57 and, as in 1983, the tallest plants in both were obtained at 12.7 cm. There was an increase in stem and petiole breaking at 30.5 cm and above for SC57 and at 50.8 cm for Lair. The mean dry matter yield for the trial was 5.42 t/ha compared with 4.11 in 1983 and 4.25 in 1982.

Effects of sowing date

A trial was sown to study the effect of sowing date (23 May, 27 June, 1 August) on the yield and other characters of four lines each of rape, radish and radicole *(Raphanobrassica)*. The trial was harvested on 10 December. The results have not yet been analysed but almost complete bolting was observed in radish and radicole for the first two sowing dates. Very little flowering occurred in radish, and none in radicole, for the third sowing date. There was effectively no flowering in rape at any of the sowing dates.

Stem hardness

A rapid mechanical method to measure stem hardness could be a valuable objective aid in the selection of more palatable stems in rape.

Increased stem palatability in new cultivars should reduce crop wastage. In an initial experiment, a texture press (Food Technology Corporation TP – 1), fitted with a shear-compression cell, was used to measure the transverse force required to crush stem samples. Replicated samples approximately 50cm long were taken from the bottom, middle and top of the stem of all entries in the F_5 trial. The analysis of these data has still to be completed but differences in scale readings of as much as 27% were noted between plants having the traditional rape morphology, as exemplified by the cultivars Crack, Emerald and Lair, and the leafier, softer types, which originated from re-sythesised *B. napus*.

(W. H. Macfarlane Smith)

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

Multiplications

Multiplications were carried out at Mylnefield in 27 polythene tunnels and 21 cages and at Pentlandfield in 20 tunnels and 15 cages. Seed was also produced at two isolation sites in East Lothian. Seed set in tunnels and cages was generally good except in some tunnels of rape transplants where planting had been delayed by severe weather conditions.

(I. K. Munro)

Trials

Sixteen trials of advanced kale, rape and swede selections were sown at Mylnefield and at six other sites in Scotland and the north of England. One kale and one rape trial on heavy land at Cockle Park (Northumberland) and one rape trial at Errol (Perthshire), also on heavy clay, failed to establish successfully owing to the dry conditions and were abandoned.

The mean dry matter yields of kale in trials at four sites varied from 11.21 t/ha at Yonderton farm (Ayrshire), to 7.03 t/ha at Couston/Henderston farm (Angus). Of the five control cultivars grown, Condor gave the highest mean yields over all sites of fresh matter (73.35 t/ha) and dry matter (9.64 t/ha), and Canson the lowest yields (60.65 and 8.32 t/ha respectively). The most outstanding selection was PX80/106, multiplied from the fourth generation of a polycross, which outyielded cv. Condor in giving mean fresh and dry matter yields of 75.45 and 10.15 t/ha respectively. All of the seven selections grown exceeded the mean dry matter yield of the control cultivars and had an overall mean dry matter content of 14.50% compared with 14.32% for the mean of the controls and 16.04% for cv. Bittern.

The mean dry matter yields of rape also were highest at Yonderton farm (5.60 t/ha) and lowest at Couston/Henderston farm (3.41 t/ha). Cv. Hobson gave the highest fresh and dry matter yields with mean values over trials at four sites of 42.68 and 5.63 t/ha respectively. B20, which was the only selection in these trials, had only moderate fresh weight yields (mean, 32.15 t/ha) and the lowest dry weight yields (mean, 3.65 t/ha), resulting in part from low dry matter content (11.81% compared

to the overall trials mean of 13.45%) and pronounced susceptibility to powdery mildew. Cv. Caron was the entry most severely affected by mildew at the three sites where records were taken.

The mean dry matter yields of swedes in trials at six sites varied from 11.69 t/ha at Yonderton farm to 7.31 t/ha at Mylnefield (no swede trial was grown at Couston/Henderston farm). Of the five control cultivars Marian had the highest fresh (99.84 t/ha) and dry matter (9.72 t/ha) mean yields. Cv. Doon Major had the second highest mean fresh matter yield (93.82 t/ha) and the lowest mean dry matter yield (7.54 t/ha) while cv. Melfort had the lowest mean fresh matter yield (81.95 t/ha) but was second in mean dry matter yield (9.58 t/ha).

Five of the 15 selections in trial exceeded the mean dry matter yield of Marian, the highest yielding being DBOxbx, which was also the only selection with a mean fresh weight yield superior to cv. Marian. Two of the same five selections had very low levels of mildew infection at the two sites where disease records were taken.

(A. J. Redfern)

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

Nature of the incompatibility reaction

The effect of *Brassica oleracea* stigma extracts on the germination of pollen of *B. oleracea* and *Petunia hybrida* was examined by TLC bioassay which revealed differences between the species in number, size and Rf of zones where germination was inhibited (*Ann. Rep. 1983,* 56).

As *P. hybrida* pollen was bioassayed at pH5 and *B. oleracea* at pH8, the differences observed may have resulted from the difference in pH, affecting either activity or mobility of the inhibitory compounds, rather than from a species specific response to the extracts. This was investigated further using high pressure liquid chromatography (HPLC). HPLC separations were carried out on leaf, pollen and stigma extracts dissolved in 70% redistilled methanol. Fractions collected at intervals of 1 minute were dried, redissolved in redistilled methanol and spotted on to appropriately prepared TLC plates. The plates were then sprayed with *P. hybrida* or *B. oleracea* pollen and pollen growth was assayed. Germination of the pollens of both species was completely inhibited by the same fractions although differences between species were still observed for certain fractions causing partial inhibition. These differences may have resulted from specific responses to compounds in the extracts, but they may have also been the result of differences in the inhibitory activity of these compounds at the different pHs for the bioassays. However, it is clear that some of the variation previously reported resulted from the effect of pH on the mobility of inhibitory compounds on TLC plates. The inhibitors were purified by a further HPLC separation, with different solvents, of adjacent fractions with inhibitory activity. This will provide material for chemical analysis.

Experiments to obtain further improvements in *B. oleracea* pollen germination on TLC plates were carried out. A range of different plate pre-treatments were tested to produce a suitably high background pH for pollen germination. The best results were obtained when plates were soaked in 1mM NaOH for 1.5 hour, cleaned and soaked in 20 mM TAPS buffer, pH7, for 0.75 hour before use. This gave higher germination percentages (70%) and longer tubes (200 – 300 μ) than any other treatment.

The occurrence of binding sites on *B. oleracea* and *B. campestris* pollen was further investigated with W. M. Robertson[1]. Fluorescent conjugated lectins (concanavalin A and wheatgerm lectin linked to rhodamine isothiocyanate) were found to bind freely to the surface of mature pollen grains. However, attempts to block binding reactions with appropriate oligosaccharides were only partially successful, suggesting that much of the binding was non-specific.

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

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

Genetic Studies

Genetic studies on phenotypic and isoenzyme variation in *Brassica campestris* continued. Additional flower colour variants were identified and inherited variation of the presence/absence of petals and of pollen colour, which may be white or yellow, confirmed. The presence/absence of hairs on the vegetative stem and of a pair of hairs, or bracteoles, at the base of the flower peduncle were each shown to be under the control of single genes. Crosses were made to determine gene linkages and to develop lines containing a number of known alleles for use in other studies. Studies on esterase variation using polyacrylamide gel electrophoresis (PAGE) revealed the existence of three zones on the gels at which genetically determined variation is present. Two alleles were detected in the slowest and the fastest moving zones and each zone has two bands when heterozygous. The third zone (Rf.0.49) is characterized by the presence or absence of a single band. Preliminary results suggest that this, and the fastest moving zone, are not linked to the *Acp-1* and *Acp-3* loci.

Stomatal apertures were measured on *B. oleracea* plants with chromosome numbers of 2n = 18, 19, 27 and 36. As expected, the diploid and aneuploid sibling plants had significantly smaller apertures than the triploid and tetraploid plants. However there were no consistent differences between diploids and aneuploids that could be used to discriminate between them.

(J. R. T. Hodgkin, A. B. Wills)

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[1] Zoology Department

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Gene expression in synthetic Brassica napus

Further crosses were made between two Chinese cabbage *(B. campestris)* lines known to be homozygous for eight corresponding genes and a Chinese kale *(B. oleracea)* line homozygous for eight corresponding genes but with different character expressions. The genes used were *Hr, An, S, Wh, Acp-1, Acp-3, Pgm* and *Pgi.* A number of hybrids were obtained from both ovule and embryo culture for use in studies on gene expression in synthetic *B. napus.*

(J. R. T. Hodgkin, I. H. McNaughton[1])

Isoenzyme variation

In experiments to find more genetic variation in *Brassica* species 30 enzyme systems were screened by polyacrylamide gel electrophoresis, bringing the total number investigated to 49.

(E. M. Wiseman)

Pollen studies

Estimates of pollen germination *in vitro* can provide breeders with a rapid indication of the suitability of individual plants as pollen parents in seed production. The development of a germination medium for brassica pollen (*Ann. Rep. 1982,* 55) has permitted such tests to be carried out in *B. campestris, B. napus,* and *B. oleracea.*

The effect on pollen germination and growth of varying the compounds in the medium was investigated by incubating pollen for 4 hours at 20°C using the hanging drop technique. Sucrose concentration was varied from 15 – 20% without affecting final pollen-tube length (400 – 600 μ) or percentage germination (70 – 90%). Replacing sucrose by PEG 400 (10%) had no effect, suggesting that germination and the first 4 hours of pollen-tube growth do not require an external metabolizable source of energy. The effects of varying the contents of the micronutrients used (KNO_3, $MgSO_4$, $Ca(NO_3)_2$ and H_3BO_3) were also examined. Omission of KNO_3 and $MgSO_4$ reduced germination by 20% but not rate of tube growth. However, the correct concentrations of $Ca(NO_3)_2$ (1 – 10mM) and H_3BO_3 (1 – 5 mM) were critical to both germination and pollen-tube growth.

Germination levels in bulk liquid culture were measured and, at 50 – 60%, were lower than those obtained in hanging drops despite tests with a variety of different shake culture procedures using a range of volumes of media and concentrations of pollen. Pollen-tube growth rates were slower than in the hanging drop controls, although tube lengths of 400 μ were obtained after 6 hours incubation.

Preliminary studies were carried out on the response of pollen, prior to fertilization, to selection for characters of relevance to the breeding programmes. Significant differences in the response of pollen from

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different plants were obtained following cold temperature (0–5°C) treatment during imbibition. Pollen from some *B. campestris* plants failed to germinate following the cold shock although up to 30% pollen germination was found from other plants. The effect of antibiotics and NaCl on germination was also tested but no inter-plant variation was detected.

In vitro incubation of pollen in a selection medium, followed by pollen rescue and pollination was examined. Pollen of *B. oleracea* and *B. campestris* was placed in a germination medium for up to 1 hour, centrifuged and used for pollination. The pollen was still viable and germinated when placed in fresh medium but it failed to penetrate the stigma and grow down the styles of buds or open flowers. However, when the stigma was removed, treated pollen grew through the style and seed set was obtained. This suggests that short periods of *in vitro* pollen selection are possible in the brassicas.

Successful use of pollen selection techniques will depend on gametophyte expression of genes that affect either sporophyte performance or are linked to such genes. Little is known of gametophyte gene expression and experiments to investigate it are in progress. Following polyacrylamide gel electrophoresis, extracts from plants heterozygous at the *Acp-3* locus produce a heterodimer and two homodimer bands. Mixed extracts from plants homozygous for different alleles do not produce a heterodimer. Pollen from *B. oleracea* and *B. campestris* plants heterozygous for *Acp-3* gave a heterodimer band on electrophoresis, suggesting pre-meiotic production of the isoenzymes. Following incubation of the pollen for 1 hour the heterodimer band disappeared from the pollen sample although the homodimers were still detected. Concentration of the germination medium with lyphogel revealed that the medium contained all three bands of acid phosphatase activity. These observations suggest the acid phosphatase gene *Acp-3* is active in both sporophytic and gametophytic generations in the brassicas, that pollen contains the products of both generations but that the sporophytic fraction is rapidly lost to the medium during *in vitro* germination.

(J. R. T. Hodgkin, A. B. Wills)

Pollen irradiation

The use of irradiated pollen for intraspecific gene transfer in *B. oleracea* was tested. Pollen from plants homozygous for genes *Hr, Go, Wh, Acp-1, Acp-3, Pgm* and *Pgi* was X-irradiated at 0, 150, 200, 250 and 500 Gy and used to pollinate plants homozygous for different alleles of the same eight genes. Seed set was low for all treatments, ranging from 3.3 seeds per pollination for the unirradiated control to 0.45 seeds per pollinations for the 500 Gy treatment. These seeds were sown and the plants obtained are being assessed to determine their genetic constitution. Early observation show that most of the seedlings from each of the four

irradiation treatments display paternal characters although some may be 'maternals.'

(J. R. T. Hodgkin)

NEW SAVOY CABBAGE CULTIVARS

LUNDIE

Origin An F_1 hybrid developed from the F_1 hybrid Ice Queen and Ormskirk.

Plant Erect, short stemmed, strongly savoyed, green outer leaves.

Head Solid, slightly flattened, yellow green without anthocyanin. Yellow green interior, short core.

Lundie is a winter-maturing savoy for the fresh market, co-seasonal with Wivoy and with similar hardiness, producing 1.0 kg heads at 400 × 600 mm row spacing.

LUSSA

Origin An F_1 hybrid developed from the F_1 hybrid Ice Queen and Alexander's No. 1 Late.

Plant Erect, short-stemmed, medium savoyed with short, grey leaves.

Head Uniform, very solid, slightly flattened, pale grey without anthocyanin. Yellow/white interior, wide, short core.

Lussa is a moderately hardy autumn cultivar producing 1.0 kg heads for the fresh market at 400 × 600 mm row spacing.

POTATO BREEDING

G. R. MACKAY

The excellent planting conditions in spring led to rapid establishment of the crop both at The Murrays and Blythbank farms. Yields at The Murrays farm were a substantial improvement on 1983 and the quantity and quality of seed tubers at Blythbank farm was very good despite the summer drought.

Names have been proposed for the three clones which completed National List Trials (NLT) in 1984 but so far only that of Sheena for the first early, code number 10337de40, has been accepted. Final reports and decision on the future of these clones are awaited from the NLT authorities.

The five clones submitted to NLT in autumn 1983 completed their first year and have been resubmitted for their second year. Interim reports on these are awaited. Five more clones, including three which are resistant to both species of potato cyst nematode (PCN), have now been submitted.

The maincrop cultivar Kirsty was offered to the trade by NSDO and substantial interest has been shown in it. Cultivars Ailsa (10442(8)) and Moira (9869a9) were entered on the National List in August and are now in the hands of NSDO. Ailsa has been performing well both abroad and in the UK, and substantial quantities of seed have been distributed by NSDO for trial overseas. A decision on cv. Rhona (10333ab18) has been deferred by the authorities pending receipt of more information from overseas.

Collaborative trials with ADAS continue to contribute to the field performance data upon which our NLT submissions are based. The PCN tolerance trials are particularly useful in this respect, providing both the only means of assessing tolerance and confirmatory evidence of resistance amongst the most advanced material.

Overseas trials continued in several Mediterranean countries and again relied on the help and collaboration of many people for their success. A number of clones identified as having export potential have been submitted for retrial in 1985. A few, e.g. cultivars Baillie and Ailsa, would have been submitted to NLT on their merits in the UK. However, several which would not have been selected in the UK have been identified as having potential for export. For example 12492ad6, which was removed from the SCRI UK trialling system, has performed partic-

ularly well in the Mediterranean area and has been requested in substantial quantities by Algeria, Tunisia and Egypt for further trials.

The results of research into the efficiency of early generation selection and the development of progeny tests are now beginning to make an impact on our procedures. A sub-sample of every progeny sown in the glasshouse was subjected to a seedling test for foliage blight resistance, permitting the rapid identification of those with the greatest likelihood of containing resistant clones. No tuber selection was practised on any of the seedlings sown in the glasshouse, a tuber from each seedling being retained to initiate a healthy stock at Blythbank farm. Further tubers from sub-samples of the progenies were kept for progeny trials at The Murrays farm in 1985. This work is aimed at confirming the accumulating evidence on the efficacy of progeny testing for agronomic traits, which to date has of necessity been based on relatively few progenies.

One hundred and seventy-nine Neo-Tuberosum clones were grown in a trial contemporary with clones reaching the routine third clonal year (M1) and have been subject to the same procedures as material from the cultivar breeding programmes. A few Neo-Tuberosum clones identified as having useful characteristics, such as resistance to potato virus Y (PVY) and/or late blight, have featured as parents in crossing schedules, as have diploid and dihaploid derivatives.

The identification in 1983 of a few clones capable of producing pale-coloured crisps after storage at 5°C amongst the material reaching the fourth clonal generation of assessment (M2) stimulated a repeat of this exercise in 1984. The preliminary results are good, confirming the superiority over the control cv. Record of most of the clones identified in 1983 and indicating some further promising clones.

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

Clones in National List Trials (NLT) or post NLT

The early maincrop cv. Kirsty is continuing to yield well in trials and has been launched commercially by NSDO. The early maincrop cv. Ailsa and the first early maincrop cv. Moira were entered on the National List but a decision on the early maincrop cv. Rhona has been deferred until 1985 pending the results from overseas trials. 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 (Sheena), completed NLT in 1984; decisions as to whether they will be entered on the National List are awaited from the authorities. The early maincrop clones 11396ab12, 11566ac7, 11328ab18, 11704ae26, and the first early clone 11291(3) completed their first year NLT and will continue into their second and final statutory trials in 1985.

Advanced selections

1984 was the third year of the reorganised regional trials carried out with ADAS. All the selections reaching the sixth clonal generation and still more advanced clones were grown at five sites: Arthur Rickwood EHF, Gleadthorpe EHF, Stockbridge House EHS, Terrington EHF, and 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 trials on the EHFs was carried out by ADAS staff while SCRI staff weighed, graded and scored the produce.

These clones were also grown by R. Thompson[1] in a trial at Mylnefield which included two treatments, narrow and wide spacing within drills. This collaboration should provide more data for selecting this advanced material, a better idea of the agronomic needs of different clones and a practical basis for physiological and agronomic studies.

The data from the 1983 and 1984 trials, together with information on disease and pest resistances, provided the major basis for deciding on the submissions to NLT (four clones were put forward) and for deciding which of the less advanced clones should be retrialled in 1985.

Five clones and seven control cultivars were grown in the first early trials at Trefloyne and Penrice in South Wales, at Cairnside in Wigtownshire, and at The Murrays farm. All five clones grew well and one (11242a1) was submitted for NLT.

Several advanced clones grown in SCRI trials were supplied, by arrangement with NSDO, to external collaborators. Their data usefully supplemented those from SCRI trials.

The five submissions for first year NLT are:

11242a1 — A first early clone which has given consistently high yields in trials in early growing areas.

12288af12 — A second early clone with good resistance and tolerance to both *G. pallida* and *G. rostochiensis.*

12721ae18 — A second early clone with an exceptional yield potential, producing very attractive parti-coloured (red splash) tubers.

12276af9 — An early maincrop clone with useful levels of resistance to both species of potato cyst nematode combined with good yield and quality characters; it also has export potential.

12290af20 — An early maincrop clone with a good yield potential and resistance to both species of potato cyst nematode. It also has a broader than average spectrum of disease resistances.

Breeding for resistance and tolerance to potato cyst nematode (PCN)

The field trialling of advanced PCN resistant clones from SCRI, PBI and DANI for tolerance of PCN continued in collaboration with ADAS at

[1]Physiology and Crop Production Department.

three sites: Nocton (near Derby), Crowle (near Leeds), and Ramsey (near Cambridge). The tolerance trials were improved by increasing the number of replicates and by 'pairing' the nematicide-treated and the untreated plots of each clone to allow more direct comparisons.

Good levels of tolerance were observed again in clones 11233ab22 and 11305a2. Three PCN resistant clones submitted to NLT in 1984, 12276af9, 12288af12 and 12290af20, exhibited acceptable levels of tolerance. The rate of multiplication (Pf/Pi) of nematode populations in the field showed a high correlation ($r = 0.82$) with the laboratory canister test assessing resistance. The results also showed that resistant clones significantly reduced not only the number of cysts remaining in the soil at harvest, but also the number of eggs per cyst.

Pot trials for potato cyst nematode tolerance

Once again, the clones tested in the field tolerance trials were also tested in the glasshouse in large (22.5 cm diameter) pots in an attempt to develop a glasshouse screening method. Two experiments were carried out, one harvested at an early date and the other after foliage senescence. As expected, there were greater differences between treated and untreated pots at the mature lift. Preliminary analyses suggest that the results correlate well with those obtained in the field. However, as in 1983, the early maturing clones had higher yields in the pots giving an artificially high assessment of their tolerance.

Seed maintenance and multiplication

Planting at Blythbank farm started during the last week of April and growing conditions were favourable. Although the season was hot and dry there was enough rain at the end of July to allow the tubers to bulk up to a good size before defoliation. Yields and numbers of tubers were high and dry weather led to very clean seed being harvested.

Cooking quality assessment

The routine cooking quality assessment continued as in previous years. The dry season appeared to have reduced the frequency of clones showing after cooking blackening. This may have been a disadvantage for selection as The Murrays farm usually produces potatoes which, if prone to blackening, do so readily. It therefore normally acts as a good screen for this aspect of cooking quality.

Replication of all The Murrays farm plots, and a fairly large 'after cooking blackening' progeny trial, increased the number of samples assessed for cooking quality to c. 6000.

Low temperature storage for crisping cultivars

The standard storage temperature of tubers for crisping is 10°C, below which sugars tend to accumulate and cause unacceptably dark brown

crisps. A cultivar capable of producing pale crisps when stored at a lower temperature could reduce processors' costs. In 1983 all clones reaching their fourth clonal year (M2), c. 200 in number, had duplicate samples stored at 5°C. These were crisped directly from the cool store and five produced pale crisps, substantially superior to the control cv. Record. On retest in 1984 four of the five again gave good results after 5°C storage, and also gave considerably superior (paler) crisps than Record when kept at 10°C. Duplicate samples of the 1984 M2 clones were again stored at 5°C and, as in 1983, 2–3% of the 200 clones exhibited this desirable feature.

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

All 53 clones which had reached the sixth clonal generation in 1983 were, in 1984, trialled in northern Spain (Rioja), in southern Spain (Valencia), at Gilat Regional Experiment Station in Israel (two trials), and in Cyprus. At each of these sites appropriate control cultivars were included in the trials as well as clones which had been selected on their performance in the previous year. In Spain 71 clones were trialled in Valencia and 68 in Rioja. Of these, 20 and 17 showed sufficient promise to be retrialled in Valencia and Rioja respectively in 1985.

As in 1983, two trials were carried out in Israel. One was solely for commercial assessment while the other was mainly for the evaluation of resistance and tolerance to *Verticillium dahliae* and *Alternaria solani*. Of the 64 clones trialled solely for commercial attributes 15 were considered to be worth re-assessment in the 1985 trials.

For the first time SCRI clones were also trialled in Cyprus. The trial included 64 clones and six control cultivars. On the basis of their performance in this trial and those in other countries, 20 clones have been returned for re-trial, three of them in larger quantities for inclusion in official cultivar trials organised by the CARI.

Ten clones which looked promising in the 1983 overseas trials were also trialled in Algeria by arrangement with the Institute de Dévéloppment des Cultures Maraichères, Staoueli, and in Tunisia and Egypt via NSDO and their licencees. Three performed particularly well and have been requested for inclusion in official trials in 1985.

Seed tubers for trials in 1985 were despatched to all these countries in the autumn. Trial arrangements will be as in 1984 except that the commercial assessment trial in Israel will concentrate on those clones which have already shown promise, and no additional unnamed clones will be submitted to Tunisia because the Tunisian authorities now wish to trial only clones which are already on the exporting country's National List.

Verticillium *and* Alternaria *field trial*

This collaborative project at Gilat Experimental Station continued in 1984. From the 300 clones of diverse origin that were trialled in 1983 183 were retrialled. The trial again involved three treatments, a control in which the plots were kept as free of disease as possible, one planted in *Verticillium* infested soil with *Alternaria* being controlled, and one with the soil free of *Verticillium* but with the spread of *Alternaria* encouraged. Various characters, such as maturity, visual disease symptoms, emergence and cover were assessed by our Israeli collaborators. Yield, and other characteristics such as internal condition in the harvested produce were evaluated by SCRI breeders. The data, which when taken together with those of 1983 are very extensive, are currently being assessed and should provide information on the efficiency of such trials and their practical application to breeding. Once grown seed from the spring crop was used to plant trials in the autumn from which data are awaited.

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

Computing

The Computer Housed Information Package (CHIP) continued to be the most frequently used computer program in the Department. Development of new routines and refinements of existing routines continued, making the package more flexible. Three Epson HX20 portable microcomputers were added to the Department's computing equipment. The data capture program (*Ann. Rep. 1983,* 178) was used on the Epsons in the potato store very successfully, and enabled faster processing by obviating the need to have data keyed into the mainframe computer.

As part of the process of computerisation of the Department's acquisition, storage, retrieval and analysis of data a number of smaller computer programs were written, among which were:

i A general analysis of variance program for factorial experiments of up to five factors. Specified tables of means can be produced, and effects in the analysis can be partitioned using orthogonal contrasts.

ii A program for simple regression, multiple regression, correlation and joint regression analysis.

iii A general data handling program to sort alpha/numeric lists, create parallel data from sequential data and vice versa and to derive new variates for CHIP.

All these programs are 'user friendly' to facilitate their use by persons not familiar with computing systems.

Early generation selection

Research continued into the efficiency of selection in the early generations of a potato breeding programme. Clones from a representative sample of progenies produced from true seed in the glasshouse in 1981, grown as single plant plots at two locations in 1982 and as three-plant plots at two locations in 1983 were trialled in replicated five-plant plots in 1984. In each year these clones were independently assessed visually by four potato breeders. Yield and several other tuber characteristics such as eye depth, stolon attachment, shape and size were also recorded at every stage. The breeders' assessments were carried out normally but no clones were actually discarded, all being retained for re-evaluation in subsequent years.

Results to date show that selection between seedlings in the glasshouse or between individual clones in the first year in the field (single plant plots) is inefficient. In both cases a large proportion of good clones would have been discarded if selection had been practised.

However, the relative rankings of the progenies examined in the different environments at the stages from seedling to third clonal year trials indicated that it would have been possible to determine the progenies of greatest commercial worth in any of the locations, years, or generations. Further investigations are now being made with a larger number (204) of progenies. The initial indications are that progeny evaluation by breeders' 'visual appraisal' can be used efficiently in a potato breeding programme.

Production of true-breeding material

Because infertility impedes inbreeding by selfing, other methods of producing true-breeding material are being investigated. One approach could involve the production of monoploids, then doubling the chromosomes to give homozygous diploids and redoubling to give homozygous tetraploids. Dihaploids can be produced routinely from tetraploids using *Solanum phureja* pollen, and the possibility of producing monoploids from such dihaploids is being examined. Anthers of dihaploids are being cultured in the hope of stimulating the reduced pollen grains to develop into monoploid plantlets. Several plantlets were obtained but when examined cytologically (after some growth) they were diploid. This may be because they were derived from original dihaploid tissue around the pollen grains or from unreduced pollen grains. It is also possible that monoploids were produced but that they doubled spontaneously. These possible explanations are currently being examined.

Limited gene changes

The possibility of making limited gene changes to existing genotypes has obvious advantages. Two promising methods are being investigated. One is the use of irradiated pollen as a means of limited gene transfer. A

further eight progenies have been obtained in this way, enabling the technique to be assessed on a representative sample of material. A second method of limited change under investigation is the use of somaclonal variation induced when plant material passes through a callus phase. Reports of such variation are fairly widespread in the recent literature. From five clones cultured cv. Désirée gave 181 plantlets while cv. Pentland Ivory gave 40, SCRI clone 12721ae18 gave seven, and two other clones gave none. These differences reflected variation in ease of obtaining differentiation from callus rather than in amount of starting material or effort. Unless culture methods can be developed which allow plantlet formation in a wider range of genotypes the usefulness of the technique will be severely limited.

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

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

Neo-Tuberosum

In previous studies in Britain, Canada and the USA heterosis for yield has been observed in Ntb × Tbr (Neo-Tuberosum × Tuberosum) hybrid progenies but usually in experiments conducted at wide spacings, or with long growing periods, or with seedlings or small seed tubers from pot-grown plants. The Ntb parents used were taken from the population early in its development and may have contributed, to the progenies, primitive characteristics such as late maturity and vigorous haulm growth which could be advantageous in such conditions.

There have also been reports that hybrid progenies having Tbr mother-plants have higher yields but bear fewer berries than those having Ntb female parents, suggesting that reciprocal differences in fertility occur and that the development of berries can detract from tuber yield.

Crosses were made in 1979 to provide progenies, involving advanced Ntb parents, for study under commercial-type conditions. The production of a full diallel was attempted involving five Tbr and eight Ntb parents together with a North Carolina II design in which an additional sixteen Ntb parents were used as males in crosses with the same five Tbr parents. One of the Tbr and two of the Ntb parents used in the diallel had little or no fertile pollen and gave progenies only as female parents and, with other random failures, only 101 of the potential 169 progenies in the diallel and 59 of the 80 in the North Carolina II design were available for study. Seedlings were raised in 1980 and a single tuber from each was planted to the field in 1981 to provide normal-sized seed-tubers.

In 1982 all the available progenies were compared in a field experiment in which four of the Tbr and 22 of the Ntb parents were also included. Each progeny was represented by a single tuber from each of 36 geno-

types, divided to three lots of twelve for the planting of three replicates. The growing period was 20 weeks.

Due to imbalance in the design arising from its incompleteness the data must be viewed with caution but the indications were as follows:

1. Tbr (female) × Ntb progenies on average were higher yielding than progenies of the reciprocal class, and also than Tbr × Tbr progenies.

2. The identities of the Tbr parents influenced the yields in Tbr (female) × Ntb progenies, some giving higher-yielding progenies than others, but the identities of the Ntb male parents had little if any effect. The latter finding was surprising as the Ntb parental clones varied greatly in yield.

3. Yields of the Ntb (female) × Tbr progenies were relatively uniform and no significant differential effects of either the Tbr or the Ntb parents could be detected among them.

4. Yields of Ntb and Tbr progenies obtained by self-pollination were lower than those of progenies obtained by cross-pollination.

5. Differences in yield and in berrying between some reciprocal pairs of progenies have been reported previously (*Ann. Rep. 1982,* 81).

A 1984 field experiment involved 280 clones from 23 progenies with from seven to 15 clones per progeny. Twenty-one of the progenies formed an incomplete diallel based on three Tbr and two Ntb parents (four progenies missing); the other two progenies were a reciprocal pair involving a fourth Tbr parent crossed with one of the other three. The growing period again was 20 weeks. The maturity, yield and specific gravity of each clone was observed. Each of the 10 Ntb × Tbr or reciprocal hybrid progenies in the experiment had a higher mean yield than any of the six Tbr × Tbr progenies; the yields of the two Ntb × Ntb progenies bracketed the boundary between the Ntb × Tbr and Tbr × Tbr ranges, and the two Ntb and three Tbr selfed progenies were lower yielding than any of the other progenies. However, there was considerable variation within progenies in yields, maturities and specific gravities and yields tended to increase while specific gravities declined with increasing lateness of maturity. Some of the progenies consisted mainly of relatively late-maturing clones so the possibility that yield differences between progenies largely reflected maturity differences was examined. Following calculation of the dry-matter yield of each clone (to adjust for differences in SG) and adjustment of these by covariance to the mean maturity for the 280 clones the picture was little changed except that the ranges of progeny means in Ntb × Tbr and Tbr × Tbr overlapped slightly and Ntb × Ntb progenies were ranked somewhat lower than before. The top 28 (10%) of the clones for yield consisted of 25 of the 124 from hybrid progenies, two of the 79 from Tbr × Tbr progenies, and one of the 27 from Ntb × Ntb progenies, while for adjusted dry-matter yields they included 23 from hybrid and five from Tbr × Tbr progenies.

The flowering and berry production of each clone was also recorded. Early maturing clones rarely bore many flowers or berries but later maturing clones were very variable in these respects. The influences of these characters on each other and on tuber yields, and indications of reciprocal differences between progenies and of effects of individual parents, are being studied.

True (botanic) seed stocks of the main Neo-Tuberosum population were renewed. About 1400 unselected plants were raised from seed from the 1978 seed-production plot and grown in isolation from other potatoes. About 1000 provided the required four berries per plant and some others fewer. A substantial seed sample is being deposited for long-term storage at −20°C in the Gene Bank at the NVRS.

The agronomic evaluation of Neo-Tuberosum clones has hitherto involved comparison with cultivars to identify those which approached commercial standards. These clones have been surveyed for disease resistances or other properties which might recommend them as parents in the commercial breeding programme. A more stringent approach is now being attempted; 179 Neo-Tuberosum clones have been compared with material undergoing selection in the cultivar breeding programme at the stage (the 'M1') at which c. 1% of the initial seedlings remain. Only those retained for further assessment as potential cultivars will be subjected to routine screening. However, investigations of disease resistances or other properties previously detected will continue, as will appropriate screenings of progenies bred for such characters.

In recent years field testing at Ayr has identified 96 Neo-Tuberosum clones with good resistance to foliage blight. Many of these appear susceptible to tuber blight but 11 of them have shown good resistance, as also have 14 others not tested at Ayr because preliminary glasshouse foliage-blight tests were unpromising. Further clones with resistance to virus Y or to leafroll have been identified in the field test at Cambridge, and glasshouse tests on seven Y-resisters showed that six of them were also resistant to viruses A and C. Regarding PCN resistance in Neo-Tuberosum see p. 75.

(D. R. Glendinning)

Diploid potatoes

The potential value of potato clones with Group Phureja/Stenotomum germplasm for use in warm regions, such as the Mediterranean, is not known. Apart from heat tolerance, important factors are reactions to warm-climate pathogens such as *Alternaria* and *Verticillium* which can severely depress the yields of many northern European cultivars in such regions. In 1982 a small but representative range of improved Phureja/Stenotomum clones and hybrids was grown in Israel. Four clones which were then scored as having high resistance to *Verticillium* were included

in the 1983 and 1984 trials. One of these, a tetraploid hybrid between a high yielding diploid and cv. Maris Piper, continued to resist infection. Another, a diploid hybrid with a Tuberosum dihaploid, rated medium to low haulm infection scores but its yield was reduced on infested ground. A wider range of tetraploid hybrids, known to yield well in Scotland, was included in the 1983 and 1984 trials. Some gave good yields. As with Tuberosum cultivars, low visual infection rates with *Alternaria* and *Verticillium* seemed to be associated with medium to late maturity.

In the 1930s a diploid variant from within the Phureja/Stenotomum group was used to a limited extent at the SPBS in breeding for earliness. A series of randomised field trials was started in 1981 to compare yields, at early harvests, of tetraploid hybrids (Tuberosum × improved Phureja) with standard early and second-early cultivars. Although the hybrids had not been bred for earliness they frequently yielded as well as the controls. Yields in a 1982 trial in south west Wales suggested that this hybrid material was better able to recover from late frosts and drought than commercial early cultivars. In 1984 four hybrid seedling progenies were raised from crosses between the Dutch early cultivars Manna and Bea and two improved diploid clones. All the 114 seedlings from Manna were tetraploid, as were 51 of the 57 from Bea. Further crosses with diploids were made using these cultivars and the second-early cultivars Draga and Wilja.

(C. P. Carroll)

Dihaploids

Dihaploids having resistance to both foliage blight *(Phytophthora infestans* and potato cyst nematode (PCN) *Globodera pallida* were crossed with the tetraploid cultivars Maris Piper, Pentland Squire and Pentland Dell to find how efficiently these characters are inherited by tetraploids via unreduced gametes. Forty-eight seeds were obtained from 1002 pollinations, the amount of seed varying between crosses from 0 to 0.3 per pollination. Additional dihaploids were produced from tetraploids which combined resistance to blight and PCN. Of 24 previously produced, six have high resistance to both pathogens. Significant differences were found in the general combining abilities (GCA) of three dihaploids for foliage blight resistance, the least resistant having the lowest GCA. Although the tetraploid parents in these crosses were susceptible to the isolate of blight used they differed significantly in their effects on the resistance of their progenies.

In glasshouse tests 25 of 76 tetraploids from crosses between blight resistant dihaploids and susceptible tetraploids were highly resistant, and four of the 25 also had high resistance to PCN derived from the tetraploid parent. Four of six tetraploids from crosses between a tuber blight resistant dihaploid and susceptible tetraploids were resistant. Thirteen of 20 produced from the chromosome-doubled derivative of the same dihaploid were also resistant but seven control tetraploids obtained

from a susceptible dihaploid were all susceptible.

In field plantings the yields of tetraploids obtained from dihaploid × tetraploid crosses are often as high as those of control cultivars. Thirty-six such tetraploids were multiplied preparatory to assessing them for other commercially desirable characters.

In an attempt at limited gene transfer three dihaploids were pollinated with irradiated pollen from four Phureja genotypes. Seed production decreased with radiation dosage from about 100 for the unexposed to one or two per pollination for pollen treated with 100 Gy of gamma radiation. There were no obvious differences between progenies in seedling phenotypes.

(M. J. De,Maine)

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

Potato cyst nematode

Seven hundred and thirty clones were screened for resistance to *Globodera rostochiensis* (Rol), 680 clones to *G. pallida* (Pa3, Lindley) and 220 to *G. pallida* (Pal). In addition, 224 clones were screened for resistance to *G. rostochiensis* and 104 to *G. pallida* for the Oak Park Research Centre, Carlow, Eire.

Resistance in Neo-Tuberosum clones to *G. rostochiensis* and *G. pallida* tends to be correlated (*Ann. Rep. 1981,* 182); however, there have been occasional indications to the contrary. Over the last 2 years 40 Neo-Tuberosum clones have been screened against four populations; *G. rostochiensis* (Rol), and *G. pallida* (Pal), (Pa3, Lindley), and (Pa3, Cadishead). No major differential reactions were detected. Analysis showed a significant clone × population interaction but this was small relative to the main effects, broadly confirming the previous finding.

Forty-eight progenies from crosses made in 1983 were screened for resistance to *G. pallida* by the bulk seedling test.

(L. A. Farrer)

Twenty-three progenies from an incomplete diallel were assessed for resistance to *G. pallida* in closed containers. These progenies were derived from seven parents; six partially resistant Neo-Tuberosum clones, and cv. Maris Piper. Twenty clones per progeny and up to four tubers per clone were planted. Analysis of the cyst counts indicated that there were significant differences in general combining ability (GCA) and in specific combining ability (SCA), GCA predominating. Progenies from the susceptible parent Maris Piper were less resistant than those from intercrosses between Neo-Tuberosum parents. Removal of the Maris Piper array from the analysis rendered the GCA source non-significant. This situation resembles that found in material derived from *Solanum vernei* for, if such material is crossed with susceptible material, GCA

effects predominate, whereas intercrosses between resistant parents result in larger SCA effects. The presence of significant SCA suggests that progeny tests are useful for assessing the value of Neo-Tuberosum parents, as they are with the other sources of resistance from *S. vernei* and *S. tuberosum* spp. *andigena* CPC 2802 currently in use.

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

A field trial was conducted on land infested with *G. pallida* at Aberlady, East Lothian to assess the feasibility of using single plant plots to evaluate clones for tolerance to nematodes. Ten tubers of each of 15 clones were planted in a randomised complete block design. Haulm growth was assessed visually and the tubers were weighed at harvest. The ranking of the clones was similar for both haulm assessments and yield. The results also agreed well with those from larger plots in ADAS trials. No nematicide was applied to the trial so it was not possible to estimate the yield loss caused by the nematodes. However, clones which were seriously affected could be identified. This type of trial therefore has potential as a tolerance screen at an early stage in the breeding programme when there are many clones to be assessed but only few tubers of each are available.

(M. S. Phillips, D. L. Trudgill[1])

Major gene resistance to potato virus Y (PVY) and potato virus X (PVX)
Sixteen thousand seedlings from 81 progenies were spray-inoculated with PVY, PVX, or both, for progeny tests or to select for resistance within progenies. Progeny tests for resistance to PVY identified another duplex parent. Seven parents probably duplex for a PVX resistance gene were identified, and three of these also appeared to be simplex at a second locus.

Two hundred clones were screened by sap- or graft-inoculation for major gene resistance to various strains of PVX and PVY. Clone 10337de40 (Sheena) showed resistance to the common and B Strains of PVX, and the A, common, a VN, and probably the C strain of PVY. The cv. Rhona showed resistance to a VN strain but not to the common strain of PVY.

Potato leafroll virus (PLRV) and potato virus Y (PVY) field trial
Three hundred clones were exposed to PLRV and PVY in a field trial at PBI, in 1983. They were grown on at PBI and scored in 1984. Infection with PLRV was so extensive that only the most resistant clones could be identified; 86% of the plants of the resistant control cv. Pentland Crown became infected, and clones of intermediate resistance were indistinguishable from susceptible ones. The extent of PVY infection was more typical: 3% in Pentland Crown and 94% in the susceptible cv. Arran Pilot.

[1]Zoology Department.

In spite of the extensive PLRV infection, 20 clones showed very good leafroll resistance with 0–33% of the plants infected. These included clones bred for virus resistance, diploid Group Phureja/Stenotomum clones and hybrids derived from such diploids. Most of these leafroll resistant clones and many others also showed very good resistance to PVY, with no plants infected, including some Neo-Tuberosum clones and most of the clones bred for virus resistance. The new cv. Sheena did not show resistance to PLRV. It showed major gene resistance (hypersensitivity) to PVY in glasshouse tests but plants in the field became necrotic.

Potato mop-top virus (PMTV)

A field trial for resistance to PMTV was grown at Braco, Perthshire, in 1983. There were very few symptoms (probably indicative of very little infection), even in the susceptible control cv. Arran Pilot, but cv. Kirsty and two breeders' clones showed a few primary spraing symptoms. No conclusions could be drawn about the PMTV resistance of other clones.

Some clones and cultivars showed internal rust spot, which was also observed, mostly in the same clones, in the 1983 tobacco rattle virus (TRV) exposure trial (described below). Whilst this might have been due to PMTV and TRV, its occurrence in the same clones in two so poorly infested trials for different viruses would suggest some other cause, at least in some cases.

Tobacco rattle virus (TRV)

A field trial for resistance to TRV spraing symptoms was grown in irrigated, infested ground at Tayport, Fife, in 1983. Unfortunately the infestation was low and patchy and although four clones were clearly susceptible, no firm conclusions could be drawn about symptomless clones.

The 1984 trial at Tayport was well infested, however, so that resistance in four clones (12768(1), 12243ac1, 12276af9 and 11291(3)) could be identified with confidence. These showed spraing symptoms in only 2–3% of tubers compared with 29% in the susceptible control cv. Pentland Dell. However, they showed internal rust spot which could have been due to TRV.

Small trials were grown in Yorkshire in 1983 and 1984 to check for differences in resistance due to trial sites, but there was very little spraing.

(R. M. Solomon)

Development of a glasshouse screening test for resistance to TRV continued in 1984 with a modified method. Pots of 12.5 cm instead of 10 cm were used. *Nicotiana tabacum* cv. White Burley was grown in soil brought from the TRV infested site at Tayport. Only soil samples in which the tobacco plants developed symptoms were used. Eye scoops

from tubers of 10 cultivars with known reactions to TRV and eight clones of unknown resistance were planted in infested soil. After harvest the daughter tubers were sliced, examined and scored for spraing symptoms. The results agreed fairly well with field trial results and NIAB ratings.

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

Bacterial soft rot

Thirty-six clones were screened for resistance to *Erwinia carotovora* ssp. *atroseptica* using jet inoculation. No extremes of resistance or susceptibility were detected in clones from the cultivar breeding programme but several bred from cultivated diploids appeared resistant, confirming previous results. Blackleg tests carried out in a growth room on potted plants of 33 clones confirmed the susceptibility of cv. Moira, and identified several resistant clones, especially among those from the diploid and dihaploid breeding programmes. One of these, HBX77.24, exhibited resistance to both the tuber and stem phases of the disease in two years of testing.

Twelve clones and cultivars were grown at Pentlandfield to determine whether jet inoculation of the tubers at planting would cause blackleg symptoms. Cultivars Maris Bard and Ulster Sceptre showed most susceptibility when scored in late July. Cultivars Maris Bard, Ulster Sceptre, Cara, Maris Piper and Wilja showed the greatest effect of inoculation and suffered the greatest yield loss at harvest in late September. Ulster Sceptre and Maris Bard are known to be highly susceptible to blackleg but Maris Piper has been reported to be resistant.

Dry rot

Fifty clones screened for resistance to *Fusarium solani* var *coeruleum* showed the generally high levels of resistance occurring in advanced commercial breeding material, as well as in certain Neo-Tuberosum clones. In contrast, clones from some diploid (Phureja) × tetraploid crosses appeared to be very susceptible.

All clones were inoculated by the standard technique of wound inoculation with a cornmeal + sand culture of the pathogen, and by the somewhat quicker method of jet injection with an agar culture macerate. Agreement between the two methods was generally satisfactory, and where there were differences lower levels of disease occurred with jet injection, perhaps because of the smaller wound it causes. Twelve cultivars were inoculated by both methods with *F. sulphureum* Schlect., the cause of powdery dry rot. The techniques gave similar results.

Gangrene

Routine cornmeal sand tests were carried out on 781 clones in the winter period 1983 – 84. One hundred and eighty-four of 366 clones

scored at least 7 on the 1 – 9 scale of increasing resistance—a level attained by only one cultivar (Home Guard) on the current NIAB Recommended List. Jet injection of agar culture macerate was compared with the standard test on 12 cultivars. Despite the different nature of the two tests, jet injection being a point inoculation method measuring tissue susceptibility rather than susceptibility to penetration and invasion, the rank ordering of the cultivars by resistance was very similar.

An experiment was conducted to verify gangrene assessments made on seedling plots of 24 progenies in 1982/83. Three susceptible, three resistant and two intermediate progenies, as determined in the seedling test, were tested as replicated clone plots in 1983/84, up to 18 clones per progeny being examined as inoculated 10-tuber samples. The mean disease scores of the 18 clones corresponded reasonably well with the progeny scores, and suggested that the seedling test could indeed be used to identify resistant and susceptible progenies. Such a test is being carried out on 25 additional progenies in 1984/85.

Common scab

Three sites were again employed for routine assessment of resistance to common scab. Archerfield, East Lothian, took fifth year commercial selections and all novel germplasm material (282 clones); Scoughall farm, East Lothian accommodated sixth year and later commercial selections and museum clones (183 clones), and Gleadthorpe EHF, commercial clones from seventh year onwards with the new SCRI cultivars (66 clones and cultivars). The method of disease scoring at Archerfield was changed in 1983 from individual tuber counts to an overall direct assessment of common scab on a 1 – 9 scale of increasing resistance, examining the plots *in situ* after hand digging. Two pairs of assessors recorded each plot, and their scores were averaged. Only one assessor was employed at Gleadthorpe EHF. Tubers from Scoughall farm were scored in the laboratory, counting the number of tubers with more than one-eighth of the surface area infected and then converting the score to a point on the 1 – 9 scale by reference to the control cultivars. Forty-seven of 66 clones (71%) screened at Scoughall farm in 1983 and 1984 fell within two points on the scale in both years, as did 24 of 26 clones (92%) tested successively at Gleadthorpe EHF. There was less agreement between scores given to the same clones at different sites in successive years, underlining the need to continue testing at different locations.

Late blight

Two hundred and sixty-eight fifth and sixth year selections from the cultivar breeding programme were tested in the glasshouse for foliage resistance to late blight. Thirty-six of 57 clones bred for blight resistance and 50 of 211 other clones scored 6 or more on the 1 – 9 scale of increasing resistance. This level of resistance was also shown by 24 of 74 diploids and 27 of 43 Neo-Tuberosum clones.

Advanced selections were assessed in a field trial at Yonderton farm, Ayrshire. The isolate of *Phytophthora infestans* used to establish the epidemic proved not to be fully complex, so the observed resistance of some clones may have been due to major genes. However, 16 clones had also been tested at Ayr in 1983 with a fully complex race and the two years' results compared well.

Clones derived from an assessment of the validity of the seed pan progeny test (*Ann. Rep. 1982,* 79) were also assessed at Yonderton farm. Of 26 clones from the population exposed to blight in the laboratory only one scored less than 5 on the 1 – 9 scale, whereas 40 of 74 clones from the unexposed population scored 3 or less.

Potted plants of 18 early and 18 maincrop clones were raised, inoculated and incubated in a growth cabinet at 20°C under fluorescent lights giving a 16h day. The same clones were also field tested at Yonderton. The two sets of results compared satisfactorily for both early and maincrop clones.

Investigations continued on the effect of the physiological age of the seed tuber at planting on susceptibility in the glasshouse test (*Ann. Rep. 1983,* 76). Five early and five maincrop cultivars were stored at 4, 10 or 20°C for 8 or 15 weeks before planting. Storage temperature made little difference to susceptibility except that storage at 20°C for 15 weeks gave plants significantly more susceptible than at 4°C in five of the cultivars, tending to confirm previous findings.

Clones from the fifth year of selection onwards were assessed for tuber resistance in laboratory tests. Seventy-one of 124 early clones and 46 of 171 maincrop clones scored 7 or more on a 1, 3, 5, 7, 9 scale of increasing resistance.

An experiment to examine the validity of a seedling test for assessing the tuber blight resistance of a progeny was initiated on glasshouse-grown plants. Ten progenies were selected on the basis of the tuber blight resistance of their parents (four resistant × resistant, three resistant × susceptibile and three susceptible × susceptible). Immature tubers from 40 seedlings of each progeny were harvested, inoculated, and the percentage of infected tubers subsequently observed. A good correlation was apparent between the proportion of infected tubers and the resistance status of the parents. This work is being repeated on field-grown plants.

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

AILSA

National List and Plant Variety Rights—1984

Maturity class	Early maincrop, slightly earlier than cv. Pentland Crown
Foliage	Medium to low height, bushy, compact, good cover; leaves short, close, light green and rugose; flowers white, small, infrequent
Tubers	Short oval, uniform and regular; shallow eyes; skin white; flesh pale cream
Cooking quality	Good. Medium to high dry matter, higher than Pentland Crown; flesh moderately firm to mealy when steamed, pale cream
Processing	Not suitable for crisping, but its dry matter and SCRI tests suggest it may be suitable for chipping
Yield	Similar yield potential to Pentland Crown, but with a tendency to produce more numerous tubers in the medium ware range; it has also performed consistently well in Mediterranean countries

**Diseases resistances:*

Wart	Field immune to the common European race 1
Blight – foliage	3
– tuber	3
Gangrene	See summary
Skin spot	5
Common scab	4
Bacterial soft rot and blackleg	6
Potato cyst nematode	Susceptible
Virus X	Susceptible
B	9
Y	2
A	9
C	9
Leafroll	4
TRV	1
PMVT – spraing	8
– haulm	3

*Numerical values on 1 – 9 scale where 9 = maximum resistance or hypersensitivity

Summary A high quality, high yielding, white skinned, cream fleshed cultivar which has performed well in all sites in the Mediterranean as well as in the UK and has never exhibited any hot-climate physiological disorder such as 'chocolate spot.' It has produced good crops when planted as cut seed pieces in Spain and elsewhere, its moderate soft rot and blackleg resistance perhaps contributing to this. Its gangrene resistance status is subject to further investigation as the conclusion from the National List tests conflicts with SCRI findings.

MOIRA

National List and Plant Variety Rights—1984

Maturity class	First early, similar to or slightly later than cv. Home Guard
Foliage	Low to medium height, soft, bushy; light medium green; very good cover. Flowers white
Tubers	Oval; white skin; shallow to medium eyes; flesh pale lemon
Cooking quality	Good; moderate to firm texture; free from after cooking blackening; pale lemon flesh. It is popular with SCRI staff
Processing	Dry matter quite good for an early, and crisp colour comparable to Home Guard, but primarily a table cultivar
Yield	Yield potential similar to Home Guard, probably slightly later bulking but earlier than cv. Pentland Javelin

**Diseases resistances:*

Wart	Field immune to the common European race 1
Blight – foliage	4
– tuber	7
Gangrene	See summary
Skin spot	5
Common scab	7
Bacterial soft rot and blackleg	4
Potato cyst nematode	Susceptible

Virus X	Susceptible
B	Susceptible
Y	9
A	Susceptible
C	9
Leafroll	2
TRV	8 – 9
PMVT – spraing	4
– haulm	5

*Numerical values on 1 – 9 scale where 9 = maximum resistance or hypersensitivity

Summary

Moira is a high quality first early, white skinned and lemon fleshed. It combines a good yield potential with an excellent spectrum of disease resistances: tuber blight, common scab, virus Y and tobacco rattle (spraing). In SCRI tests Moira is also highly resistant to gangrene but this conflicts with the NLT data and is the subject of further investigation. Moira has occasionally yielded very well in SCRI Mediterranean trials but where cut seed pieces have been used 'blanking' has often been a severe problem. Moira is therefore regarded as a cultivar primarily for the UK and similar environments.

SOFT FRUIT BREEDING

D. L. JENNINGS

Useful discussions were held with staff from EMRS about the reorganisation of raspberry breeding in the UK. SCRI will have national responsibility for breeding cultivars which fruit on second-year canes while EMRS will retain national responsibility for breeding primo-cane fruiting types. Collaboration and exchange of material between the two institutes, as well as observations on, and selection for pest and disease resistance at the two sites, should help improve the efficiency of both breeding programmes.

The transfer of material from the EMRS *Ribes* breeding programme to SCRI continued: gall-mite resistant germplasm from EMRS should be especially useful. SCRI will assume responsibility for black currant breeding for the UK.

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

Propagation began of the four advanced selections recommended for inclusion in regional trials in England and Scotland. A high incidence of abberant mutant forms was recorded in selection 7331/7 in the trial at Brogdale EHS, due to mutation of the gene L_1 to a recessive allele, and it was therefore recommended that testing of this selection be discontinued. Good yields were obtained again from two of the other selections, 7515C5 and 7133R40, and the former was again notable for its excellent fruit quality, especially its bright colour. New first stage trials were planted at Brogdale and Invergowrie.

Yield studies

The extremely dry summer revealed shortcomings in certain genotypes with high numbers of fruit per lateral where this was achieved by the presence of two or more fruits at lateral nodes. The second and third fruits at such nodes usually developed so poorly relative to the first fruit that the final fruit sample contained two distinct size grades. Genotypes varied in proneness to the stress, but the observation emphasised the need for caution when selecting genotypes with high expression of this yield component.

Resistance to fungal pathogens and midge blight

Further observations were made in spring 1984 on the experiment (*Ann. Rep. 1983,* 85) in which mycelial inoculations of canes with *Botrytis cinerea* and *Didymella applanata* were compared with petiole inoculations as a means of assessing the relative resistance of seven cultivars. A notable feature for both diseases was the high proportion of axillary buds of the inoculated petioles which either failed to grow or failed to produce laterals of normal vigour; however, the cultivars differed in this respect and in their ranking for resistance following cane inoculation. The scores for lateral development were also correlated with the scores for spring symptoms, though in all cultivars there were many instances where lateral development was fully suppressed even though spring symptoms were very mild or absent.

Principal component analyses of the data for five different assessments of resistance to each disease showed that 40% of the variation could be accounted for by a vector which described combined resistance to the two diseases and identified three levels of resistance: a resistant one containing the cultivars Meeker, Chilcotin, Willamette and Leo; an intermediate one containing cv. Haida; and a susceptible one containing cultivars Glen Prosen and Malling Jewel. The second vector described tolerance to the two diseases, and açcounted for 22% of the variation, while only 12% of the variation resulted from independent resistance to *B. cinerea* and *D. applanata.* The latter occurred because Haida showed slightly more resistance to *D. applanata* and less to *B. cinerea* than predictable from the first vector.

Wide segregation for cane resistance to *B. cinerea* occurred in several families of second backcross *Rubus pileatus* hybrids and several selections of excellent overall merit were among the most resistant.

Resistance to *Leptosphaeria coniothyrium* was tested in *R. pileatus* and its F_1, and first and second backcross hybrids with raspberry. Lesions measured on 6 November from mycelial inoculation on 9 August averaged 69, 32 and 48 mm in length for susceptible raspberry, *R. pileatus* and F_1 hybrids respectively, while those of the backcross hybrids indicated segregation for resistance with a predominance of susceptible segregates. The result indicated that inbreeding will be necessary to retain an adequate level of resistance, and three second backcross hybrids were selected for use as parents.

Forty-four advanced selections were assessed for fruit resistance to *B. cinerea* by studying grey mould development on fruit samples obtained from the field. The average incidence of fruit botrytis in samples taken from a plot planted in 1982 was twice that of samples taken from an adjacent plot planted in 1981, possibly because plants in the former were smaller with fruits less well exposed to the drying action of the wind and sun. The result emphasised the need for improved screening techniques

based upon a better understanding of the factors which affect the development of *B. cinerea.*

A non-splitting cane rind confers midge blight avoidance because it does not provide egg-laying sites for the midge. Segregants with this characteristic were selected from two families derived from *R. crataegifolius,* and studies of their stem anatomy confirmed the association between a lack of rind splits and an ability to produce abundant wound periderm. This characteristic has now been detected in first backcross hybrids of one accession of *R. crataegifolius* and in F_2 hybrids derived from another. Selections have been made for sibbing and for further backcrossing to a raspberry genotype noted both for its good fruit quality and its low incidence of rind splits.

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

Infection of flowers by B. cinerea

The techniques previously described (*Ann. Rep. 1983,* 120) were used to study the growth of *B. cinerae* in the inoculated styles of 40 genotypes under glasshouse conditions. It was found that in 30 of the genotypes hyphal growth continued to the proximal end of the style, in eight the infection was limited to the distal portion and in two the conidia were apparently prevented from germination. The variation observed suggests the occurrence of resistance to stylar infection. Experiments on the importance of stylar infection for the development of post-harvest grey mould of the fruit are reported on p. 119.

(B. Williamson[2], R. J. McNicol, A. Dolan[2])

Resistance to virus

Further study of the segregation of immunity from raspberry vein chlorosis virus in progenies related to the immune cultivars Latham, Viking, Newburgh and Cuthbert provided further evidence contrary to the hypothesis that immunity is conferred by a single gene: a more complex genetic control is therefore indicated. Immunity also occurs in the black raspberry and was identified in the red raspberry cv. Glen Isla, which is a second backcross to red raspberry of a red raspberry × black raspberry hybrid. An F_1 family from this species was graft-inoculated to study the inheritance of immunity from this source.

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

Evaluation of the suitability of red raspberry genotypes for fresh fruit marketing

Fruit destined for the fruit market should ideally retain its turgor and a bright red colour without rotting for as long as possible after harvest. In

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[1] Virology Department

[2] Mycology & Bacteriology Department

the USA fruit is traditionally harvested for this market and the berries develop colouring during transport. Eleven selections from the SCRI breeding programme, eight cultivars from the UK and three from the USA, were evaluated at Invergowrie after the fruit was picked underripe (at the red ripe stage of maturity—fully coloured but very light red) for changes in weight, colour and glossiness over a 6-day period. Berries stored at 6.5°C during the first 2 days lost weight at a rate of one-half of that which occurred during the remaining 4 days of the test when berries were held at room temperature (c. 21°C). Total losses ranged from 9.4% for SCRI clone 18E6 to 16.9% for cv. Malling Jewel. Small fruited genotypes lost a greater proportion of their harvest weight than those with large fruit.

Fruit colour of all the genotypes became more purple, less saturated and darker during storage. Cv. Chilcotin retained its light and bright red colour best and clones 1/53 and 18E6 were almost as good. All genotypes remained lighter than cv. Willamette, fruit of which became very dark within a day or two of picking. Skin glossiness was influenced by both genotype and time in storage. Glossy fruited clones became duller with time; dull clones remained dull throughout. Genotype M30 was the glossiest and retained its gloss better than any other. Although no pre-harvest fruit rot was observed, the incidence of post-harvest rot, after 6 days of storage, ranged from 0% for cv. Glen Prosen to 70% for cv. Malling Delight. The incidence of rot was correlated with the leakage of juice onto the filter papers used to line the plastic funnels.

(P. R. Bristow[1])

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

Black currant breeding material transferred from EMRS to SCRI consisted of 1,000 gall-mite resistant selections from 30 families (2,500 1-year-old plants), selected after exposure over 4 years to gall-mite infestation in a field screening plot. Other (non-gall-mite resistant) hybrids received included 1-year-old plants of 130 selections from 50 families, and hardwood cuttings of 747 selections from 24 others.

Regional trials and commercial assessments

At Brogdale EHS, in an unusually cold but frost-free flowering period, cv. Ben Lomond and three-late flowering, frost-tolerant SCRI hybrids selected for their juice processing qualities (*Ann. Rep. 1983,* 81) maintained their high level of cropping for the fifth year in succession. For 1980–84, P8/12/7 (cv. Ben More × Ben Lomond), P8/5/24 Ben More × *R. nigrum* × *R. dikuscha* hybrid) and P9/8/7 (a complex Ben Lomond hybrid) outyielded cv. Baldwin by 84, 61 and 47% respectively,

[1]Western Washington Research and Extension Center, Washington State University, USA

equivalent to mean annual yield increments of 8.0, 5.8 and 4.5 t/ha. During the same period, the dates of full flower and harvesting ranged from 14 – 21 and 12 – 13 days later than those of Baldwin.

At Mylnefield, these clones and all other late flowering hybrids, including Ben More, dropped most of their flowers shortly after anthesis following 4 successive days of low air minimum temperatures in early May.

Virus tested stocks (ex EMRS) of the three hybrids are currently undergoing propagation by NSDO with a view to the commercial release of at least two in the winter of 1986/87. Although similar in their flowering and date of ripening patterns, they differ in juice processing qualities. Juice of P8/12/7 is outstanding for its high total pigment concentration, and P9/8/7 and P8/5/24 juices for their high concentration of acylated pigments, which confer colour stability.

The first fruit samples for bulk juice processing tests were submitted to Beecham Products Ltd., Coleford from a trial planted in 1982 at Bradenham Hall Farm, Norfolk under the aegis of SCRI/NSDO/ADAS/ Beecham Products Ltd. The most noticeable feature of the trial was the remarkable vigour of the Scottish hybrids. One of the most productive frost tolerant hybrids in the trial, F6/3/39 (Ben Lomond × *(R. nigrum* × *R. dikuscha),* was of particular interest because it ripened about one week earlier than Ben Lomond.

Trialling of SCRI hybrids abroad

The Kise Agricultural Research Station, Norway requested the commercial release in Norway of the SCRI hybrid P8/13/13 (cv. Westra × (cv. Goliath × cv. Öjebyn) × *(R. nigrum* × *R. dikuscha* F_2)), which has been on trial there since 1978. Fruit sampled by the Norwegian Food Research Institute gave a higher yield of better coloured juice than comparable samples from the standard cv. Silvergieter Swarte, although flavour was less pronounced.

The Swedish Nursery Growers' Association has found cv. Ben Sarek very suitable for home gardens and has requested cuttings to propagate 20,000 plants for distribution to its members.

(M. M. Anderson)

Frost tolerance tests

Tests on potted plants in a frost chamber were largely nullified because of technical problems with temperature control. This problem was later overcome by the addition of a second cooling coil.

Three groups of pot plants were propagated and grown-on for screening tests in 1985: Baldwin and eight SCRI cultivars or hybrids; two Norwegian cultivars and three Swedish (Balsgård) hybrids; and four winter-hardy Russian cultivars which survived the extremely severe 1978/

79 winter in the USSR. The objectives are to test the relationship between winter hardiness, time of loss of winter dormancy and spring hardiness; to identify superior sources of tolerance of freezing injury in flower tissue after anthesis, and also tolerance of freezing injury from even lower temperatures between grape stage and anthesis.

(J. Taylor, M. M. Anderson)

Resistance to reversion virus

Graft inoculations with reversion virus to find suitable donor parents of extreme resistance continued with four cultivars imported in 1982 from the Nordic Gene Bank and recently released from quarantine, two of which, bred in the USSR, the cultivars Novost and Nigros—are reputed to be resistant. The other cultivars, raised at the Division of Fruit Breeding, Balsgård, Sweden, Triton (cv. Golubka × (cv. Consort × cv. Wellington XXX) and Titania (cv. Altajskaja desertnaja × (Consort × cv. Kajaanin Musta) are complex derivatives of one or more *Eucoreosma* species.

Two progenies, one each of P8/12/7 and P10/18/121 (Ben Sarek × Ben Lomond) crossed with Golubka, comprising a total of 225 plants, were also graft-inoculated.

Plants received from EMRS during the year and potted for graft-testing included 76 gall-mite resistant hybrids from two families and 137 1-year-old plants of a *R. dikuscha* F_3 progeny, a proportion of each of which should inherit extreme resistance to reversion virus from a resistant *R. dikuscha* hybrid parent.

Also potted for the same purpose was one of two plants of *R. dikuscha* or *R. nigrum sibiricum* cultivars, four hybrids from cv. Koksa × *R. pauciflorum* and 11 Golubka hybrids, all of which had been graft-inoculated with reversion virus at EMRS between 1976 and 1981 and which have so far remained symptom-free. A second, non-potted plant of each pair was retained for field observation.

(M. M. Anderson, J. Taylor)

Mildew resistance

The unusually dry summer in 1984 provided excellent conditions for screening progenies for resistance to mildew *(Sphaerotheca mors-uvae).* Seedlings of complex parentage derived from frost-hardy cv. Sunderbyn II F_1 and F_2 hybrids segregated for a form of resistance which precluded sporulating lesions. Of 2,150 seedlings planted in May and June, 47% showed resistance of this type (group 0 on a 6 point scale) and a further 32% exhibited forms of resistance which involved sporulating lesions.

The non-sporulating form of resistance in Sunderbyn II is known to have remained constant for about 40 years and is superior to less potent sporulating forms. It reduces the probability of occurrence of more

virulent physiological races of mildew, and obviates the need for both protective and eradicant sprays.

A similar non-sporulating form of resistance occurred in about the same proportion in small progenies of *R. sanguineum* and *R. glutinosum* derivatives.

(M. M. Anderson)

Juice quality

A characteristic of Ben Lomond is the remarkable colour stability of its juice at pH 3.0. The fractionation of black currant anthocyanins by high pressure liquid chromatography (HPLC) at Beecham Products Ltd., showed that the juices of Ben Lomond, Ben Nevis, Ben Sarek, SCRI P9/8/7 and SCRI P8/5/24, but not SCRI P8/12/7 (see below), are characterised by the appearance of two new anthocyanin peaks whose chromatographic properties suggest that they are acylated anthocyanins not previously recorded in black currant. Anthocyanins possessing at least two acyl groups have been discovered recently which display extraordinary colour stability throughout the whole pH range but little is known of the occurrence of such anthocyanins in the genus *Ribes*. In view of the increasing worldwide interest in naturally occurring coloured anthocyanins, and because the future use of synthetic colour additives is likely to be progressively eroded by anti-toxicological legislation at home and abroad, HPLC has been introduced to identify sources of acylated anthocyanins in black currant hybrids of diverse genetic background and of wide geographic origin. Particular interest is attached to germ plasm from *Ribes* centres of diversity in the USSR.

Origin of acylated anthocyanins in Ben Lomond

The Canadian cultivar Consort (Cv. Kerry × *R. ussuriense*) is an elite source of intense juice colour but its juice and that of its two sister cultivars Coronet and Crusader lack acylated anthocyanins. The colour stability attribute of Ben Lomond therefore has *not* been inherited from Consort (*Ann. Rep. 1982,* 83) but from one or more of its parent cultivars Brödtorp, Janslunda or Magnus.

Commercial juice quality assessment of trial selection

Fruit samples from 10 cultivars on trial at Brogdale EHS and seven from Luddington EHS were evaluated by Beecham Products Ltd. SCRI P8/12/7 was rated highly for juice colour (60% higher than Baldwin), and its juice had a more intense flavour than that of Baldwin when tasted initially as a standard commercial formulation and also after storage for 6 months at 3°C. Juices of both SCRI P9/8/7 and P8/5/24 were found to possess acylated anthocyanins, a high delphinidin/cyanidin (Dy/Cy) ratio and a Baldwin-type flavour.

A fruit sample of SCRI P9/8/8, a sister seedling of P9/8/7, was also found to possess acylated anthocyanins, gave an 18% higher juice yield than Baldwin and was rated very favourable for flavour after 3 months' storage. This hybrid is inferior in yield to P9/8/7 but is being used as a donor parent for its combination of these particular juice quality attributes.

Classified upon pigment fractions, SCRI 243/7 (*Ann. Rep. 1983,* 81), P8/12/7 and Consort were rated highly for total pigment concentration; P9/8/7, Ben Sarek, P8/5/24 and P9/8/8 for a high concentration of acylated pigments; and P8/12/7, P9/8/7 and P8/5/24 for a high Dy/Cy ratio. Ben Sarek received a low rating for both juice colour and Dy/Cy ratio. Baldwin, F6/3/39 (*Ann. Rep. 1983,* 81) and Ben More gave only moderate total pigment concentrations.

(J. Taylor, M. M. Anderson)

Cold tolerance

Investigations were made to explain the high flower drop in Ben More under cold conditions. The results of both *in vitro* and *in vivo* pollen germination experiments indicated that Ben More pollen was capable of a higher percentage germination and longer germ-tube growth at 10°C than pollen of Ben Lomond or Baldwin, while at 5 and 22°C the behaviour of all the pollen was similar.

Studies of pollen germination on stigmas, pollen-tube growth in styles, fruit set and seed numbers per fruit in a 3×3 diallel cross involving Ben More and two advanced selections derived from Ben Lomond suggested that neither self nor cross-incompatibility are likely to be the cause of the fruit drop.

(R. J. McNicol)

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

The progenies raised to transfer a dominant gene for spinelessness to the Tayberry have contained a high proportion of poorly adapted plants (*Ann. Rep. 1983,* 85), apparently because of the persistence of unwanted germplasm from the non-adapted donor parents. An attempt to limit gene transfer was therefore made by subjecting pollen from two near-hexaploid donor parents to radiation doses of 50, 150, or 250 Gy prior to further backcrossing to the Tayberry. Comparisons with non-irradiated pollen showed that the treatments had small but significant effects on drupelet set, and large effects on the proportions of pyrenes which contained seeds (*i.e.* those which sank in water) and on the proportion of the latter which germinated. Consequently, very few seedlings were obtained from crosses with the pollen subjected to 150 or 250 Gy of irradiation but adequate numbers were obtained from the crosses where the pollen was subjected to 50 Gy. The advantages of irradiation will be assessed in the second generation after the pollen treatment (M2).

The problems encountered when transferring the dominant gene for spinelessness to Tayberry were less apparent in parallel progenies raised to transfer it to hexaploid blackberries, and three promising selections from this material were made for further breeding.

At the tetraploid level, progress was made in selecting for earlier ripening among spine-free blackberries. Lateness in this material is associated with a requirement for some 750 heat units (defined as accumulated degrees above 6°C) after flowering, and selections are sought which require 450 units. Several advanced spine-free selections required 500 – 600 units in 1984 and were considered early enough for southern England but not for Scotland. However, new selections related to cv. Ashton Cross ripened particularly early, apparently because they combined the lower requirement for units of Ashton Cross with early flowering.

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

PU 13(d) Identify strawberry genotypes adapted to the Scottish environment

Over 240 selections from the discontinued SCRI breeding programme were assessed for fruit quality, evenness of fruit set and truss production. Forty were selected for further trial.

The advanced selections DK60 and EW30 cropped well in spite of the dry season. The former was significantly earlier than cv. Cambridge Vigour, the most widely grown early cultivar in Scotland, and more than 75% of its crop had been harvested when Cambridge Vigour was only at 50% harvest. It yielded 11 t/ha, considerably more than cv. Cambridge Favourite, and had large, firm fruit. It also produced a bigger second crop than its parent, cv. Redgauntlet, which is the most important double cropping cultivar in the UK. EW30, a later selection, also yielded more than Cambridge Favourite (see p. 165).

Eleven selections from the EMRS breeding programme were planted in observation plots to assess their adaptation to Scottish conditions. This procedure will be repeated each year to assist EMRS breeders to produce cultivars suitable for Scotland.

(R. J. McNicol)

TISSUE CULTURE AND CYTOLOGY

I. H. MCNAUGHTON

Investigations into the production of useful, so-called 'somaclonal variation,' through the culture of leaf explants and thence callus and adventitious shoot development, have been extended to three crop groups. In potato some 'somaclones' have reached the tuber formation stage, prior to field evaluation. Rooted plantlets have been obtained in brassica. Experiments to engender callus from raspberry cultivars have been started.

In addition to routine cytological screening, work has continued on the cytogenetical analysis of the products of pollen irradiation and work has been initiated on the meiosis of potato plants derived by anther culture.

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

Pollen and ovule irradiaton

Meiotic analysis of the M_2 generation, derived from the cross cv. Triumph × cv. Tweed (irradiated pollen), was completed. Translocations, detected in M_1, were observed in the M_2 at a relatively high frequency, demonstrating transmission to the M_2 of at least two paternally-derived chromosomes. A further cross (cv. Golden Promise × S138) is being analysed to enable correlations to be made between phenotypes of individual plants and their cytological behaviour. Mitotic and meiotic analysis of the M_1 showed a relationship between the proportion of plants carrying translocations and irradiation dose.

Emasculated whole ears were irradiated prior to pollination and plants regenerated from the ovules have been mitotically and meiotically examined. All plants investigated so far have been euploid and of normal karyotype.

(E. M. Borrino)

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

Embryo rescue techniques

Embryo culture and ovary culture continued to be used to raise hybrid crosses between *Brassica oleracea* and *B. campestris,* resulting in either *B. napus* (from autotetrapolid parents) or, effectively, haploid *B. napus* (from diploid parents). This work is currently restricted to particular

combinations of parents for genetical studies or as requested by the breeders.

A number of F_3 artificial *B. napus* forms were grown in the field in drilled plots, with spaced transplants of F_2s and semi-artificial forms, for observation and use in the *B. napus* breeding programmes.

Somaclonal variation

Haploid *B. napus,* produced originally by embryo rescue, is being used to initiate callus cultures. Leaf lamina and petiole segments, taken from young micropropagated plants, were used as initial explants. Callus developed readily and shoots are currently being regenerated. Shoot regeneration from older callus could not be achieved on various media tried. The advantage of using haploid tissue is that induced mutations, normally recessive and masked in diploids or higher polyploids, will be revealed in a haploid or an autodiploid derived from it. This work is directed particularly at inducing desirable biochemical mutations.

Anther culture

Some limited success was achieved with anther culture of *B. oleracea* (kale cultivars). Embryoid formation was virtually restricted to one of nine cultivars used, indicating a strong genotype effect. All the derived embryos were deformed and required transfer through several differentiating media for more normal shoot development and plantlet production. Chromosome numbers have yet to be assessed. The objective is to obtain haploid tissue for the induction of somaclonal variation aimed particularly at mutating the biochemical pathway leading to the synthesis of the toxin SMCO (causing haemolytic anaemia) which is a particular problem in *B. oleracea.*

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

Introgression studies

Methods for introgressing *B. campestris* ($2n = 20$) factors into *B. napus* ($2n = 38$) are being investigated by the Forage Brassica Breeding Department. Reciprocal F_1 hybrids of *B. napus* and *B. campestris* were backcrossed to *B. napus* as both pollen and seed parent. Cytological examination of the progeny indicated that introgression was more rapid when *B. napus* was used as the female parent in the backcross. Progeny with $2n = 36 - 38$ chromosomes were retained to investigate possible nucleus/cytoplasm interactions.

(E. M. Borrino)

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

Somaclonal variation

Somaclonal variation is being investigated in *Solanum tuberosum* with the aims of mutating skin colour to meet foreign market requirements and removing undesirable pigmentations in nematode resistant breeding material. Leaf petiole and lamina segments were induced to produce callus and regenerate shoots. Cv. Désirée was particularly amenable to the technique. Clones from the breeding programme proved either slow to regenerate shoots or completely recalcitrant. Shoots were produced from the same initial callus cultures over a period of 6 months. Other media are being tested in attempts to enhance the shoot productivity of difficult clones. So far over 250 somaclones have been passed to the Potato Breeding Department for evaluation.

Anther culture

Anther culture of *S. tuberosum* dihaploids (2n = 24) was conducted on a modest scale, with a view to producing monoploids (2n = 12) and thence homozygous lines. *S. tuberosum* is extremely heterozygous and homozygous material would be valuable for studies such as an evaluation of heterosis, gene transfer by pollen irradiation and the genetical analysis of disease resistances. A few embryoids were induced from anthers cultured on an agar based medium containing activated charcoal. Two plantlets were raised and both were shown to be diploid. *In vitro* chromosome doubling is a common phenomenon and may have occurred in this instance. If so progeny tests should reveal homozygosity.

In vitro *storage*

In vitro conservation of potato clones, using a liquid medium containing a growth retardant (Alar or B-nine at 50 mg/l), was only partially successful giving 40% survival after c. 18 months storage at low temperature (13°C) and low light (c. 200 lux). Periodic sub-culturing would seem to be necessary for the technique to be successful. For long term storage, cryopreservation of shoot-tips at −196°C in liquid nitrogen could provide the best answer. Shorter term storage, i.e. for 6–9 months, using an agar based medium containing 4% mannitol, presented no problems and is being used routinely to provide clean plant material of particular value for pathogenic studies, throughout the year.

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

Pollen irradiation

Mitotic chromosome counts were made on further M_1 and M_2 progenies from pollen irradiation experiments. Aneuploidy, detected in unirradiated

control material, makes interpretation of the cytological effects of irradiation difficult. Meiosis in plants from normal pollinations between cultivars Pentland Ivory and Cara was sometimes found to be aberrant and various sized pollen grains were produced. Since abnormal meiosis has now been found in progeny from irradiated and from unirradiated, control pollinations, interpretation of treatment effects is, again, difficult.

Ploidy levels were assessed of plants obtained from a series of interspecific crosses in which irradiated, unirradiated and mentor pollen had been used.

(E. M. Borrino)

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

Routine cytological screening of material from the diploid breeding programme was completed and agronomically improved diploids were assessed for pollen fertility and diploandroid frequency.

Ploidy levels from numerous tetraploid × diploid crosses were determined and pollen fertility estimates of tetraploid hybrids made.

Putative dihaploids, induced by the phureja technique, were confirmed as dihaploids by cytological examination. Progeny of dihaploid *tuberosum* × *phureja* (irradiated pollen) all possessed $2n = 2x = 24$ chromosomes.

(E. M. Borrino)

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

Chromosome counts of occasional phenotypic variants were obtained.

(E. M. Borrino)

MYCOLOGY AND BACTERIOLOGY DEPARTMENT

R. A. FOX

The evidence of variation in resistance to potato blackleg and soft rot continues to encourage optimism in the potential of breeding for resistance, but information on the nature of resistance is scant. The ranking order of resistance of different cultivars grown in the field is not consistent from season to season, but comparisons of genotypes must take account not only of cumulative (total) incidence but of the onset and rate of disease development as affecting yield and progeny tuber contamination. The latter is most directly affected individually during growth by very large numbers of bacterial cells from the rotting mother tuber, but of greater potential consequence is the widespread dispersal of lesser numbers on to many progeny tubers from infected plant debris at harvest, and in store from machinery contaminated by rotted tubers. Copper sprays during the growing season have again proved effective in reducing the consequences of widespread aerial dispersal of *Erwinia carotovora* pv. *atroseptica* but the site of bacterial multiplication after deposition has proved to be leaf debris rather than the growing leaves.

Electron microscopy of rotted tuber tissue treated with cationised ferritin revealed changes in the surface structure of cells of *E. carotovora* pv. *atroseptica* characteristic of those induced *in vitro* by rishitin, the first direct evidence of the activity of this phytoalexin *in planta*. The level of response of the bacterial cells varied from one individual plant cell to another suggesting that the bacteria themselves may be used as biological probes to investigate variation in phytoalexin concentration.

Oospores of *Phytophthora infestans* have been induced in single isolates of this heterothallic fungus, creating a valuable tool for genetic investigations. The care taken in keeping this in laboratory isolation has now been somewhat overtaken by the isolation of the A2 mating type from the foliage of potato plants grown commercially in Scotland, the first record of this mating type in the field in the United Kingdom that follows soon after a report of its occurrence in mainland Europe.

Comparisons of the root microflora of potato plants grown in the field from tubers and of micropropagated origin, revealed that the tuber may not only be an important source of root and tuber pathogens but also of saprophytes that interact with both tuber- and soil-borne pathogens. Co-operation from the staff of the DAFS Plant Inspectorate facilitated a large-scale survey of selected cultivars grown for seed over the whole of

the production area in Scotland. This survey, unique in its coverage, revealed that over 90% of the crops bore vesicular-arbuscular mycorrhiza and that there were no site or genotype interactions in the occurrence of this phenomenon.

Numerical analyses to provide similarity coefficients have provided valuable information on host-pathogen interactions of forage brassicas and *Plasmodiophora brassicae,* and of strawberry and *Phytophthora fragariae.* In the former there was an emphasis on furthering the invesigation on genetic control of resistance in *Brassica napus,* and in the latter to throw new light on races of *P. fragariae* and the use and mis-use of differential host genotypes of strawberry in characterising the races.

Several purportedly host-specific species of *Botrytis* were shown to be able to invade not only flowers and fruits of raspberry but canes also on which *Botrytis elliptica* proved to be as pathogenic and as freely sporulating as *Botrytis cinerea.*

After many years of painstaking investigations that led into many blind alleys, it now appears that the cause of cavity spot of carrot will be established. Species of *Pythium* were often suspected in the past of being implicated but their role could never be proved. In particular, species of this genus could never be consistently isolated from lesions nor their characteristic mycelia observed. What has now been shown, is that *Pythium* spp., especially *P. violae* initiate lesions that continue to be self-propagating after the fungus has been killed by host reaction.

PU 3(a) Develop control measures by studying the biology of fungal root diseases of barley

Snow rot on winter barley

In a field trial to examine the prospects for control of snow rot of winter barley with fungicides, in collaboration with ESCA at Purgavie Farm near Kirriemuir, ten treatments were replicated four times on cv. Igri sown in a field where snow rot was recorded in the previous year. Snow covered the trial for at least 6 weeks from early January and when the snow thawed many plants were dead. Both *Typhula incarnata* and *Fusarium nivale* were observed on dead plants and they were isolated from diseased tissue. Two seed treatments were tested and a mixture of triamimenol and fuberidazole reduced the number of rotted plants recorded on 29 February, while carboxin had no effect. Fungicides were sprayed on 16 November and by 29 February triadimenol, triadimefon and propiconazole had reduced the proportion of rotted plants and benodanil, iprodione and oxycarboxin had no effect. The beneficial effects of triadimenol plus fuberidazole seed treatment and triadimenol and triadimefon sprays remained evident in the number of plants/m^2 recorded on 15 May, and in the grain yields. The effect of propiconazole

did not persist. Although benodanil had no influence on rot recorded immediately after the snow thawed, the treated plants recovered to produce more fertile shoots and a higher grain yield than those untreated.

A second trial at the same site showed that the cultivars Igri and Sonja were more susceptible to snow rot than cv. Gerbel. Application of benodanil on 29 November enabled the susceptible cultivars to recover and produce more grain than those sprayed on 19 October or those not sprayed. The late spray of benodanil was associated with lower numbers of sclerotia on susceptible rotting plants in March compared with those sprayed early or not sprayed.

Sclerotia of *T. incarnata* produced in the laboratory were placed 5 mm deep in pots of field soil outdoors on 8 June. Sporophores were first seen on 8 October and were continuously produced until 20 November. Petri dishes containing malt yeast extract agar were inverted over the sporophores and showed that viable spores were ejected throughout the period. Basidiospore suspensions were obtained by shaking active sporophores in water containing 100 μl/l Tween 80. Basidiospores germinated on agar at 15°C but no symptoms were produced when 0.1 ml droplets were placed in the axils of the first leaves of barley seedlings incubated at 5°C.

Sclerotia were placed on the soil surface of pots in which seedlings of Igri were growing. Plants were (1) enclosed in a polythene bag, (2) compressed on to the soil surface with wet cotton wool, (3) untreated. They were all placed in a growth cabinet at 5°C air temperature and 2°C root temperature, 98% r.h. and an 8 hour day length. Sclerotia germinated after 6 weeks to form white mycelial strands and those close to seedlings produced a mass of mycelium investing the stem base. The mycelium was formed regardless of the presence of a covering but plants rotted only in the polythene bags and under cotton wool.

Surface sterilized barley seeds were sown in sterilized sand inoculated with spore suspensions of *F. nivale* and incubated at 10 and 20°C. Samples were taken on three occasions after sowing, coleoptiles measured and plated on PSA. The rate of infection was slower at the low than at the high temperature but the percentage of coleoptiles infected at 10°C was greater than at 20°C after they had grown to similar lengths. At both temperatures infection occurred at the mesocotyl soon after extrusion of the coleorhiza. Distal portions of the roots and coleoptile were rarely infected despite growing through spore-infested sand.

In vitro growth of four isolates of *T. incarnata* was completely inhibited on agar containing >1 μg/ml benodanil. Triadimenol was less effective and some growth occurred at 10 μg/ml. Growth of one of four isolates of *F. nivale* was prevented by 10 μg/ml triadimenol, while the other three grew slowly at 100 μg/ml. The isolate sensitive

to triadimenol was unaffected by 100 μg/ml benodanil, while one of the resistant isolates was completely inhibited by 50 μg/ml benodanil. The remaining two isolates were intermediate in their response. The differential responses of *F. nivale* to the fungicides indicates the presence of either a wide intrinsic variation within the population or the rapid development of resistance to the chemicals.

(D. A. Perry)

PU 4(a) Develop control measures by studying the biology of fungal diseases of brassica forage crops

Results from previous trials (*Ann. Rep. 1983,* 95) suggested that there was an interaction between host resistance and the fungicidal and phytotoxic effects of calcium cyanamide when it is used at the rate recommended for control of clubroot. The formulation of calcium cyanamide used in these trials (Perlka, SKW Trostberg, Aktiengesellschaft, Germany) contains 20% nitrogen and acts as a slow release fertilizer. The different nitrogen levels affected the expression of disease resistance when calcium cyanamide was used at different rates in the pot test.

Four swede cultivars Doon Major, Marian, Ruta Øtofte and Sator Øtofte, were inoculated with two populations of *Plasmodiophora brassicae* which showed differential pathogenicity to the cultivars at high (4,500 spores/g soil) and low (0.45 spores/g soil) inoculum levels. Calcium cyanamide was mixed with the soil 15 days before the seedlings were pricked out at 0, 0.625, 1.25 and 2.5 g/kg soil. A nitrogen fertilizer (Nitram, 34.5% N) was added to the soil mixtures so that they all received the equivalent of 0.5 g N/kg soil. No phytotoxicity was observed at the two lower rates of calcium cyanamide but mean dry weights of uninoculated plants of all cultivars were significantly reduced at the highest rate compared with those uninoculated control plants which received no calcium cyanamide. At the high inoculum concentration a significant reduction in mean disease category occurred between 1.25 and 2.5 g/kg, whereas at the low inoculum concentration an equivalent reduction occurred between 0 and 0.625 g/kg. Complete disease control was achieved at 1.25 g/kg with the lower inoculum concentration in all host parasite combinations except the very susceptible Doon Major inoculated with the more pathogenic population. At the higher inoculum concentration, disease control was only obtained in the susceptible host × parasite combinations at 2.5 g/kg, which was also phytotoxic.

These results suggest that there is a threshold level of viable propagules, or of infection sites which is necessary for successful infection and disease development. The level is higher in more resistant cultivars and for less pathogenic populations and it was increased by addition of calcium cyanamide.

(C. J. Williamson)

PU 4(b) Identify the components of pathogen virulence and host resistance in fungal diseases of brassicas

Tests of seedling disease reactions of 41 swede and forage rape cultivars inoculated with 18 populations of *Plasmodiophora brassicae* in the glass-

house were completed. Disease indices from each of the 738 combinations were included in hierarchial cluster analyses to examine the relationships between parasite populations and between cultivars. Some *P. brassicae* populations had similar arrays of disease indices and where they also had high similarity coefficients, they were combined. In this way the 18 original populations were reduced to 14 showing differential pathogenicity. A dendrogram derived from single linkage cluster analysis provided the basis for grouping cultivars into 16 groups according to their differential response to the pathogen populations. These groups will be used in further investigations of the genetic control of resistance in *Brassica napus*.

Young plants of six forage rape cultivars, Barsica, Crack, Lair, Giant Rape, Canard and Emerald, which did not show differential resistance to any of the *P. brassicae* populations in the survey, and three other cultivars, Bishop, Hobson and Winfred, were examined for other forms of resistance. The optimum environment for *P. brassicae* in a standard clubroot seedling test and the resulting rapid disease development on susceptible hosts makes small differences in susceptibility between cultivars difficult to detect. Consequently, to enhance any such differences, low concentrations of resting spores (45.5 and 4.55 spores/g soil) from seven pathogen populations were used to inoculate seedlings and a comparison was made between plants grown in standard conditions in a glasshouse and a polythene tunnel. The differential resistance of Winfred, which had been observed in the survey, was confirmed and significant differences between the other cultivars were obtained whether or not data from Winfred were included. The least severe symptoms were obtained on Canard and the ranking of cultivars with all pathogen populations was similar except for Hobson.

There was a significant interaction between cultivars and environment and between parasite populations and environment. There were also marked differences in pathogenicity between populations of *P. brassicae*. These results confirmed that the choice of an appropriate environment is important in detecting relatively small differences in resistance between cultivars. It is not yet clear if these differences are of sufficient magnitude to be worthwhile exploiting in a breeding programme.

Genetic studies on resistance to clubroot in *B. campestris* with J. R. T. Hodgkin[1] will be facilitated if isolates of *P. brassicae* with characters for differential pathogenicity can be obtained. So far, four host plants have been infected following inoculation with single resting spores but the pathogenicity of these isolates has not yet been determined.

(C. J. Williamson)

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[1]Forage Brassica Breeding Department

PU 4(c) Develop control measures by studying the biology of the chocolate spot disease

Factors affecting lesion development

Results of experiments in which a pectolytic strain of *Bacillus lentus* was inoculated on to bean leaflets together with *Botrytis fabae* were inconsistent. Sometimes lesions expanded faster than when the inoculum was *B. fabae* alone, but often the bacteria had no effect on the rate of lesion expansion. The pH of juice crushed from bean leaflets after inoculation with *B. fabae* increased from 5.0 immediately after inoculation to 8.3 6 days later, when large aggressive lesions were present. Polygalacturonase, the principle pectic enzyme produced by *B. fabae,* was found to have maximum activity at pH 5.7, while the activities of the two predominant pectic enzymes produced by *B. lentus,* polygalacturonic acid trans-eliminase and pectin methyl trans-eliminase, were greatest at pH 9.0 and 9.2 respectively with little activity below pH 6.0. Populations of *B. lentus* in non-aggressive, limited chocolate spot lesions reached a peak of 3.2×10^8 per g fresh weight of leaf tissue 1 day after they had been inoculated on to bean leaflets. Two days later the population had fallen to 1.8% of this value.

The importance of the timing of contamination of lesions by pectolytic bacteria and the relevance of pH changes to pectic enzyme activities during lesion development are now being studied.

(J. G. Harrison)

Factors affecting sporulation of Botrytis fabae

The production of conidia by actively-growing hyphae of *B. fabae* on agar at a constant 18°C was stimulated by irradiation with light from fluorescent lamps for 12 h per day. One 12 h exposure was only half as effective as three.

There was no further stimulation when the light was supplemented with near-u.v. irradiation. However, when kept at 4°C for 12 h per day irradiated hyphae produced 68% more spores than those kept continuously at 18°C. Conidia were nearly absent from mycelium grown in continuous darkness irrespective of temperature. Irradiation of mature hyphae, 4–5 days old, did not induce sporulation. Hyphae which grew in continuous darkness from previously irradiated and sporulating mycelium did not produce conidia.

B. fabae sporulated well when grown in liquids with an initial pH 3.0–9.0, although the pH, especially of the more alkaline media, often decreased as the fungus grew. It also grew well, but did not sporulate, in liquid initially of pH 2.2 which, after 14 days growth, had risen to pH 2.6. No growth was observed at pH 10.0.

(J. G. Harrison)

PU 9(c) Study the biology and assess the effects of fungal and bacterial diseases of the growing potato plant

Blackleg etiology: field studies

The susceptibility of 20 potato cultivars to blackleg in the field following seed inoculation was determined as previously described (*Ann. Rep. 1982,* 128; *1983,* 99). Overhead irrigation was applied weekly from July to early September because of continuous dry weather. The average blanking was 6.4% and mean blackleg incidences were 3.8% in late June, 26.0% in late August and 41.0% in September. Plants grown from inoculated seed yielded 28.2% less than those from non-inoculated seed in which disease level was <1%. Although the relative susceptibility of most of the cultivars was the same as in previous years, there were some exceptions, namely King Edward, Maris Piper and Pentland Squire were classed as 'intermediate' instead of 'resistant.' Of four recently released cultivars, Rhona was the most resistant, Kingston and Provost were intermediate and Moira, the most susceptible, also suffered from a high incidence of blanking (33.5%). Classification into resistance categories should be done with caution, because susceptibility to blackleg appears to vary throughout the season. For example, Bintje developed 31.3% blackleg in July and 72.3% in September while the corresponding figures for Estima were 1.0 and 60.3% respectively.

Tubers of Maris Bard and Désirée were inoculated with c. 10^4 cells per tuber of *Erwinia carotovora* pv. *carotovora* (Ecc) of *E. carotovora* pv. *atroseptica* (Eca) by vacuum infiltration and planted in the field. Because the plants were not irrigated blackleg incidence was low and senescence was premature. Mother tubers rotted earlier after inoculation with Eca than with Ecc and by mid July half of them rotted and by August they were all rotten. Irrespective of the size of the rot more than 10^6 cells/g fresh weight rotten tissue of erwinia were present. Prior to mid July the pathovars detected were the same as those inoculated to the tubers but, later, both were found in tubers inoculated with Eca, possibly because high soil temperatures in late July encouraged growth of Ecc contaminants on the seed. Erwinias were detected in the vascular tissue of the basal portion of healthy stems only when the mother tuber was extensively rotted or when rotting reached the vascular tissue of the mother tuber. The numbers of bacteria present in suspensions of blended stem segments in water were $<10^2$/cm in early July, $<10^3$/cm in late July, early August, and was barely detectable in late August. Eca was always present in greater numbers than Ecc even when they both occurred in rotting mother tubers. Only Eca was found in stems attached to rotting mother tubers in which Eca predominated. A similar contamination pattern was found in healthy stems taken from plants with one blackleg affected stem.

Tubers were contaminated with erwinias during mechanical harvesting from rotting mother tubers, tubers with stolon end rot from blackleg

plants and decaying leaf debris. Tubers harvested in early October with a single row harvester and hand picked were more contaminated than those which were lifted by fork. The increase was larger and Eca was the more common contaminating erwinia in plots with blackleg than in those without.

(M. C. M. Pérombelon, L. J. Hyman)

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

The contamination pattern of progeny potato tubers of potato plants by different antibiotic marker strains of Ecc and Eca during the growing season was examined as previously described (*Ann. Rep. 1982,* 128; *1983,* 101).

In 1984, leaves sprayed with 10 cells of Ecc or Eca/ml remained contaminated throughout the season and the bacteria spread to non-inoculated leaves in late September when wild type erwinias were also detected. The numbers were always low and an enrichment procedure was needed to detect them. Marker strains in inoculated buried tubers did not at any time spread to the leaves. Leaf debris taken from the soil surface was not detectably contaminated by the sprayed marker strains until September when 10^3 cells/g fresh weight leaf were found and wild-type erwinias were also present.

Contamination of rhizosphere soil by leaf and tuber marker strains followed the same pattern as with leaves and leaf debris. Progeny tubers in plots with placement tubers became contaminated with the marker strains in early September. As found previously, progeny tubers in all plots including those whose leaves were not inoculated, were contaminated by leaf marker strains in September. Wild-type erwinias were found on progeny tubers in early August in all plots. Although Ecc and Eca marker strains were present in equal numbers on the mother tubers only Ecc tended to survive to contaminate progeny tubers.

Wild-type erwinias which were predominantly Ecc were probably air-borne into the crop.

Analysis of these results in terms of rainfall distribution and soil moisture level during the growing season suggests that progeny tuber contamination occurred where conditions favoured (1) multiplication of the bacteria in the mother tuber and in the leaf debris, (2) spread of the bacteria into the soil.

Twice weekly 250 ml of copper oxychloride (Cuprokylt; Universal Crop Protection Ltd.; 5.0 g/l) was applied by tractor mounted sprayer to field plots each of 144 micropropagated plants of cv. Désirée commencing on 1 June or 15 July. Contamination of leaves, rhizosphere soil and progeny tubers was determined at weekly intervals during the growing season. Erwinias were not detected on leaves until September when the haulm of an adjacent potato crop was pulverised but only low

numbers were detected irrespective of the spray regime. High numbers of erwinia were found in leaf debris of unsprayed treated plots in early September but never from the spray treated plots. Similar results were obtained from rhizosphere soil. Contamination of progeny tubers was low until the end of September and thereafter erwinias were found in all tubers from unsprayed plots but from <12% in the sprayed plots. Ecc was the dominant erwinia in all situations. In a similar experiment, copper oxychloride was sprayed onto plants grown from seed tubers inoculated with mixtures of streptomycin-resistant Ecc and rifampicin-resistant Eca. Progeny tubers were contaminated, more by Ecc than by Eca marker strain, irrespective of the spraying treatment.

Although soil taken at progeny tuber depth from the sprayed plots contained up to 50 μg EDTA extractable copper/g soil, which is twice the concentration in unsprayed plots, both Ecc and Eca survived *in vitro* in soil with the highest copper concentration. Growth of both erwinias was not affected by 100 μg $CuSO_4$/ml in nutrient agar but was completely inhibited at this concentration in a soil extract plus mineral salts agar medium. The results support the hypothesis that leaf debris rather than leaves on the plant is an important source of erwinias and that control of tuber contamination in sprayed plots resulted from the bacteriocidal effect of copper in leaf debris and not in the soil.

(J. G. Elphinstone[1], M. C. M. Pérombelon)

A comparative study of blackleg epidemiology in Scotland and in Israel

Field experiments were carried out as described previously (*Ann. Rep. 1982,* 130; *1983,* 100) in Scotland and in the spring- and Autum-planted growing seasons in Israel. In one experiment the seed of the cultivars Désirée and Pentland Crown with low levels of erwinia contamination were inoculated with Ecc, Eca and Echr alone and in different combinations, and planted in February and April in Israel and in Scotland respectively except for seed inoculated with Echr which was not grown in Scotland. More blanking, caused by seed decay, occurred in all treatments in Israel than in Scotland. Blackleg (the name used to describe the stem symptoms regardless of the causal organism) incidence was similar in both Israel and Scotland (6.2 and 5.7%) and was higher in Pentland Crown than in Désirée in both countries. In Israel Echr alone caused three times more blackleg than Eca whereas none was caused by Ecc. Disease incidence in plots planted with seed inoculated with different combinations of the bacteria was lower than when only one erwinia (Eca or Echr) was present. In Scotland, blackleg was caused only by Eca and it developed throughout the growing season whereas in Israel it occurred rarely after April when the mean maximum air and soil temperatures were >25°C. In contrast, Echr in Israel caused blackleg late in the growing season when temperatures were >30°C. Symptoms caused by

[1] Research Student

Echr in the dry and hot conditions in May – June were characterised by the plant wilting followed by a progressive desiccation of the leaf from the margin inwards eventually affecting the whole stem. Although the symptoms were similar to those caused by Eca under hot conditions, Echr did not cause any internal or external stem rot below ground level.

Isolations made from diseased stems from plants grown from inoculated seed and from commercial fields in Scotland showed that although blackleg was caused by Eca, Ecc was also present in some stems, particularly during the later part of the growing season. In Israel Eca was the most common organism isolated from plants grown from Scottish seed, especially during the early part of the spring season, while Ecc and Echr were obtained from commercial crops planted with Dutch and locally produced seed. A high proportion of stems contained more than one erwinia and Ecc was rarely found alone.

Both blanking and blackleg levels were lower in the autumn than in the spring-planted crops in Israel. Blackleg was usually caused by Echr in the first 4 weeks of the growing season when temperatures were >25°C but Eca-blackleg predominated at lower temperatures during the winter months.

The disease resistance ranking of five cultivars grown from tubers inoculated with Eca was similar in the spring season in Israel and in Scotland although blackleg incidence was 30% lower in Israel than in Scotland. The relatively lower disease incidence in Israel may be due to temperatures >25°C occurring earlier than average in the growing season which inhibited Eca-caused blackleg development, and partly by the fact that irrigation of the crops in Scotland maintained a high soil moisture content hence increasing disease incidence to a level higher than it would have been otherwise.

Blackleg incidence was proportional to the number of Eca cells with which seed tubers of the cultivars Maris Bard and Désirée were inoculated in Scotland and Israel as found previously (*Ann. Rep. 1983,* 100). More blackleg developed in Maris Bard than in Désirée plants and the difference was greater at the higher (10^5 and 10^7 cells/tuber) than at the lower (10^1 and 10^3 cells/tuber) inoculum levels. A lower inoculum concentration was required in Israel to cause the same disease incidence in both cultivars as in Scotland.

(V. M. Lumb[1], M. C. M. Pérombelon)

Diseases caused by Erwinia carotovora *in potato crops grown in Spain from imported Scottish seed*

Crops grown from seed imported from Scotland have repeatedly failed in mainland Spain (Valencia) because of emergence failure. Seed tubers of VTSC grade with low levels of erwinia contamination of the cultivars Pentland Squire and Spunta, reputedly susceptible and resistant respect-

[1]Research Student

ively to blanking in Spain, were vacuum inoculated with different concentrations of Ecc and Eca and planted in Valencia in mid-January and the crop harvested in May. Seed tubers were cut into two or three pieces 24 h before planting and the field was surface irrigated three times before emergence and subsequently at about fortnightly intervals. Blanking was not as prevalent as in previous years in commercial crops grown from Scottish seed tubers possibly because soil temperatures during emergence in early March were >5°C below average. More blanking and blackleg developed in Spunta than Pentland Squire and when the seed tubers were inoculated with 10^4 cells/tuber than with 10^2 cells/tuber of Eca. Ecc caused occasional blanking but no blackleg in either cultivar. Blanking was caused by a soft rot of the seed pieces in which large numbers of Eca were usually present. In contrast, Ecc predominated in seed pieces which rotted later when soil temperatures were higher.

The susceptibility of 16 cultivars to blanking and blackleg was assessed in an experiment in which seed tubers were inoculated with c. 10^4 each of Ecc and Eca to overcome the different background contamination levels and cut pieces were planted in the field as described above. The cultivars Royal Kidney, Ailsa, Rhona, Kondor and Pentland Dell were classed as resistant with <10% blanking, cultivars Etoile du Leon, Kennebec, Marfona, Maris Bard, Spunta, Pentland Squire and Kirsty were intermediate with 10–25% blanking and Kingston, Morene, Moira and Estima were susceptible with >25% blanking. Blackleg was <3% in most cultivars except in Moira and Maris Bard where it was 10.9 and 14.6% respectively at harvest time.

(M. C. M. Pérombelon, J. Carbonell[1], M. Milagros Lopez[2])

Investigate effects of the environment on potato foliage blight

Detached terminal leaflets of a similar age of cv. Bintje were inoculated with single 0.02 ml droplets of water containing a mixture of sporangia and zoospores of *Phytophthora infestans* prepared by chilling an aqueous suspension of 3×10^4 sporangia/ml for 2h at 5°C. Spores were derived from cultures grown on rye agar for 5–8 days at 17°C. Six leaflets with their petioles in water, were kept in a sealed Perspex chamber immersed in a temperature-controlled water bath and through which compressed air was passed. Before entering the chamber the air was saturated by bubbling it through water in flasks, immersed either in the same water bath as the leaf chamber, or in a separate bath in order to control its humidity before entering the leaf chamber. Two independent chamber-bubbling flask systems were usually used simultaneously. The humidity of air entering and leaving the leaf chambers was measured periodically with an electronic dewpoint hygrometer and water bath temperatures

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checked with an NPL-certified mercury-in-glass thermometer. The r.h. was kept at 100% for 48h after inoculation to allow infection to occur, and leaflets were kept in darkness.

In saturated air at 17°C small brown necrotic flecks often, but not invariably, appeared under the inoculum droplet with 1–2 days. An expanding zone of dark green, apparently water-soaked tissue then developed around the initial infection site and became covered with sporulating aerial mycelium 3–4 days after inoculation. Uninfected surrounding tissue often turned yellow-green, as it did around sterile droplets on control leaflets. Exposure to near u.v. irradiation from a lamp (LCF–610G, A. Gallenkamp & Co. Ltd.) 150 mm above the leaflets for 12 h/day together with normal laboratory lighting had no apparent effect.

Under similar conditions but at a constant 7°C, or when the temperature was 17°C for 12 h and 7°C for 12 h per day, the pattern of lesion development was similar but slower than at a constant 17°C, with aerial mycelium not appearing until 6–7 days after inoculation. When infected leaflets were kept either in saturated air for 12 h only and at 52% r.h. for 12 h per day at 17°C, or at a constant 52% r.h. and 17°C for 12 h per day, an expanding zone of collapsed, crumpled, dry green tissue surrounded the inoculation site. Aerial hyphae were either absent or sparse and few sporangia developed. Uninfected tissue became chlorotic.

In another experiment leaflets were kept in saturated air at 17°C for only 24 h after inoculation before the r.h. was reduced to 95%. After a further 6 days a few sporangia had developed on the upper surface of the laminae of only three leaflets. Sporangia were abundant on the lower surface of all six leaflets where the proximity of a Perspex plate may have impeded the air flow allowing transpired water vapour to increase the humidity.

(J. G. Harrison, R. Lowe)

Incidence of selected fungi on roots of potato grown from commercial seed

The frequency of occurrence and survival of certain root and tuber pathogens has been investigated by planting as baits axenically micro-propagated plantlets of cv. Maris Piper in sites cropped with potato for differing numbers of years (*Ann. Rep. 1983,* 103). This work is continuing at a new site to be cropped in various rotational patterns for up to 6 years. In 1983, it was examined for local soil variation by planting a test crop of cv. Record, known to be sensitive to moisture stress and to exhibit readily symptoms of drought-induced potash deficiency. By September there was much variation in haulm senescence and sites with similar levels were identified, marked and then used in 1984.

To enhance or introduce into the soil populations of potential pathogens, the site was planted with a stock of FS1 Maris Piper that, despite its

certification grade, was evidently heavily contaminated. Its roots were sampled (*Ann. Rep. 1982,* 108) on 30 July and 10 September. The incidence of the ubiquitous root coloniser *Cylindrocarpon destructans* rose from 36 to 68% between the two sampling dates and there were increases also in the much lower numbers of isolations of *Colletotrichum coccodes* (black dot, and a contributor to the 'early dying' syndrome), *Rhizoctonia solani* (stem canker and black scurf), *Polyscytalum pustulans* (skin spot) and a *Fusarium* sp. (probably *F. solani*). Other *Fusarium* spp. detected were *F. culmorum, F. nivale* and *F. oxysporum.* The numbers of *Verticillium* spp. were unusually low and included *V. dahliae, V. nubilum* and *V. tricorpus.* The dominant '*tricorpus*-like' form (*Ann. Rep. 1983,* 108) has now been identified, by courtesy of the Centraalbureau voor Schimmelcultures, Barn, The Netherlands, as, *V. tricorpus* lacking micro sclerotia.

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

The contribution of tuber-borne inoculum to the incidence of selected fungi on potato roots

Plants of cv. Maris Piper were grown in replicated split plots in a field where potato had not been grown for 16 years. One half of a plot was planted with FS1 grade seed and when it had emerged the other half was planted with micropropagated plants initially raised in a glasshouse. Root samples were taken at 10 day intervals from 24 July to 24 September, surface sterilized and plated on low-nutrient agar containing antibiotics (*Ann. Rep. 1983,* 108).

The results were again affected (*Ann. Rep. 1983,* 104) by lignicolous and cellulolytic fungi, mostly species of *Chaetomium* and *Trichoderma,* that were rare on the roots of tuber-grown plants but were stimulated to grow profusely on the roots of micropropagated plants by the peat in the Jiffy pots used for their initial growth. Nevertheless some clear differences were detected that demonstrated the role of the seed tuber as a pathogen source. The skin spot fungus, *P. pustulans,* was never detected on c. 3,500 root pieces from the micropropagated plants. It was consistently present on roots of the plants grown from tubers but at much lower levels than on roots of the same cultivar of plants grown from the heavily contaminated seed referred to in the previous section. There were similar comparisons in the incidences of *R. solani.* Among the micropropagated plants it was found on only one piece of root taken at the last sampling date; it was not common on the roots of the tuber-grown plants although, again, it occurred commonly on those of the heavily contaminated seed.

The incidences of *C. coccodes* and *V. tricorpus* rose to 10% at the last sampling date on the roots of tuber-grown plants but their frequency was never more than 1% on those of the former axenic plants in which *V. nubilum,* very rare on tuber-grown plants, was never found. In contrast, *V. dahliae* was more common on the roots of the former axenic plants

indicating a competitive pathogenic advantage attributable to the lack of other pathogens, that it survives in the soil as microsclerotia, and that it has other weed and crop hosts.

The two most common species were *C. destructans* and *Microdochium bolleyi* that occurred equally freely on all roots their numbers rising three- to four-fold as the season progressed. There was little difference in the occurrence of soil-borne forms such as *Phoma exigua* var *exigua, Phoma eupyrena* and *Fusarium* spp.

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

The occurrence of vesicular-arbuscular mycorrhiza and Verticillium spp. *on potato crops entered for FS grade seed in Scotland*

Five well established cultivars, Désirée, Maris Piper, Pentland Crown, Pentland Squire and Record together accounted for two-thirds of the acreage entered for maincrop FS grade in Scotland for 1984. Their registration dates (1932 – 1970) span nearly 40 years, they were variously bred in Scotland, England and the Netherlands and their parentage includes five *Solanum* species—*andigena, chiloense, demissum, phureja and tuberosum*—most common in the lineage of commercial cultivars. Through the co-operation of the DAFS, c. 350 root samples were obtained from sites all over the seed growing areas in Scotland.

The time in transit of samples necessarily varied from 2 days up to more than 2 weeks (samples from the Orkney Islands). On receipt samples were cold stored and, as soon as possible, sub-samples were processed through a fixative and staining schedule to reveal vesicular-arbuscular mycorrhiza (VAM). Plating sub-samples to detect *Verticillium* spp. (>5,000 root pieces) was necessarily protracted and the combined delays resulted in many samples being overgrown by fast growing fungi such as *R. solani* and *F. culorum*. These and other fungi largely overgrew and/or suppressed the growth of *Verticillium* spp. Most of the isolates could be assigned to *V. tricorpus* and there was no evidence of host genotype selection. The overgrowth only infrequently obscured the VAM and these were detected on c. 95% of the root systems examined. There was, therefore, no evidence of host genotype/VAM interaction nor of site effects and it is safe to extrapolate and conclude that 95% of potato crops in Scotland will have VAM. No such survey has ever been done before and the information is not only unique but important because of the known role of VAM in P uptake, mitigating water stress and interacting, usually beneficially, with root pathogens and pests.

(R. A. Fox, E. P. Dashwood, H. M. Wilson, T. H. Nicolson[1], D. Spencer[1])

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[1]Department of Biological Sciences, University of Dundee.

PU 9(d) Study the biology and assess losses due to fungal and bacterial diseases of stored potato tubers

Contamination of seed stocks by Erwinia carotovora

The annual survey of VTSC stocks in the process of multiplication was continued at the same three commercial farms examined previously (*Ann. Rep. 1978,* 83) using qualitative and quantitative tests to determine tuber contamination after harvest but before grading. Contamination was not detected in the first two multiplication years and it varied in subsequent years from farm to farm; on one farm, tubers were not contaminated even after multiplication for a further 3 years; on another, 50% of the tubers were contaminated in the third year rising to 100% in later years and on the third, 100% tubers were contaminated in the third and subsequent years. However, the mean number of erwinias were $<10^2$/tuber on all contaminated stocks and Ecc predominated during the first three multiplication years but in subsequent years >70% of them were Eca.

Sixteen stocks of different grades (FS1 – 3 and AA1) from 14 farms were contaminated after the stocks had been graded and the level of contamination was not related to the quality of the seed grade. Populations of $>10^3$ cells/tuber of Ecc and of Eca were found in eight and four stocks respectively.

(M. C. M. Pérombelon, L. J. Hyman)

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

The effects of natural plant products on recognition sites on pathogens

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

The potato phytoalexin rishitin modifies the cell walls of *E. carotovora* pv. *atroseptica* (Eca) *in vitro* in several ways (*Ann. Rep. 1983,* 110). These included the removal of an outer layer, the formation of negative charges on the outer surface, and the exposure of new binding sites for avidin and lectins. Thus it was shown that rishitin-damaged cells of Eca had a characteristic surface structure.

Rotted tissue from inoculated potato tubers stored at 16°C under aerobic conditions was therefore examined by electron microscopy to investigate the surface structure of the bacteria to determine whether they had the same characteristics thus providing evidence on the activity of the rishitin *in planta.* Using the cationised ferritin as a cytochemical probe it was shown that some, but not all of the bacteria had a surface structure characteristic of that shown for rishitin-damaged cells *in vitro* thus providing the first direct evidence that the rishitin was capable of affecting the bacteria within the plant. In general, bacteria within a single plant cell tended to be either not affected or affected to a similar extent

suggesting that rishitin had reached a toxic concentration within that cell. In other areas of the rot few of the bacteria were affected by rishitin. Thus the bacterial cell can be used as a cytochemical probe to demonstrate the presence or absence of certain concentrations of phytoalexin within individual plant cells.

The fact that not all of the bacteria were affected by the rishitin is in accordance with the rotting propensity of the Eca under these conditions because, although some degree of resistance against rotting is being shown by the potato tuber, the rot continues to expand slowly, showing that not all the bacteria can be contained.

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

Phytoalexin elicitors

The investigation of the phytoalexin elicitor activity of polygalacturonic acid lyase in culture filtrates of *E. carotovora* pv. *carotovora* (Ecc) has continued.

Ecc elicits the accumulation of phytoalexins in potato tubers and soybean plants. A purified preparation of an extracellular pectic enzyme, polygalacturonic acid lyase (PG lyase), elicits phytoalexin accumulation in soybean cotyledons. It is believed that this pectic enzyme liberates a fragment of the plant cell wall which acts as an endogenous phytoalexin elecitor.

Previous experiments, using a number of isolates of Ecc which differ in their ability to produce pectic enzymes *in vitro,* have failed to show a simple correlation between phytoalexin elicitor activity of dialysed culture filtrates and PG lyase concentration. There may be an unknown interaction between phytoalexin elicitor activity of the PG lyase and other pectic enzymes, such as endopolygalacturonase or pectin lyase, or high molecular weight compounds in the culture filtrates. Other workers have shown that an endogenous phytoalexin elicitor (dodeca-a-1,4-D-galacturonide) isolated from soybean plant cell walls (and also from pectin) is degraded by endo-a-1,4-polygalacturonase or pectin lyase. Thus it is possible that the phytoalexin elicitor activity of culture filtrates from *Erwinia* spp. (and in turn, of the bacterial cells themselves) is an interaction of the PG lyase releasing the endogenous elicitor whilst endo-polygalacturonases or pectin lyases may be simultaneously degrading it.

(G. D. Lyon)

The relationship between tuber calcium level and resistance to Erwinia carotovora

The relationship between tuber calcium content and resistance to rotting by *Erwinia carotovora* pv. *atroseptica* (Eca) was examined in 31 cultivars grown at one site, harvested in late September and stored at 5°C. Tubers were point-inoculated 8 mm deep with 0.02 ml of six dilutions of an Eca

[1]Zoology Department.

suspension (10^3 to 10^8 cells/site) and incubated at 22°C in 10% O_2 + 90% N_2. After 5 days cultivar susceptibility was expressed by probit transformation as the number of bacteria causing rot at 50% of the sites. Calcium content of tubers was assessed by removing medullary tissue c. 8 mm from the surface of non-inoculated tubers. After 24 h at 105°C, the tissue was milled and Ca determined by atomic absorption spectrophotometry at MISR. In contrast to results obtained in 1982 (Ann. Rep. 1982, 112), Ca concentrations were not correlated with tuber rotting.

In a second experiment three diferent inoculation methods were used; (1) tubers of four cultivars were inoculated at a depth of 3 mm with 9×10^7 Eca cells/site and incubated at 22°C in 2% O_2 + 98% N_2 and the size of the rotting lesion was determined after 5 days, (2) tubers were vacuum infiltrated in a suspension containing 10^5 Eca cells/ml dried overnight at c. 15°C and incubated in water at 22°C for 5 days after which the extent of rotting was obtained by weight, (3) the infectivity-titration method described above was used except that tubers were inoculated 3 mm deep and Ca contents of the periderm, the first 2 mm and the next 2 mm of the cortex, were determined. The rank order of cultivars for resistance to rotting varied with the method of inoculation and the order for Ca content depended on the depth of tissue sampled. Therefore, the relationship between resistance and Ca content depended on the methods used; for example the order, using the vacuum infiltration method, was similar to that of the Ca concentration of the periderm plus the first 2 mm of cortex but not of other Ca concentrations. The Ca content of tubers was highest in the periderm of all cultivars and decreased with depth.

Plants of cv. Croft were grown in field plots to which different amounts of $CaSO_4$ (gypsum) was applied. Tubers were harvested in late September and their relative resistance to rotting determined by the vaccuum infiltration method. An increase in Ca content from 2850 to 5450 ppm resulted in a 30% decrease in susceptibility.

Tubers, cv. Majestic, grown in plots adjusted with lime to a range of pH values from 4.5 – 7.5 at Craibstone Farm (NSCA) were examined for their resistance to rotting by the point-inoculation method described above and their Ca content determined. The Ca content of the periderm but not of the cortex increased linearly with increasing soil pH. However, the extent of rotting was not linearly related to soil pH.

Tubers of the cultivars Pentland Crown and Bintje were vacuum infiltrated in different concentrations of $Ca(NO_3)_2$ solutions or with water and the resistance of the tubers to rotting after 3 days at 15°C was determined. Results showed that the treatment decreased tuber susceptibility by half and a third respectively with Pentland Crown and Bintje tubers infiltrated with a 1% solution.

(R. A. Bain[1], M. C. M. Pérombelon)

[1]Research Assistant

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

A rapid method to identify soft rot erwinias

A method was developed to identify and quantify soft rot erwinias to species or pathovar level without prior isolation and purification of the bacteria, based on the different temperature tolerances and sensitivities of the bacteria to erythromycin.

Sub-cultures from individual colonies were spot inoculated on to plates of crystal violet pectate (CVP) medium, with or without 35 μg/ml erythromycin, incubated at 27, 33.5 and 37°C and identified according to the pattern of growth and cavity formation. Erwinias in mixed populations can be quantified by dilution plating on the media and incubating at different temperatures. Spot-inoculated plates were incubated for 24 h, dilution plates for 48 h. Eca formed the characteristic cavities at 27°C but not at higher temperatures on CVP +/− erythromycin; Ecc grew at 27 and 33.5°C on CVP +/− erythromycin but not at 37°C; and Echr grew at all temperatures on CVP and could also be identified by failure to grow at 33.5°C on CVP + erythromycin.

Of 50 Eca, 90 Ecc and 43 Echr strains from the SCRI culture collection from different sources and climatic regions 80% were correctly identified using this method. The precision increased to >95% when recent Ecc and Eca potato isolates previously identified using convential differential physiological tests were examined.

(M. C. M. Pérombelon, L. J. Hyman)

Genetics of Erwinia carotovora: *cloning of chromosomal DNA*

A transposon mutagenesis system has benn developed for Ecc strain SCRI 193 using the suicide vector pJB4JI, and several Tn5 insertion mutants were isolated and characterised (including *arg*::Tn5, *trp*::Tn5, *lac*::Tn5, *fru*::Tn5). Mutant 15.29, is a cysteine-requiring, pectate lyase-negative, cellulase-negative, protease-negative phenotype which was non-pathogenic to tuber slices, possibly because extracellular enzymes are essential for maceration of host tissue. Reversion analysis proved that this pleitropic phenotype was the result of a single Tn5 insertion. The Tn5 element and flanking sequences of DNA from 15.29 were cloned into plasmid pBR322 by direct selection from a gene library made from 15.29 chromosomal DNA. Following transformation and selection in SCRI 193 (*Ann. Rep. 1983,* 114), this clone, pJH1, was used to construct a Tn5-free derivative designated pJH3 by selecting for precise excision of the transposon from its point of insertion. pJH3 carried a 12Kb chromsomal DNA insert containing one or more active wild-type genes which complement the mutant phenotypes of 15.29 described above. The gene library of 15.29 was also used to clone other genes, including

the structural gene/s for pectate lyase and cellulase and the clones can now be analysed as with pJH3.

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

Oospore production by Phytophthora infestans

Some isolates of *P. infestans* behaved as though they were homothallic producing oospores when a membrane pairing technique was used without an A2 inducer isolate (*Ann. Rep. 1983,* 115). The numbers of oospores varied greatly and some isolates produced up to several hundred/cm^2 of culture. Many oogonia contained intact oospores and when these were plated on 1% distilled water agar some germinated but, as yet, no cultures have been established from them.

Single-zoospore cultures of oospore-forming isolates also produced oospores on membranes but, apart from an isolate from tomato, neither the original isolates nor their single zoospore derivatives produced oospores in agar plates without membranes. They did not produce oospores when mated conventionally with an A1 isolate of *P. nicotianae* but did form them with an A2 isolate of the same species thereby demonstrating that they were of A1 mating type. The tomato isolate formed a few oogonia and oospores in single culture but it formed many oogonia, apparently without antheridia, and oospores when mated with the A1 *P. nicotianae*, but none in matings with the A2 *P. Nicotianae* suggesting that it may be of A2 mating type.

The numbers of apparently viable oospores produced in single cultures with the membrane technique were increased by addition of β-sitosterol and lecithin the effect being greater with lecithin from soya bean than lecithin from eggs.

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

When isolate of *P. infestans* were paired in culture with an isolate of *P. drechsleri* of A2 compatibility type, oospores formed in abundance in areas where colonies of the two species met. This indicated, as expected, the A1 compatibility type constitution of the *P. infestans*. Some pairings did not yield oospores and three of the isolates also did not produce oospores when selfed, but they did so in abundance when paired with isolates of *P. infestans* identified as the A2 compatibility type. Thus, it was revealed that the three isolates of *P. infestans* which did not form oospores with *P. drechsleri* were of A2 compatibility type.

(J. F. Malcolmson)

Maintenance of Phytophthora infestans *culture collection and cryogenic storage*

Isolates of complex races have been received but it has been difficult to assess their virulence because of their low agressiveness. None has proved

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to be virulent on all the differential hosts. Five single-zoospore cultures from each isolate and from others collected locally, were established and tested for virulence, sporulation, mating type and their ability to produce selfed-fertilised oospores, and two of the five were selected for cryogenic storage. Single zoospore isolates from a given culture often varied greatly in their aggressiveness to the differential host series, but the patterns of virulence were similar for each set of zoospore isolates.

Various combinations of cooling rate, cryoprotectants and thawing techniques have been tested in attempts to improve recovery of *P. infestans* from agar discs in cryogenic storage. Recovery was best with slow cooling, rapid thawing and 10% glycerol as the cryoprotectant and from isolates that grew vigourously and sporulated well. However, the recovery rates from agar cultures were usually only 30–40%, much lower than from pieces of infected micropropagated plants.

(J. M. Duncan)

Virulence testing of Phytophthora infestans

Progress has been made in confirming the purity of stocks of the R gene differentials for identifying races of *P. infestans.* Also, families raised from true seed derived from the original R-9 differential, 2573(2), have been screened for R-genes and are undergoing selection to establish a replacement for the R-9 differential which has not been available for several years.

Nine samples of *P. infestans,* maintained on leaves for several months following collection in the field, were transferred to leaflets of the differential hosts for race identification. Leaflets of the differential hosts were inoculated at the same time with sporangia from cultures secured from the same nine samples, either by direct isolation onto pea agar, or onto selective medium containing rifamycin before maintenance on pea agar. Reaction on the leaflets of the differential hosts was the same with each sample irrespective of the inoculum source, indicating that neither the selective medium nor maintaining isolates on pea agar had affected race identity.

The differential host clone possessing gene R-10 can react in a susceptible or hypersensitive manner to the same isolate of *P. infestans* and it may often develop intermediate type lesions with restricted necrosis and little or no sporulation. Tests revealed that with compatible isolates of the fungus, lesion expression was determined by the age of the host; with incompatible isolates of *P. infestans* the expected hypersensitivity is always expressed.

(J. F. Malcolmson)

Virulence testing and bacteria

Hypersensitive reactions and, less frequently, compatible reactions in leaflet virulence tests were sometimes made ambiguous by browning and

clearing of the leaflet tissue which apparently was not always due to invasion by *P. infestans*. Bacteria were isolated from the tissue by shaking it in nutrient broth and then streaking the broth over nutrient agar. A wide range of bacteria were present as judged by colony morphology and by multidisc antibiotic testing.

To test the effect of antibiotics on leaf clearing, whole leaves of a number of R-gene differential genotypes in which the phenomenon had been observed previously, were removed from plants and their petioles were placed in dishes containing solutions of various antibiotics at 100 μg/ml active ingredient. The leaves were held for 2 days in a growth cabinet (20°C, continuous light 300 u mol, 90% v.h.) to promote uptake of the antibiotics in the transpiration stream, and then inoculated with droplets of a sporangial suspension of *P. infestans*. Leaves freshly detached from the original plants were inoculated at the same time. Some of the antibiotics affected infection and lesion development, in particular streptomycin restricted the spread of lesions, but the largest differences were between the freshly detached leaves and the leaves that had been cut and put in distilled water for 2 days; fewer lesions developed on the latter and those that did develop were restricted in size and fungal sporulation was reduced.

(J. M. Duncan, J. G. Harrison)

Electron microscope studies of the potato plant and Phytophthora infestans

Further SEM studies (using the Cambridge S180 scanning electron microscope) at the MRC Clinical and Population Cytogenetics Unit, Edinburgh, confirmed that in leaves of normally susceptible potato cultivars, the hyphae of *P. infestans* are intercellular. Cytoplasmic disintegration progresses in the host cells from the area adjacent to the hyphae and in the more susceptible clones the cells rapidly empty. In the resistant clones studies, the fungus was observed within the cells either as haustoria or as normal, intracellular hyphae. In the former, the host cells were emptied but in the latter it was noteworthy that the cells were not emptied, so that the hyphae were embedded in the host cytoplasm.

(J. F. Malcolmson)

Clostridia on potato in the field

Populations of pectolytic clostridia in the surrounding soil, the rhizosphere and the tubersphere of the mother and daughter tubers of cv. Maris Piper were monitored throughout the 1984 growing season in the field as described previously (*Ann. Rep. 1983,* 129). Populations in the soil averaged 1.6×10^4 colony forming unit (cfu)/g soil while those in the rhizospheres were 1.4×10^4/g. The maximum R:S ratio was 1.5 on 13 July and in two samples in June they were <1.0. Similar low ratios were recorded for the tuberspheres of both mother and daughter tubers. The contrast with the previous year when higher populations were found both

in the rhizospheres and tuberspheres, particularly in August, was probably due to the exceptionally dry conditions in the field.

Clostridia on stored potato

Samples of five medium sized tubers of cv. Maris Piper from the field were placed in polyethylene bags. A wad of wet cotton wool sufficient to keep the tuber surfaces moist was added to half of the number of bags to form a wet tuber treatment, while the remainder contained dry tubers. All the bags were sealed and stored continuously at 10°C in the dark. Populations of pectolytic clostridia in the tubersphere were determined as for samples taken in the field experiment.

Following the 1983 growing season, the initial population on the tubers before imposing the treatment was 6.7×10^3 cfu/g soil. After storage for 1 month the populations of the dry and wet tubers were 5.2×10^4 and 8.8×10^5 respectively. The experiment was repeated after the 1984 season when the initial population was 1.5×10^4/g but after storage for 2 months at 10°C, populations of both the dry and wet tubers had not increased. After a further month there was a slight rise to 2.1×10^4/g on the wet tubers only. In 1983 tubers were kept for 3 months after harvest in a commercial store before experimental storage conditions were imposed, whereas in 1984 tubers were subjected to treatments 4 weeks after harvesting.

Pectic enzyme production by Clostridium *spp.*

Six strains of pectolytic clostridia isolated from soil and plant rhizospheres were cultured anaerobically at 25°C in broth containing yeast extract, mineral salts and either purified pectin or polygalacturonic acid (5 g, Sigma Chemical Co.). After 7 days the cultures were centrifuged at 10,000 g for 20 min., the supernatants dialysed against water at 4°C and stored at −25°C until required. The centrifuged pellet was suspended in 0.1 N NaoH and protein determined by the Lowry method. None of the isolates produced polygalacturonase but all of them produced differing levels of both pectin methyl esterase (PME) and pectate lyase (PL). The optima for PL activity for all the isolates was between pH 9.3 − 9.7 and the maximum activity recorded from polypectate culture was 3.3 units/mg protein. The PL activities after culture in pectin were less than in polypectate, the maximum was 1.8 units/mg protein and the ranking of activities of the isolates differed from those obtained from polypectate cultures. High PL activities from pectin culture were associated with high PME activities on a plate test and de-esterification of pectin by PME may be a required first reaction before PL can degrade the polypectate chain. Alternatively, the cultures may have contained two enzymes, pectate and pectin lyase, in different quantities. However, the pH optima of the enzymes remained the same whether produced in pectate or pectin media. Pectic enzyme activities were not associated with the amount of protein, i.e. cell growth, present in the cultures.

Rotting of potato by Clostridium *sp. at low temperatures*

A pectolytic *Clostridium* isolate selected from among the low temperature tolerant group (*Ann. Rep. 1982,* 116) was inoculated into washed tubers of cv. Maris Piper by introducing 0.1 ml cell suspension into wells 3 mm diam and 5 mm deep in the tuber surface. A series of tenfold dilutions from 2×10^3 to 2×10^7 cfu/ml were used and tubers were stored anaerobically at 5, 10 and 20°C. Tubers were weighed initially and after rotted tissue had been removed and rotted tissue was plated to test for the presence of *Clostridium* spp., *Erwinia* spp. and *Pseudomonas* spp. Mean percentage weights of rotted tissue per tuber at 20°C after 5 days, at 10°C after 26 days and at 5°C after 40 days were 25.8, 54.4 and 11.3 respectively. Although the proportion of rotted tissue was greatest at the highest inoculum potentials, the relation with cfu/ml in the inoculum was not linear. Only *Clostridium* spp. were detected in the rotted tissue.

(D. A. Perry)

PU 10(a) Improve control strategies by studying the biology of fungal diseases of cane fruit

Effects of inoculation of raspberry flowers with Botrytis cinerea *on post-harvest grey mould*

In a glasshouse, flowers of three raspberry cultivars were dusted with dry conidia of *B. cinerea.* In post-harvest tests the mature berries from dusted flowers rotted more rapidly than those from non-inoculated flowers, but there was no 'flower blast' or pre-harvest berry rot (*Ann. Rep. 1983,* 120). This pattern was confirmed in a replicated field experiment containing the cultivars Glen Clova, Glen Isla, Malling Jewel and Malling Orion. Intact flowers were inoculated on 14, 20 or 25 June with conidia of *B. cinerea,* and the berries were picked when ripe and incubated at high humidity in the laboratory. Berries from inoculated flowers, though apparently healthy when picked, rotted twice as quickly (2.5 days) as those from non-inoculated flowers (4.9 days) and berries of Glen Clova rotted more quickly than those of the other cultivars. In another experiment, flowers of the same cultivars had their sepals, petals and stamens removed and following pollination were inoculated with conidia on 26 June. Flowers and developing berries were sampled 7, 14, 21, 28 and 35 days after inoculation, and some ripe, non-inoculated berries were frozen, sectioned and stained in aniline blue. The conidia germinated on the stigmas but grew so slowly in the transmitting tissues that hyphae reached the base of the style only after 28 days. No endophytic mycelium was seen within carpels or mature drupelets of berries, as found in laboratory tests (*Ann. Rep. 1983,* 120) and in the glasshouse (Soft Fruit Breeding Department Report). *B. cinerea* produced conidiophores on the stigmas of all cultivars 28 days after inoculation and new conidia were produced before the fruits had matured.

Floral organs and pollen as saprophytic bases for *B. cinerea* were studied on Malling Jewel in the glasshouse. The shelf life of berries derived from inoculated intact flowers was compared with that from flowers which had been emasculated and inoculated when their stigmas were moist, when fruit ripened, and when pollen had been added to the ripened drupelets before inoculation; non-inoculated flowers were treated similarly. All emasculated non-pollinated flowers were dipped in a hormone solution of gibberellic acid 500 ppm, 4-chlorophenoxyacetic acid 100 ppm and 2-naphthoxyacetic acid 100 ppm to simulate the stimulation normally provided by pollen. The ripe berries were inoculated at high humidity. Inoculation with *B. cinerea* reduced shelf life by c. 7 days, irrespective of prior treatment, and berries from whole flowers rotted as rapidly as berries from emasculated flowers, without added pollen, had a significantly longer shelf life than berries from whole flowers, but rotted as rapidly as those inoculated immediately before picking.

These results suggest that pollen shed on ripening drupelets may provide saprophytic bases for *B. cinerea* and play as important a role in the development of grey mould as the sepals, petals and stamens which separate completely from the berry at harvest.

To distinguish mycelium derived from conidia inoculated on to flowers and fruits from natural populations of *B. cinerea*, conidia were labelled with the fluorescent vital stains Calcofluor PMS and Calcofluor M2R by irrigating 14 day-old cultures with nutrient broth containing the fluorescent label, recovering conidia by filtration and incubating them in label overnight at 4°C. Conidia were filtered, rinsed in sterile distilled water and used to inoculate raspberry flowers, leaves and canes in the glasshouse.

Conidia imbibed and germinated to produce extensive hyphae carrying the label and when inoculated to wounds on canes they produced lesions as effectively as non-labelled conidia, indicating that their pathogenicity was not impaired.

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

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

Conidia from 14 day-old cultures of seven isolates of *B. cinerea* derived from strawberry leaves and one from a raspberry cane were inoculated to newly opened strawberry flowers of 23 cultivars grown in growth cabinets, glasshouse and field. The infection of styles and carpels was examined by u.v. microscopy after softening tissues in 1N sodium hydroxide and staining in 0.1% aniline blue (*Ann. Rep. 1983,* 120).

Conidia from all the isolates germinated on the stigmas, and hyphae grew into the transmitting tissues of the styles of all cultivars in all the

[1]Soft Fruit Breeding Department.

environments, but growth was extremely slow compared with that in raspberry and hyphae approached the base of the styles only after 6 weeks. *B. cinerea* grew from the style into the carpel only in cv. Troubador, but did not progress to the receptacle. Conidia occasionally germinated on the side of styles and penetrated a single epidermal cell or a few superficial cortical cells. Germination on stigmas of emasculated flowers was as high as on those where pollen was present. Inoculum density was unimportant; hyphal growth in styles was often as extensive when derived from only a few conidia as when stigmas had been laden with conidia. *B. cinerea* can infect strawberry styles and produce a persistent mycelium which may constitute a saprophytic base and a site of sporulation on the surface of the fruit from which the fungus could invade the ripening receptacle. In Scotland, it seems unlikely that *B. cinerea* can infect the carpels (achenes) of strawberry and thereby directly enter the receptacle, as it did in raspberry in laboratory tests (*Ann. Rep. 1983,* 120).

The anther and the connective tissues between the lobes were also readily colonised by *B. cinerea* in the field and it sporulated on the anthers. The fungus grew to the base of some filaments of all the cultivars and hyphae entered the receptacle. Germinating conidia did not directly penetrate the epidermis of the filament. In the glasshouse, conidia remained ungerminated on anther filaments, petals and sepals until incubated in a moist chamber. Short hyphae were then produced which rapidly penetrated the epidermis of petals and sepals and colonised internal tissues.

Retention of raspberry and strawberry petals, stamens and styles on fruits as sources of inoculum for grey mould

Six flowers of each of eight raspberry and 11 strawberry cultivars were observed daily in the field from the time immediately before opening of flower buds until petal fall and then less frequently until berries ripened. Raspberry flowers opened more rapidly than those of the strawberry and they began to shed petals as soon as they were almost fully open but they retained a higher proportion of petals after 10 days (20%) than strawberry flowers (4%). In contrast, strawberry flowers did not begin to shed petals until a day or two after full opening. A few petals were retained on ripe berries of both crops. On strawberry petals were held between the calyx and the swollen receptacle of the ripe berry. Shrivelled raspberry petals were held amongst the dead stamens which themselves came into contact with the proximal ring of drupelets 10 days after the flower opens and persisted until the fruit was picked. Petal retention in raspberry but not strawberry, was affected by cultivar.

Most styles were present and intact on ripe drupelets of raspberry but their retention on strawberry varied with cultivar. The percentage of achenes with styles was recorded in four areas of eight field-grown

strawberry fruits (proximal ring, shoulder, face and distal end) from each of 11 cultivars. The styles were probably broken off by abrasion against other plant parts, with c. 90% of achenes at the proximal end retaining styles whereas those on the shoulder, face and distal end of berries retained only 51, 47 and 41% respectively. Retention of styles may be related to the development of grey mould in strawberry because cv. Tyee, which retained fewest styles (33%), is more resistant than cv. Shuksan, which retained most (74%), and the incidence of mould is highest at the proximal end of fruits.

(P. R. Bristow[1], B. Williamson, R. J. McNicol[2])

Cane botrytis

The virulence of 31 isolates of *B. cinerea*, obtained from sites throughout the British Isles, was compared by inoculating scalpel wounds on the internodes of young canes of SCRI selection M30 in July 1983, and measuring the lengths of lesions in early September 1983. All isolates produced lesions and abundant sclerotia; there were significant differences between isolates for lesion lengths, but there was no relationship between their origin and virulence.

The petiole of the leaf on the fifteenth node from soil level of young canes of the cultivars Glen Clova, Malling Jewel and Malling Orion was wound inoculated with mycelium of *B. cinerea* at weekly intervals from 18 July to 30 August 1983. There were two control treatments; wounded and not inoculated, and unwounded petioles. The lengths of the axillary buds were measured in late November and emergence of lateral shoots was scored in mid May 1984.

In Malling Orion, buds at inoculated nodes were shorter than control buds following all dates of inoculation, but in Glen Clova and Malling Jewel buds at nodes inoculated on 24 and 30 August did not differ from the controls. Inoculations which produced dwarfed buds also produced lateral shoot failure in spring. These findings suggest that although post-harvest fungicide sprays might reduce cane botrytis in Scotland, they may be impractical except in the vegetative phase of a biennial cropping system.

(B. Williamson)

Spur blight

Fourteen isolates of *Didymella applanata* were wound inoculated to the fifteenth internode of young canes of several cultivars in a replicated field trial in late July 1983. The lengths of lesions were measured on 17 September and sporulation assessed in late April 1984. Glen Clova and

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Malling Jewel had the longest lesions with most fruiting bodies, Chilcotin and Meeker were the most resistant and Glen Prosen, Leo, Willamette and Haida were intermediate. Isolates differed in virulence, but joint regression analysis showed that the isolate × cultivar interactions were small and did not affect the rank order, as previously found for petiole inoculations (*Ann. Rep. 1983,* 122). Cane inoculation is an easier and more precise method for testing cultivar × isolate interactions than the petiole inoculation technique. However, the latter discriminated best between tolerant (Glen Clova) and intolerant (Malling Jewel) cultivars. Therefore the response of a genotype to spur blight can best be evaluated by using both techniques.

(B. Williamson)

Pathogenicity of Botrytis *spp to raspberry*

Botrytis tulipae was isolated from a surface-sterilized raspberry fruit during routine plating of fruit from field-grown plants during July, 1983 to detect fungal infection. Raspberry flowers on plants in a glasshouse were dusted with dry conidia of either *B. tulipae, B. cinerea, B. fabae, B. elliptica, B. narcissicola* or *B. paeoniae* on 4 June. Thirty-seven days later five mature, apparently healthy fruits from inoculated flowers were bisected, shaken in 5% Chloros for 5 min., rinsed and the pieces of fruit placed on malt extract agar (MEA) in individual Petri dishes. After 14 days at room temperature the species with which the flower had been inoculated was isolated from five, six, six, ten, six and seven out of ten fruit halves for the above species of *Botrytis* respectively.

In a second experiment conidia of *B. tulipae* only were dusted over raspberry flowers in a glasshouse during November. Forty-one and 61 days later several fruits were each cut into 16 pieces of drupelets only and four pieces of plug only. Each piece was washed in a small volume of autoclaved water and the washings from each piece spread over MEA in individual Petri dishes. After 14 days every plate had become covered with *B. tulipae*, demonstrating that conidia can survive for long periods on developing raspberry fruits in a glasshouse.

Canes of raspberry SCRI selection M30 in a field were wound-inoculated c. 500 mm above ground level on 2 August 1984 with mycelium of *B. cinerea, B. fabae, B. narcissicola, B. elliptica, B. tulipae* and *B. paeoniae*. After 14 days the mean lesion lengths were 153, 43, 34, 160, 19 and 47 mm for the different species respectively and all the inoculated fungi were recovered from the edge of the lesions when surface-sterilized pieces of cane were placed on MEA.

On 3 September *B. elliptica* was sporulating profusely on all canes inoculated with that species, but conidia were absent from all other lesions. By 14 September sclerotia were present on only the canes inoculated with *B. cinerea* and had not appeared on any other canes by the end of January.

(J. G. Harrison, B. Williamson)

Root rot of raspberry

Phytophthora megasperma var *megasperma* was isolated from roots and from black lesions at the base of raspberry canes from two plantations in South Wales and one in Buckinghamshire where dieback and root rotting were a problem.

Isolates from all three sites were used to screen four raspberry cultivars and the hybridberry, Tayberry, for susceptibility to root rot. One week after a zoospore drench, rooted cuttings of Glen Moy and Glen Prosen had collapsed, followed a week later by those of Glen Clova and Malling Jewel. The root systems and stem base were rotted and in the first two cultivars named the rot extended through petioles into the leaf base. Oospores were present in the roots and petioles and the fungus was re-isolated from all rotted parts. Tayberry showed no symptoms.

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

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

Verticillium wilt of raspberry

Glasshouse tests for screening *Rubus* genotypes for susceptibility to *V. dahliae* produced good differentiation between the susceptible black raspberry cultivars and the more tolerant red raspberry cultivars. Results with three red and black raspberry crosses suggested that at least one had a high level of tolerance to the disease.

(D. M. Kennedy)

Verticillium dahliae *Kleb*

Isolations from wilted shoots of sea buckthorn *(Hippophae rhamnoides)* grown at SCRI yielded a species of *Verticillium* identified by CMI as *V. dahliae* Kleb. This is a new host record for this fungus.

(D. M. Kennedy)

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

Midge blight

Earlier studies indicated that pycnospores of *Leptosphaeria coniothryium* produced at wounds might play a role in the infection of periderm damaged by cane midge *(Resseliella theobaldi)* larvae at the base of the same canes (*Ann. Rep. 1983,* 121). Young plants of the cultivars Glen Clova and Malling Jewel, were grown in a replicated trial where there were no fruiting canes or old cane stubs—the vegetative phase of a biennial cropping cycle—and were sprayed on five dates at fortnightly intervals from 13 July to 7 September 1983 with the insecticide fenitrothion or the fungicide benomyl, or with both chemicals. There were two unsprayed control treatments; in one the old cane stubs were left as sources of inoculum and in the other they were removed. Canes

were cut in January 1984 and scraped to detect vascular stripe lesions *(L. coniothyrium)* and patch lesions (*Fusarium* spp., *Phoma* spp.).

The incidence of stripe lesions at the base of canes of Glen Clova was 31.3% in control plots without stubs only 11.3% and <1% respectively in plots sprayed with fenitrothion and with the combined programme of fungicide and insecticide. A similar pattern was found in Malling Jewel except that overall fewer canes were affected by stripe lesions.

Fenitrothion, either alone, or in combination with benomyl, reduced the incidence of patch lesions from 86.3% in controls without stubs to 3.8% in Glen Clova and from 52.5% to <1% in Malling Jewel. Canes from plots sprayed with benomyl alone had a higher incidence of patch lesions than controls in both cultivars. Removal of old cane stubs increased the proportion of canes with patch lesiosn in both cultivars but did not affect the incidence of stripe lesions.

The control of stripe lesions by sprays of fenitrothion alone, suggests that *L. coniothyrium* may be one of several fungi involved in the midge blight complex in Scotland. This work shows the potential benefit from the use of mixed insecticide/fungicide programmes after harvest or within the vegetative phase of biennial cropping.

(B. Williamson)

Effect of fungicide sprays on post-harvest infection of raspberry grey mould

The relationship between frequency and date of application of spraying with dichlofluanid on the severity of grey mould development was examined in 1982 and 1983 (*Ann. Rep. 1982,* 123; *1983,* 116). In each season both cryptic infection, as revealed by *in vitro* culture, and levels of grey mould were significantly decreased by increased spray frequency. Single spray treatments applied at flowering were most effective in reducing cryptic infection but later, single pre-harvest sprays gave better protection against mould development. This apparently anomalous result was ascribed to the potential of superficial contamination to induce post-harvest rot in berries with no, or slight cryptic infection. Variable results in both years, particularly for late harvests, were thought to be affected by locally high concentrations of inoculum on fruit picked in the vicinity of mouldy berries (*Ann. Rep. 1982,* 125; *1983,* 116).

In 1984 one spray programme was applied early and one late in the harvesting period. In each programme the effect of surface contamination on grey mould development was investigated by using a surface disinfectant to control superficial fungi and by testing fruit from canes which had been treated with either an early fungicide spray at flowering, a late spray one week before harvest or left unsprayed. Control fruit samples, either wetted or left dry were collected from the same treated canes. To induce mould development fruit samples were placed individually in compartmentalised trays and stored for 8 days under conditions similar to those occurring in commerce; viz dim illumination,

18°C and high humidity. There were 20 replicate fruit from each of two field sites in each assessment.

Overall, the second harvest had fewer moulded berries than the first, the surface disinfectant (Chloros) treatment reduced mould substantially, wet fruit moulded more than dry, and, in accordance with previous years' results, a single late spray was better than a single early spray.

In previous years, levels of grey mould have consistently been found to increase as the season progressed and later-harvested fruit to have a higher inoculum potential than that early-harvested and consequently more prone to grey mould. The anomaly in 1984 may be attributable to the weather in July being exceptionally dry so that field infection and inoculum levels were low, moreover the late harvest was in the third week of July rather than in early August. In addition, this season was the first time that the late harvest consisted of fruit which had received fungicide applications timed to coincide with the flowering or the 1-week pre-harvest stage; in earlier experiments the fruit tested were no more than late-ripening berries collected after the end of a timed fungicide programme applied largely for the purpose of evaluating fungicide persistence.

Site of grey mould development

Conidia of *Botrytis cinerea* often first develop on drupelets adjacent to the fruit 'collar' (*Ann. Rep. 1983,* 120) In the spray programmes described above the frequency of grey mould symptoms originating at the collar, on isolated drupelets, or as non-localised general infection of the fruit shells were recorded during the assessment of grey mould development in the compartmentalised trays. Collar infection occurred in 12 and 44% of the early and late-harvested fruit respectively, drupelet infection in 20 and 9% respectively, and general infection in 78 and 45% of the fruit respectively. The higher proportion of collar infection in the later harvest may have arisen because berries were relatively dry when picked and infection remained localised. After the wetting treatment or surface disinfection treatment the incidence of collar infection was only half that of the untreated fruit and general infection had increased proportionately. Symptoms originating from drupelets were relatively infrequent; however much of the general infection may have spread from drupelet to drupelet as fine hyphae which did not produce evident grey mould until the fungus was well established.

Incidence of fungi other than Botrytis cinerea *in stored fruit*

Cladosporium herbarum was second to *B. cinerea* as the most common fungus colonising fruit shells incubated individually in compartments of divided trays. Its incidence was generally inversely proportional to that of *B. cinerea*, the highest incidence occurring in the surface disinfected

samples and the lowest in the wetted samples. Whereas in the earlier harvested samples *C. herbarum* was detected mainly on isolated drupelets or small groups of drupelets, in the later samples a large proportion of the berries had only their stigmas infected and the fruit appeared superficially healthy. The fungicide treatment had no evident effect either on the frequency or the site of infection of *C. herbarum*.

Other species of fungi were rarely detected probably because the post-harvest incubation environment was very conducive to rapid development and spread of grey mould so that less aggressive fungi either failed to become established or their presence was masked by *B. cinerea*. They included species of *Penicillium, Phoma, Trichoderma, Alternaria,* and *Epicoccum nigrum* and *Fusarium culmorum*; yeasts were even less common. As with *C. herbarum*, fungicide and post-harvest treatments which result in lower frequencies of *B. cinerea* had correspondingly higher frequencies of other fungi. Much of the fruit from the second harvests, which had lower levels of grey mould, had a dusty appearance due to infection by the powdery mildew fungus *Sphaerotheca macularis* which was present in 15% of the berries. In those fruits affected by mildew, *C. herbarum* when present was confined to the stigmas or to one or two isolated drupelets in the collar region.

Effect of dichlofluanid on infection of green fruit by Botrytis cinerea

The proportion of green fruit infected by *B. cinerea* following surface sterilization was compared with that of unsterile fruits in samples collected 1 week after, or three weeks after the dichlofluanid spray applied at flowering in each of the two spray programmes. Before incubation, berries from half the samples were sprayed with molten agar to enhance symptom expression.

Of the very young fruit collected in the first harvest and surface sterilized, 80 and 55% berries were infected respectively from the unsprayed and sprayed canes of the first spray programme and 35 and 23% respectively from the equivalent canes in the second programme. The molten agar spray substantially enhanced detection in fruit from the second spray programme but not from the first. The relationships between the results of the various spray programmes, spray treatments and post-harvest treatments did not generally differ as a result of the presence of the agar coating or none.

The effect of dichlofluanid on saprophytic fungi in green fruit

The numbers of green fruit with superficial and deep-seated (i.e. resistant to surface sterilization) colonisation by common saprophytes was determined concurrently with assessments of *B. cinerea*. The results broadly confirmed those described previously (*Ann. Rep. 1983,* 118).

C. herbarum was again ubiquitous and its apparent frequency was markedly increased when fruit was covered by an agar film in the

absence of which neither surface sterilization nor fungicide sprays influenced the infection levels. Numbers of *Alternaria* spp. and *Ulocladium consortiale* substantially increased following surface sterilization indicating that they were largely restricted to the surface but the fungicide sprays were again found to increase their incidences (*Ann. Rep. 1983,* 118).

Many other fungal species occurred but at frequencies too low to establish treatment effects although there were more fungi in the 1-week old than in the 3-week old fruit. The species included *Penicillium* spp. *Epicoccum nigrum, Fusarium* spp., *Rhizopus* spp., *Chaetomium* spp. and, rarely, *Phoma macrostoma, Trichothecium roseum, Phomopsis* sp., *Coniothyrium* sp. and *Pestalotia* sp.

Site of infection by Botrytis cinerea *in young green fruit*

To verify that patterns of infection for flowers and young fruit were similar to those found in previous years (*Ann. Rep. 1977 – 1980*), small samples of immature fruit were picked on 29 June from tagged plants, either 1 week or 3 weeks after flowering and the individual parts tested for *B. cinerea.* The fruit stems were cut with sterile scissors and the berries collected in individual compartments of divided trays. Sepals, stamen rings and drupelet heads were excised aseptically and transferred without surface sterilization to compartments in new divided trays and stored in dim light at room temperature for 14 days.

In the younger, 1-week old berries, two of 20 sepal rings, no stamens and seven of 20 carpel heads developed *B. cinerea.* The corresponding incidences in 3 week old berries was four, seven and seven for the sepals, stamens and carpels respectively. The low level of sepal infection confirms similar observations made previously but lack of stamen infection in very young fruit was unexpected. The highest overall incidence occurred in the carpels and was probably associated with previously infected decaying stigmas and styles.

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

PU 10(d) Improve control strategies by studying the biology and host reaction to gall-forming bacteria in *Rubus*

Biovar types of *Agrobacterium* strains isolated from *Rubus* spp. in the SCRI culture collection were determined by testing; namely utilisation of L-arabitol, erythritol, melizitose, tartrate, D-glutamate production of 3-keto-lactose, oxidase test and growth on 2% NaCl. Isolates obtained from galls on *Rubus* belonging to biovars 1 and 3 or possibly a new biovar related to 3. Biovar 1 strains predominated, possibly because they grew faster and did not require yeast extract in the selective medium originally used to isolate them, in contrast to the other biovars. Growth and utilisation of octopine, nopaline, agropine, deoxymannotyl glutamate

and deoxymannotyl glutamine in minimal medium by pathogenic strains and their sensitivity to agrocin 84 showed that both octopine and nopaline positive strains were present. Some strains could not be typed and the possibility of a different opine type cannot be excluded at present especially since a hitherto unknown opine close to nopaline has been found in galls caused by these strains.

Many pathogenic strains showed varying degrees of sensitivity to agrocin 84 and the use of strain K84 as a biological control agent against galling in raspberry nurseries should be considered.

(A. Kerr[1], M. C. M. Pérombelon, L. J. Hyman)

Variation among isolates of Phytophthora fragariae

Isolates of *P. fragariae* from the cultivars Saladin and Cambridge Favourite grown at SCRI, were assigned to races B66-3 and B66-11. Isolates of the latter race were separated into two sub-groups by the amount of root rotting they produced on Saladin and other cultivars. Thirty-two single zoospore isolates, each from a different mass transfer isolate, were inoculated to 11 strawberry genotypes and the amounts of root rotting scored. Their scores and those of three standard isolates from the culture collection (169, 171 and 293) were subjected to Single Linkage Cluster Analysis and Centroid Cluster Analysis which grouped the isolates in two major clusters equivalent to races B66-3 and B66-11. The latter was further split into three sub-clusters, two of which were equivalent to the sub-groups noted above.

Some of the strawberry genotypes gave similar or even identical scores with each fungal isolate as did other genotypes; for example, the scores on Redgauntlet and Auchincruive Climax were always very close. Thus only five of the 11 genotypes, including the universally susceptible Cambridge Favourite, were required for distinguishing the clusters and the scores on genotypes giving similar results could be amalgamated in the analyses without affecting the clusters.

Three combinations of strawberry genotype and fungal isolate were used to investigate the effect of inoculum size on root rot scores using zoospore concentrations ranging from 60 to 20,000 zoospores/ml. Root rotting increased with increasing zoospore concentrations, but the average overall increases were only c. 1.0 points on the 0 – 5 root scale. Moreover the ranking of the scores for the three combinations were the same at all zoospore concentrations.

Two isolates, 315 and 329, which belonged to different sub-clusters of race B66-11, were inoculated on to the cultivars Siletz and Talisman, on which they produced, respectively, scores of 3 and 5, and 5 and 2.

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Mass transfer isolates, obtained from infected roots 2 weeks after inoculation, were used to inoculate more plants of the same cultivars. After four cycles of inoculation and re-isolation, the original single-zoospore isolates and the final set of mass transfer isolates were compared for their pathogenicities on eight strawberry genotypes. In each case the pathogenicity of the final isolate was similar to that of the original. Similar results were obtained when an isolate of race B66-3 was inoculated to the genotype 53A13. The only symptoms observed were occasional necrotic root tips from which the fungus could readily be isolated. Following four cycles of inoculation and re-isolation, there was, again, no evidence that the pathogenicity of the fungus altered, thereby confirming that the pathogenicities of single-zoospore isolates are stable.

Zoospores suspensions of isolate 169 (race B66-3) and isolate 171 (race B66-11) were mixed in the proportions 90/10, 75/25, 50/50, 25/70 and 10/90, and used to inoculate four genotypes which differed in their susceptibilities to the two races. Genotype 52AC18 is usually attacked severely by isolate 169 and only lightly by 171 and only isolates similar to 169 in pathogenicity and colony morphology were recovered from it, regardless of the proportions of zoospores in the mixtures. Correspondingly, only isolates similar to 171 were recovered from Auchincruive Climax and Saladin, both of which are susceptible to 171 but scarcely at all to 169. The univerally susceptible Cambridge Favourite is usually attacked severely by both isolates but an isolate similar to 171 was recovered only from one root of one plant inoculated with the 10/90 mixture of 169/171. All other isolates recovered from plants inoculated with this or any of the other mixtures were identical to 169, suggesting that isolate 169 is 'fitter' than isolate 171 on Cambridge Favourite.

The occurrence of isolates of different races within roots on the same plant or even within the same root of field grown plants has been reported previously (*Ann Rep. 1983,* 126). In a more detailed study, three mass-transfer isolates from different roots of a single Saladin plant were found to differ. Race B66-3 does not produce symptoms on Saladin in glasshouse tests but, surprisingly, one isolate and eight Hyphal tip and eight single zoospore cultures derived from it belonged to race B66-3. The other two isolates belonged to different sub-clusters of race B66-11, both of which cause root rotting on Saladin, although in different amounts.

One isolate yielded hyphal tip and single-zoospore cultures identical to itself, but the other did not; two of seven hyphal tip cultures gave different reactions, although all single zoospore isolates reacted in the same way as the parent. The two anomalous hyphal tip cultures were assigned to race B66-11 but they produced more severe rotting on all the differential genotypes than any of the isolates in the three sub-clusters of race B66-11, detected by Cluster Analysis.

A similar pattern of diversity has been noted among isolates recovered from roots of a Cambridge Favourite plant from the same site. Field populations of *P. fragariae* may therefore be heterogeneous but it is noteworthy that, as yet, no single-oospore progeny of isolates belonging to B66-3 or to two of three sub-cultures of B66-11 have differed in pathogenicity from their parent isolates. The role of the sexual cycle in generating new pathogenicities is therefore uncertain.

A re-examination of the culture collection of *P. fragariae* has shown that it contains isolates only of races B66-1, B66-2, B66-3 and B66-11; cultures designated as race B66-10 proved to be either B66-3 or B66-11.

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

Differences between isolates of some fungi in their growth and pathogenicity have been linked with infection by mycoviruses detectable by the presence of species of double-stranded RNA in mycelial extracts.

Nucleic acids were extracted from mycelial of six isolates of *P. fragariae* (168, 169, 171, 172, 173 and 293) differing in pathogenicity and the fraction bound to cellulose in ethanolic buffer (putative double-stranded RNA) isolated, but no dsRNA was found when these samples were analysed by electrophoresis in polyacrylamide gel.

(M. A. Mayo[1], D. M. Kennedy, J. M. Duncan)

In vitro *studies of* Phytophthora fragariae

Various systems for producing high numbers and concentrations of zoospores for genetical studies have been investigated. When a non-sterile solution was used to irrigate cultures it stimulated sporangial production more than a sterile one, and when bacterial isolates from the former were introduced into the latter, singly or in pairs, the numbers of sporangia formed and zoospores released were sometimes increased.

Hyphae and other debris were removed from suspensions by filtration through 20 μm mesh monofilament cloth and zoospores were then concentrated by their being retained upon 8 μm pore size membrane filters. The establishment and germination of zoospore cysts was best on corn meal agar (CMA) plus rifamycin. A later overlay of sucrose/asparagine medium containing rifamycin encouraged mycelial growth. Alternatively the zoospores were encysted and germinated in the liquid phase by addition of V-8 juice, following which they stuck to the bottom of the plastic Petri dish. The V-8 juice was poured off and replaced immediately with CMA plus rifamycin followed by the overlay of the sucrose aspargine medium.

Protocols based on these techniques were used in attempts to recover the fungus from the drainage water from infected plants growing in pots of soil. Colonies of *P. fragariae* were seen on plates but fungal contaminants prevented the establishment of pure cultures.

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

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[1] Virology Department.

PU 14(a) Study the epidemiology and control of cavity spot of carrots

Several *Pythium* spp. were isolated on selective French bean agar from cavity spot lesions on carrots collected from field trial sites in 1983. Isolates identified as *P. violae* consistently induced sunken lesions on carrots in the laboratory when disks of actively growing cultures on corn meal agar were applied to the surfaces of washed roots. Characteristic pythiaceous hyphae were seen ramifying through cortical cells of lesion tissue in microscope sections prepared soon after inoculation and the fungus was re-isolated from pieces of lesion tissue after surface sterilization in 100 ml/l Chloros. Twenty-one days after inoculation, hyphae were no longer visible in the collapsed lesions and the fungus could not be re-isolated. Histochemical tests revealed an accumulation of phenolic compounds beneath the inoculation sites 36 h after application of the fungus. Isolates of *P. intermedium* and *P. sylvaticum* similarly inoculated to carrots induced lesions but at a lower frequency than *P. violae*.

In East Anglia, *P. violae* was isolated along with other *Pythium* spp. from cavity spot lesions collected from field outbreaks but it was not identified in enumerations of colony forming units of *Pythium* spp. in soil suspensions from fields where cavity spot had occurred.

Carrots, cv. Red-Cored Chantenay were sown at Mylnefield on 15 May and samples harvested regularly from 27 July until 15 December. The roots were washed and inoculated with disks of *P. violae* cultures. Lesions were formed at <20% of the inoculation sites on samples collected until 26 August but on 19 September the incidence increased to 87% and remained between 67 – 95% on all successive harvests.

Twelve carrot cultivars grown in pots in the glasshouse were inoculated as described above with *P. violae* on three occasions. On the first and second occasion when roots were 18 and 23 weeks old large differences in lesion incidence between the cultivars were recorded; cv. Chantenay Red-Cored Supreme was the most and cv. Vita Longa was the least susceptible. However, when the roots were 31 weeks old lesion incidence increased on those cultivars which had appeared to be resistant at first and second harvests.

Two field trials were carried out on commercial carrot crops in collaboration with ESCA. In the first, metalaxyl plus mancozeb (Fubol, Ciba Geigy) was sprayed at rates varying from 1.5 to 12.5 kg/ha pre-emergence, post-emergence and mid-season, and in the second, products containing other acylalanine compounds and oomycete-specific fungicides were to be compared. No measurable cavity spot developed at either site, probably due to the exceptionally dry growing season.

(M. R. Groom[1], D. A. Perry)

[1]Research Assistant

ZOOLOGY

D. L. TRUDGILL

On a world basis potato cyst nematodes are amongst the most important pests of potato, challenging both crop protection specialists and plant breeders. Until recently, resistance was only available to the yellow species (*Globodera rostochiensis*), but potato clones with partial (quantitative) resistance to the white species (*G. pallida*) have now reached an advanced stage. Unfortunately, there is not yet agreement on how best to define and measure this resistance, especially for National List testing, but studies at SCRI and elsewhere to solve these difficulties are now well advanced. Our research has also resulted in the recent widespread acceptance that the use of clones with quantitative resistance in the scheme currently used to classify pathotypes of *G. rostochiensis* and *G. pallida* is fundamentally unsound and impracticable. Field studies have provided evidence that selection for virulence occurs when *G. pallida* is reared repeatedly on clones with quantitative resistance. Therefore, the resistance of such clones is likely to break down eventually. In laboratory studies further evidence was obtained that resistance to *G. rostochiensis* is associated with re-emergence of juveniles from the roots of resistant plants and that carbohydrate residues on the juvenile cuticle may be involved in their acceptance or rejection by the host plant.

Co-operative studies on the distribution of longidorid nematodes in Europe have continued during this penultimate year of the European Plant Parasitic Nematode Survey. Distribution maps have now been prepared for most of the countries in Western Europe and several computer techniques have been developed to map and analyse the data.

Studies on potato leafroll virus provided further evidence that early roguing can control virus spread and that when aphids arrive late and are scarce granular insecticides need not be applied to most crops to control virus spread. The search continued for an alternative to DDT for controlling clay-coloured weevil but further work is required to identify an equally effective alternative chemical and method of application.

PU 9(h) Study the ecology of aphid vectors of potato viruses and devise control methods

Effect of roguing on spread of potato leafroll virus (PLRV)

The effect of progressively later roguing on the spread of PLRV was

assessed in 1983 in a trial which was planted with a small proportion of PLRV-infected plants in a similar design and layout to that used in 1982 (*Ann. Rep. 1983,* 141), but using no insecticide treatments. To overcome the variability in the spread of PLRV due to large variations in natural infestations of aphids the infector plants in half of the plots were inoculated with five small nymphs of *Myzus persicae* in mid June. Equal numbers of inoculated and non-inoculated infector plants were removed on 24 June, 4 and 21 July using conventional roguing or careful foliage removal, as in the 1982 trial. The foliage was examined in the laboratory and any aphids found were transferred to indicator plants to test their infectivity. In 1983 any aphids that had been dislodged were killed by spraying the soil surface with nicotine before removing the tubers beneath the cut infector plants.

Following the cold spring in 1983, natural infestations of aphids were not found until late June, and populations remained lower than in recent years throughout the season. In July greater numbers of *M. persicae*, but not of *Macrosiphum euphorbiae*, were found in the inoculated plots than in those in which the plants were infested naturally. At each roguing date *M. persicae* able to transmit PLRV were recovered from about half of the inoculated infector plants. A few were also recovered from the foliage of the naturally infested infectors.

Tubers from plants adjacent to the PLRV infector plants were grown in 1984 and assessed for PLRV infection. The results showed that PLRV had spread much less in 1983 than in 1982 but, as expected, there was more spread in plots which had been inoculated with *M. persicae* (16% tuber infection) than in the naturally infested plots (4% tuber infection). Delaying roguing had little effect on the spread of PLRV in normally rogued plots but a major effect in plots where the infector foliage was removed carefully. This latter treatment only decreased virus spread at the first roguing date, 9 days after aphid inoculation, but it had no effect 3 weeks after inoculation (4 July), and apparently increased the virus spread in infested plots rogued 5 weeks after inoculation (21 July). The reason for this unexpected increase is unknown but *M. euphorbiae* was found on most infector plants by this date, and aphid behaviour on neighbouring plants may have been affected by sub-lethal concentrations of the nicotine spray used in 1983.

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

'Bench-mark' trials for assessing annual variations in the spread of potato leafroll virus (PLRV)

It has been difficult to compare the spread of PLRV in commercial seed crops with that in our field trials because, to maximise the contrasts in experiments comparing different kinds of insecticide or method of application, infector plants have often been left in the plots throughout

the growing season. In a new approach bench-mark trials were started in 1983 in collaboration with G. N. Foster[1] to monitor the spread of PLRV in reference plots of seed potatoes. Foundation Stock grade (Super Elite) tubers from the same stock of cv. Maris Piper were planted at SCRI and at Monkton, Ayrshire in single row plots of c. 0.15 ha. Each plot was planted with cv. Désirée infected with PLRV in a systematic lattice arrangement to give a known initial PLRV infection level of 1%. At each site similar plots were treated at planting with thiofanox at 5.6 g a.i./100 m. The infector plants were rogued at both sites on 11 July, and no Maris Piper with secondary leaf roll were found.

Aphid populations remained small at both sites and there was little difference in the numbers found before or after roguing. Thiofanox gave slightly better control of *M. persicae* at Monkton than at SCRI and in August more winged *M. euphorbiae* were trapped at SCRI than at Monkton. After haulm destruction on 31 August at SCRI and 9 September at Monkton samples of 2,000 tubers were collected from each plot. These tubers were grown in 1984 to assess the proportion infected with PLRV and the results showed that thiofanox had decreased the incidence from 1.2 to 0.7% at SCRI and from 0.3 to 0.1% at Monkton. Thus, even without thiofanox, normal roguing in 1983 prevented the level of infection of PLRV increasing at SCRI and decreased it at Monkton.

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

Control of aphid vectors of potato viruses

Assessments in 1984 of the proportion of PLRV infected tubers from a trial in 1983 to compare methods of applying insecticide granules (*Ann. Rep. 1983,* 143) showed that there had been less spread of PLRV than in a similar trial in 1982. In untreated plots 20% of the tubers were infected in 1983 compared with 67% in 1982. Thiofanox at 5.6 g a.i./100 m and aldicarb at 8.6 or 4.3 g a.i./100 m of row, both applied in-furrow, restricted PLRV spread to a quarter or less of that in untreated plots. Aldicarb as a side-band dressing at 4.3 g a.i./100 m row applied to the growing crop controlled aphids as effectively as the in-furrow treatments but was inferior at controlling the spread of PLRV.

One explanation for the poorer control of PLRV by the side-banded treatment is that stems growing in the line of the ridge received inadequate chemical protection. The translocation of aldicarb from the parent tubers was tested in the glasshouse by a 'tuber-bridge' experiment using an aphid bioassay to assess pesticide activity. Two stems were allowed to develop on each tuber and the two root systems were grown in separate pots (18 cm square). Aphid survival was compared on leaves excised from stems with roots growing in aldicarb-treated soil and on

[1] Biological Sciences Division, WSAC

leaves from non-treated stems at the opposite end of the tuber growing in untreated soil. In bioassays 3 – 5 weeks after applying aldicarb at 20 – 40 mg a.i./pot and 4 – 9 weeks after applying aldicarb at 80 mg a.i./pot, more aphids survived when the soil was untreated. However, there was some evidence for limited translocation of aldicarb through the tuber because aphid survival on leaves from the non-treated stems was less than on leaves from stems growing from tubers in which neither root system grew in treated soil.

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

PU 9(i) Develop the management of cyst nematodes in seed potato crops and control of damage in ware crops

Variations in yield losses caused by potato cyst nematode (PCN)

Assessments of the relationship between the initial density of PCN populations and the associated crop yield losses have proved difficult because of the problem of producing suitable trial sites. Consequently, most trials have been conducted at uniformly infested sites using a non-fumigant nematicide in some plots to obtain an estimate of the yield in the absence of PCN. However, there has been disagreement amongst nematologists as to whether the difference in yield between treated and untreated plots provides a reasonable estimate of the damage caused by PCN. A re-examination of results from trials at sites free of PCN, and not heavily infested with other pests, showed that non-fumigant nematicides had little effect on yield. At infested sites, nematicides applied at the commercial rate were shown to protect the crop from almost all of the damage caused by PCN. Thus, trials using nematicides at sites infested with PCN generally provide a reasonable estimate of the effect of PCN on yield.

With this established, the data from trials with nematicides at infested sites were re-analysed to examine the relationship between the initial density of PCN and its effect on yield. This showed large differences between trials, the crop losses apparently being much greater at some sites than others. For example, at sites infested with 25 – 30 eggs/g soil the losses varied between 3 and 28 t/ha. The reasons for such huge variations between sites are not fully understood, but soil type, husbandry practices, the cultivar grown and interactions with soil fungi are all possible causes.

(D. L. Trudgill)

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

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

The reproductive rates of *Globodera pallida* were compared in a pot and

in a field experiment using four Solanum clones: the susceptible cv. Maris Piper and three *Solanum vernei* hybrids cv. Fiona, cv. Corsair and clone 11233 ab 22. The field trial utilised 12 plots which in the 3 years previously had grown four clones with differing levels of nematode resistance and provided a range of initial population densities of 3.5 to 150 eggs/g dry soil. Each of the clones was planted as a single row of twelve tubers in each plot. At planting, soil was removed from each plot and used in a small pot (10 cm diam.) experiment.

In the pot experiment, as found in a previous test (*Ann. Rep. 1983,* 78), the numbers of eggs/g dry soil increased relative to the initial density, with the increases and final densities being inversely proportional to the degree of resistance of the clones. In the field experiment the relationship was similar except that at the higher initial population densities the final numbers were less than the initial. The results from both experiments showed that, whatever the initial density, the resistance ranking of the clones remained constant and was similar for the pot and the field trial. The pot and field results differed in that the average multiplication rate observed in the pot experiment was 2.5 times greater than that in the field.

These results are further evidence of the inappropriateness for official testing of using absolute multiplication rates as criteria for delineating categories of resistance. Multiplication rates vary both with initial population density and in different environments, the latter being particularly important when trying to relate pot test results with those obtained in the field. The similarities that do exist between pot and field experiments, i.e. similar resistance ranking of clones and the similar effects of initial density on multiplication rates, indicate that comparisons can be made but that this should be done indirectly using partially resistant and non-resistant standards for which the relationship between pot and field performance is well established.

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

Virulence of population of Globodera pallida

Although ware potato cultivars resistant to *G. pallida* are only now becoming commercially available in the UK it is important to know whether their introduction will result in an increasing virulence in *G. pallida* through selection, and whether their resistance would eventually break-down. To investigate this a field trial was established in 1981 using four clones: non-resistant cv. Maris Piper, two partially resistant *S. vernei* hybrids 9559 and cv. Corsair, and the partially resistant clone D40/8 (derived from *S. tuberosum* ssp. *andigena* CPC 2802). All were grown in three plots which had been inoculated with a low population density of *G. pallida*, and with the same pattern of cropping being maintained in subsequent years.

In 1984, to test for possible changes in virulence, cysts were extracted from these plots and their rate of reproduction on a range of partially resistant clones was examined in a pot experiment. In addition to the four clones mentioned above, the experiment included the *S. vernei* hybrids cv. Fiona and clones 11233 ab 22 and 62.33.3, and a CPC 2802 hybrid 11417. The pot results showed that, compared with the nematodes from the Maris Piper plots, those from the Corsair plots reproduced better on Fiona, 11233 ab 22, Corsair and D40/8. The cysts from the D40/8 plots reproduced best on that clone. The sub-population from clone 9559, the least resistant of the field grown clones, reproduced better on 9559 and on Fiona. Thus, there is now evidence of selection for virulence in the field.

Studies of the differences in virulence between populations of *G. pallida* were continued. It was previously reported (*Ann. Rep. 1982,* 76) that there was little interaction between potato clones derived from *S. vernei* or *S. tuberosum* ssp. *andegina* CPC 2802 and populations of *G. pallida*. Further studies which included eight populations of *G. pallida* and a range of clones with differing degrees of resistance have confirmed the earlier findings. The main differences in the numbers of cysts formed on each of the clones was determined by its degree of resistance and the virulence of the *G. pallida* population being tested. The clone X population interaction was relatively small, all the populations tending to rank the clones in a similar order of resistance and all the clones tending to rank the *G. pallida* populations in a similar order of virulence.

Even though the *G. pallida* populations were chosen to represent the different pathotypes Pa2, Pa3 and New Leake, there were no clear-cut differences between them. Overall, on both the ex *vernei* and the ex *andigena* clones there was a threefold range in the reproductive rates of the *G. pallida* populations. Hence, as we proposed previously, and is now widely accepted, potato clones with quantitative resistance are unsuitable for use as differentials for separating pathotypes, and the pathotypes Pa2, Pa3 and New Leake are not distinct, being parts of a continuum.

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

Re-emergence of juveniles from the roots of resistant plants

Last year it was reported that many juveniles that had entered the roots of potatoes with H_1 resistance derived from *S. tuberosum* ssp. *andigena* CPC 1673, or quantitative resistance derived from *S. vernei*, subsequently re-emerged (*Ann. Rep. 1983,* 77). Further studies which included a resistant clone derived from *S. tuberosum* ssp. *andigena* CPC 2802 indicate that this may be a feature of most, if not all, types of resistance to potato cyst nematodes.

As part of an investigation to establish why many more juveniles re-emerge from the roots of resistant than from non-resistant plants,

emigrants from clone 12380 ab (2) (ex *vernei*) and cv. Arran Banner (non-resistant) were treated with wheat germ agglutinin-tetramethylrhodamine isothiocyanate to test for carbohydrate residues. Only three of 20 juveniles from the ex *vernei* showed labelling on their head region compared with 10 of 20 from the Arran Banner, and 24 of 25 freshly hatched juveniles. Third stage juveniles dissected from the roots of Arran Banner were labelled over the whole of the body surface. Work is continuing to determine if carbohydrate residues are involved in the acceptance or rejection of invading juveniles by the host plant.

Studies on the fate of the juveniles which did not re-emerge showed that many more males were produced in clone 12380 ab (2) than on Arran Banner.

(J. M. S. Forrest)

PU 1(o) To understand the effect of natural plant products on recognition sites on plant pathogens

Role of carbohydrates in virus retention, host recognition and pathogen-prey relationships

The surface sugar moieties present on the outer cuticle of virus vector and non-vector species of *Longidorus* have been studied using lectins from *Triticum vulgaris* (WGA), *Canavalia ensiformis* (CONA), *Glycine max* (SBA) and *Arachis hypogaea* (PNA) conjugated to tetramethylrhodamine isothiocyanate (TRITC). Initial results show that labelling of adults and larvae of the vector species *L. elongatus, L. attenuatus* and *L. macrosoma* and the non-vector species *L. caespiticola, L. gooddeyi* and *L. leptocephalus* is concentrated mostly at the head and the tail. Intense labelling was found with PNA-TRITC on the side of the head of specimens of *L. macrosoma, L. attenuatus* and *L. elongatus.* No labelling was observed with SBA-TRITC. Attempts to stain nematodes with the other lectins showed that there were labelled and unlabelled specimens within each species. It was not clear if these differences were due to their physiological state or to genetic differences within the populations examined. However, labelling on the outer surface appears not to harm the nematodes and offers the possibility of making selections within a species.

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

Carbohydrate on potato cyst nematodes (PCN)

Last year the apparent absence of sugar moieties on the surface of freshly hatched juveniles of PCN was reported (*Ann. Rep. 1983,* 77). However, because the nematodes examined showed marked autofluor-

[1]The Volcani Centre, Bet Dagan, Israel

escence at the wavelengths used to detect the presence of lectin-fluorescein isothiocyanate, any binding which may have occurred could have been obscured. The tests were therefore repeated with lectin-TRITC conjugates which emit fluorescence at a wavelength where no autofluorescence occurs with juveniles of PCN. In these studies freshly hatched juveniles from populations representing *Globodera rostochiensis* pathotypes Ro_1 and Ro_5 and *G. pallida* Pa_1 and Pa_2 /Pa_3 were treated with six different lectins (CONA, PNA, WGA and agglutinins of *Dolichos biflorus, Ricinus communis* and *Ulex europaeus*). Five of the six bound specifically to small areas on the head region, indicating the presence of N-acetyl glucosamine, galactose, N-acetyl galactosamine and mannose or glucose and the absence of fucose.

Wheat germ agglutinin was shown by electron microscopy to be bound to an exudate from the amphids. This exudate is of interest because of its apparent similarity to certain elicitors of phytoalexin production found in fungi. Not only is it in close proximity to the developing syncytia but there are differences in its composition between individuals and certain pathotypes.

(J. M. S. Forrest, W. M. Robertson)

PU 1(c) To understand and relate the structure and functioning of plant parasitic nematodes

Stucture of the feeding apparatus of trichodorids

Trichodorids transmit plant viruses but the structure of their feeding is substantially different from that of longidorid vectors. Trichodorids graze on epidermal cells, rather than feeding deeply within galls as do most longidorids, and have a feeding apparatus that enables them to feed rapidly. The stylet has several functions. It is used to penetrate the cell wall, to form a special feeding tube and to make rapid pumping movements which help withdraw the cell contents. Ultrastructural studies of *Trichodorus primitivus, T. similis* and *Paratrichodorus pachydermus* have shown that as a consequence of the pumping function the innervation of the stylet muscles is complex. The same muscles are thought to be involved in both stylet protraction and retraction being by the indirect action of muscles attached to the stylet and the basement membrane enclosing the stylet lesion. During retraction these muscles draw in the sides of the membrane causing the enclosing sac to elongate by hydrostatic pressure thereby pulling the stylet backwards.

During feeding trichodorid nematodes produce a salivary secretion which solidifies at the point of penetration of the cell wall to form a feeding tube. Electron-microscopy has shown that, compared with the longidorids which have hollow stylets and do not produce this feeding tube, trichodorid nematodes have two extra nuclei in the oesophagus—the cells of which are the probable source of the feeding tube material.

(W. M. Robertson)

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

Techniques

Many of the basic assumptions made during studies on ectoparasitic nematodes have not been fully investigated: for example, field sampling and data analysis are done without regard to possible differences in characteristic distribution patterns of different species; the losses occurring during sample handling are ignored; and the effect of man's activity on nematode population density and distribution is largely unknown.

Studies have shown that populations of *Longidorus elongatus* had a similar index of aggregation at several sites and that a $\log(x-1)$ transformation is appropriate when analysing data from plots larger than 1 m^2; that tractor wheelings contained significantly fewer nematodes than the surrounding uncompacted soil; and that soil from tractor wheels contained sufficient live nematodes to make it a potent means of distributing virus vector nematodes.

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

The influence of competition on migratory ectoparasitic nematodes with 'r' and 'K' survival strategies

Observations over 4 years at a site infested with *Rotylenchus robustus, Trichodorus primitivus* and *Paratrichodorus pachydermus* indicated that these nematodes had relatively long life-cycles and slow rates of multiplication i.e. they acted as 'K' strategists. In plots with low population densities of these nematodes following treatment, with a fumigant nematicide, a *Paratylenchus* sp. rapidly increased in number with alternating annual peaks and troughs in population density, but in the untreated plots in the presence of the other nematodes the numbers of the *Paratylenchus* sp. remained low. These results suggest that interspecific competition prevented the *Paratylenchus* nematodes from increasing, whereas, in the fumigated plots, where an 'ecological vacuum' existed, the *Paratylenchus* sp. acted as an 'r' strategist.

(B. Boag, T. J. W. Alphey)

Longidorus vineacola

L. vineacola was found in sandy loam and sandy soils from the Island of Coll. This nematode has not been found on mainland Scotland but been recorded from three Hebridean islands where it appears to be an indigenous species.

(B. Boag)

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[1]Data Processing Department

Population studies of two sympatric trichodorid species

In a replicated field trial, the changes in the population densities of two trichodorid species in plots of Scots pine (*Pinus sylvestris*), of a grass/clover (*Lolium perenne/Trifolium repens*) mixture and in fallowed plots were recorded over 3 years. Both *T. primivitus* and *P. pachydermus* had aggregated distributions with 'b' values (Taylor's aggregation index) at the start of the study of 1.64 and 1.51 respectively. The two species also had different modal depth distributions, the optimal depth for *P. pachydermus* being less than that for *T. primitivus.*

At the end of the 3 years the numbers of *T. primivitus* were largely unchanged but those of *P. pachydermus* had decreased in the fallow plots and increased in those growing Scots pine. The degrees of aggregation were similar, the 'b' values being 1.70 and 1.49 for *T. primitivus* and *P. pachydermus* respectively.

(T. J. W. Alphey)

European plant parasitic nematode survey (EPPNS)

An atlas of the distribution of Longidoroidea, Heterodoroidea, Anguinidae, Pratylenchidae, Rotylenchulinae and Tylenchulidae in the Maltese islands was produced. Computer files for the production of an atlas for Bulgaria were completed and data files for an atlas for Italy were established. Further work was undertaken developing subroutines to transfer national distribution data at present recorded for each participating country on a 10 km basis, into files with 50 km grid references for mapping Europe as a whole.

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

Faunistic analysis

Using data from the EPPNS, the faunal relationships of 56 species of longidorid nematodes in 14 countries of Europe and one from the Near East were analysed. This showed that geographic proximity and faunal similarity were not always closely related. Comparatively few species are present in northern Europe and Switzerland, probably because of Quaternary glaciations, whereas in the eastern Mediterranean region the longidorid fauna is highly diverse, possibly as a result of Miocene plate tectonics in that area.

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

Advances in the use of the computer as an aid to the identification of nematodes

The technique used to identify plant parasitic nematodes with the aid of a microcomputer has been further developed to increase its effectiveness and reduce costs. A new system, which relies on the 95% confidence

[1]Data Processing Department

limits of the relevant parameters and in which characters are weighed, is being developed to replace the previous system which relied on absolute values. By using a BBC microcomputer, two disc drives and a digitising tablet, the actual cost of the equipment has been reduced c. £11,000 in 1981 to c. £1,500 in 1984. The increase in use of computers in nematode taxonomy is greatly simplifying the updating of data and information exchange between taxonomists.

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

Effect of a change in biotope on the morphometrics of Xiphinema diversicaudatum

The morphometrics of adult *X. diversicaudatum* from several countries were found to have changed significantly after culture for 4 years in a heated glasshouse. Nematodes from the glasshouse cultures tended to have significantly longer stylets than nematodes from the original populations. These increases in stylet length were not consistently associated with increases in other body measurements.

(D. J. F. Brown)

The reproductive capacity and longevity of Xiphinema index

In a small pot (25 cc) experiment using *Ficus carica* as the host plant, the longevity and total reproductive capacity of female *X. index* from populations from Italy and the USA were similar. At 18°C females lived for c. 64 weeks and produced c. 150 progeny. This is equivalent to one egg being laid every 25 day degrees C (day°C) above a minimum daily threshold soil temperature of 10°C. The day°C requirement for egg production on *F. carica* was confirmed in a second experiment in larger pots (250 cc) at 22°C, an average of 21 day°C above the threshold was required for the production of each egg. In the same experiment with *Vitis vinifera* as the host 48 day°C were required for each egg. Under *Lycopersicon esculentum* cv. Moneymaker females of *X. index* from Italy, Israel and USA lived for c. 40 weeks and their reproductive capacity was decreased, 62, 90 and 64 day°C respectively being required for the production of each egg.

(D. J. F. Brown, M. I. Coiro[2])

PU 1(e) Study mechanisms of virus transmission by nematodes

Accurate information about the capacity of nematodes to transmit viruses causing plant diseases is a prerequisite for effective disease control measures. We have developed a comprehensive system for examining the acquisition, retention and transmission of virus by longidorid nematodes. Spurious results, caused by contamination, can be

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obtained in transmission tests; therefore the following criteria were established:

(1) nematodes used in virus transmission studies should be identified, preferably by an authority on the genus, noting any differences from type specimens
(2) the virus isolate must be identified before and after each transmission test
(3) each test should be done with hand-picked nematodes, preferably only adults, and with such controls that the nematode is shown to be the vector
(4) it must be shown that the virus has infected the bait plant.

Presently, only nine of 20 published reports of *Longidorus* species transmitting viruses and 10 of 27 with *Xiphinema* species fulfil these criteria. The nineteen substantiated reports are further supported as the nematodes and viruses have been variously reported associated with diseased crop plants. Those reports not fulfilling the criteria do so because: systemic infection of the bait plant with virus was not adequately established; the methods are inadequately described; inappropriate or inadequate controls were used and nematodes and or virus was not adequately identified. In the British Isles established longidorid vectors and their associated viruses are *L. elongatus* with raspberry ringspot (RRV) and tomato black ring viruses (TBRV), *L. attenuatus* with TBRV, *L. macrosoma* with RRV and *X. diversicaudatum* with arabis mosaic and strawberry latent ringspot viruses.

(D. L. Trudgill, D. J. F. Brown)

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

Effects of nematicides on potato cyst nematode

Previous studies (*Ann. Rep. 1980,* 112 and *Ann. Rep. 1981,* 125) have shown that the susceptibility of *Pratylenchus penetrans* and *Longidorus elongatus* to carbamoyl oxime nematicides was affected by their physiological condition, and the presence or absence of a host crop. These studies have now been extended to the potato cyst nematode (*Globodera rostochiensis*). In replicated pot experiments the effect of aldicarb applied at one-fifth of the normal field rate on the numbers of juveniles invading the roots of potato cv. Désirée was compared for two cyst populations previously under potato 1 and 11 years ago. The results showed that for juvenile and cyst inoculations respectively, the numbers of juveniles in roots after 4 weeks were decreased by 27 and 55% for the 1-year-old population but 45 and 65% for the 11-year-old population.

(T. J. W. Alphey)

Natural plant products as nematicides

The nematicidal activity of a group of natural plant products has been investigated. During *in vitro* studies *Xiphinema, Longidorus* and

Globodera spp. were repelled from a point source containing these products. Initially, nematodes actively migrated away from the source but later they became moribund and eventually died. However, if they were removed before death they appeared to recover. Further investigations are under way to study the nematicidal effects of these products in the soil.

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

Loss of glasshouse cultures

It is known that the plasticiser dibutyl phthalate (DBP) is phytotoxic to a range of plants. As the plasticiser has been used in glazing strips of glasshouses, studies on its effect on nematode cultures have been initiated. In replicated experiments neither DBP contaminated strips added directly to the soil nor DBP vapour passed through the soil reduced numbers of nematodes in the genera *Rotylenchus, Tylenchorhynchus, Trichodorus, Pratylenchus, Longidorus* or *Xiphinema*. Its indirect effect on nematodes via their host plants is still under investigation.

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

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

Effect of pesticides on Longidorus elongatus *and the yield of swede*

The population density of *L. elongatus* after grass is usually large and following crops are vulnerable to damage. A trial in 1984 investigated the effect of several pesticides on the yield of swede which followed grass at a site infested with moderate numbers of *L. elongatus* (68/200 g soil). Dichloropropene (Telone II) a partial soil sterilant applied pre-planting at 207 l/ha, and aldicarb (Temik 10G) a systemic nematicide applied at planting at 3.3 kg/ha, decreased numbers of *L. elongatus* by 94 and 76% respectively and significantly increased swede yields by over 30%. Chlorpyrifos (Dursban 5G), an insecticide applied at planting at 4.5 kg/ha, and benomyl (Benlate), a fungicide also applied to the soil at planting at 25 kg/ha, did not markedly affect numbers of *L. elongatus* and had no effect on yield. Yields were also not greatly affected by three difference levels of fertiliser, probably because of the drought during the summer.

(B. Boag)

PU 10(g) Devise improved control strategies for insects and mite pests of cane fruit

Clay-coloured weevil

Laboratory and field trials were continued to find a suitable replacement

[1]Mycology and Bacteriology Department

for DDT to control adult clay-coloured weevils (*Otiorhynchus singularis*) in raspberry. The dermal and stomach toxicity of 12 insecticides were compared with those of DDT (0.1% a.i.) in a laboratory experiment. Adult weevils were either dipped for 2 seconds in a solution of the insecticides before being dried and transferred to untreated foliage for up to 8 days, or were exposed to treated raspberry leaves and observed for up to 8 days. Cypermethrin, deltamethrin and flucythrinate (each at 0.01% a.i.) and fenitrothion (0.1% a.i.) were each more effective than DDT as dermal insecticides. Azinphos-methyl (0.1% a.i.) + demeton-S-methyl sulphone (0.3% a.i.) (azinphos-methyl mixture), carbofuran (0.1% a.i.), fenitrothion (0.1% a.i.), HCH (0.1% a.i.) and cypermethrin (0.01% a.i.) were more effective than DDT as stomach poisons.

Two field trials were done in May and June in a plantation with a history of weevil damage. In one, fenitrothion (1.1 l a.i./ha), azinphos-methyl mixture (0.28 + 0.08 kg a.i./ha) and a standard, DDT (1.0 l a.i./ha) were applied by tractor mounted sprayer at a rate of 1000 l /ha. Azinphos-methyl mixture was applied either during the day or at night when weevils were actively feeding on the foliage (*Ann. Rep. 1982,* 150). Weevil numbers, assessed by nocturnal sampling 9 days later, were significantly decreased by the nocturnal spray of azinphos-methyl mixture ($P<0.05$) and DDT but not by the other treatments.

In the second trial, single applications of the synthetic pyrethroid insecticides, cypermethrin (50 ml a.i./ha), and deltamethrin (22.5 and 15 ml a.i./ha), and the organochlorine insecticide HCH (156 ml a.i./ha) were compared with DDT and an untreated control. The chemicals were applied during the day and all treatments had significantly decreased weevil numbers 7 days after treatment. However, after 14 days weevil numbers in the plots treated with a lower rate of deltamethrin did not differ from those in the untreated plots.

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

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

Pratylenchus penetrans *damage to raspberry*

The first phase of research on *P. penetrans* which was identified as a potential pest of raspberry in 1974 has now been completed. The studies made included five replicated and four unreplicated field trials, surveys of raspberry plantations and planting stocks, and numerous pot experiments.

In summary, the results of these studies show that *P. penetrans* is able to damage raspberry directly, that it is widely distributed in Scottish raspberry plantations and within planting material, and it is therefore an important problem in Scotland. At infested sites pre-planting treatments with dazomet (Basamid) dichloropropene (Telone II) and metham sodium

(Vond Metam) all greatly improved the growth of newly planted raspberries and, at sites with more than 20 *P. penetrans*/200 g soil, were generally cost-effective. Initially dazomet appeared to be the most effective chemical for controlling *P. penetrans* but in later years dichloropropene and metham sodium proved to be equally effective. Dichloropropene and metham sodium have the advantage of being less costly than dazomet, but their effectiveness is adversely affected in cold, wet soils. In one trial, a combination of metham sodium with a low rate of dazomet (50 kg/ha) incorporated in the soil surface (2 – 4 cm) was more effective than the full rate of either chemical applied alone.

Pot-experiments with infested soil indicated that *P. penetrans* is not the only pathogen causing damage to raspberry when replanted on the same site. In some soils, fungicides which did not control *P. penetrans* greatly improved raspberry growth, with yet further improvements being obtained when these soils were treated with both a fungicide and a nematicide.

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

PHYSIOLOGY AND CROP PRODUCTION

P. D. WAISTER

The mathematical model for estimation of potential crop yield has proved valuable in assessing the extent to which farm or plot yields of potatoes fall short of those theoretically attainable. Attempts to quantify reasons for shortfalls have concentrated first on water and nitrogen as constraints, so that these factors may ultimately be incorporated in the model. Methods of estimating size grade distribution are also under development, as a basis for modelling the effect of environmental and cultural factors on the proportion of the crop suitable for particular uses. Collaborative work with the potato breeders aims to establish the relative sensitivity of genotypes to manipulation of stem numbers and hence size grades.

By the end of the year a new member of staff was in post to investigate the factors responsible for variation in tuber dry matter and in reducing sugar content. The potato physiology programme therefore now embraces each stage of the crop's development from seed preparation through to the quality of the harvested product.

Investigation of cane vigour control in raspberry has shown the variability of cultivar response and highlighted the need for more detailed examination of the characteristics that determine whether a cultivar responds to this potentially valuable technique.

POTATO

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

Potato: pre-emergence growth of sprouts

Experiments to examine the dependence of time from planting to 50% emergence on temperature were continued.

In one experiment seed tubers of five cultivars which had been presprouted by a treatment of 365 degree days (DD) above 4°C from dormancy break in the light were planted in compost at 2.5, 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.

Another experiment was designed to examine the possible equivalence, between the thermal time accumulated by a tuber during physiological ageing and that which elapses from planting to emergence. Seed tubers of cv. Pentland Javelin were given 800, 600, 400, 200 and 0 DD above 4°C before planting at two depths in six temperatures. At the higher temperatures the more aged seed gave higher average rates of sprout growth. At the lower temperatures differences between the growth rates from the several different ages of seed tuber were reduced, but growth was always more rapid when the tubers had sprouted than from unsprouted seed. At 5°C and below, sprout growth from middle-aged seed (200 and 400 DD) was slow but normal whereas seed which had been given 600 and 800 DD gave a proportion of 'little potato.'

In an experiment to examine pre-emergence sprout growth in a naturally fluctuating thermal environment, unsprouted and pre-sprouted seed of 13 cultivars were planted in the fields. The dates of 50% emergence from pre-sprouted and unsprouted tubers ranged over periods of 10 and 9 days respectively.

Over all cultivars the average date of 50% emergence from pre-sprouted tubers was 7 days earlier than from unsprouted. This interval represented 71 degree days above 4°C.

(D. K. L. MacKerron)

Potato: effects of drought on several cultivars

The potato cultivars Désirée, Maris Piper and Record were grown either fully irrigated or droughted. In the droughted treatment plants were grown through clear polythene laid at emergence to protect the soil from rain, and the maximum soil moisture deficit was 100 mm.

In Désirée, Maris Piper and Record respectively drought reduced total yield by 41, 52, and 47%, while ware yield was reduced by 42, 64, and 55%. Ware yield was less affected by drought in Désirée than in Maris Piper and in Record, because Désirée produced fewer tubers and consequently a greater proportion of the tubers attained ware size. There was no differential response to drought in total dry matter production of haulm and tuber, which was reduced by 38% (SE±2.2) over all cultivars. By limiting canopy expansion drought reduced the total amount of light intercepted by 32% (SE±6.6) over all cultivars, yet the coefficient for the conversion of light into dry matter was not reduced significantly. It is concluded that increased dry matter production under drought conditions might be best achieved by improvements in canopy expansion and duration under water stress.

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

Potato: water stress and tuber initiation and development

A field experiment examined the effects of water stress early in the season on tuber initiation and growth of cv. Maris Piper. Seed material,

consisting of bundles of four single-eye cores of 10 g fresh weight were planted in three treatments. These were (a) moist soil which was then fully irrigated, (b) moist soil from which water was withheld until 59 or 73 days after planting, and (c) dry soil from which water was withheld until 59 or 73 days after planting. Soil moisture deficits at planting were 10 and 20 mm for the moist and dry soils respectively, while the deficits after 59 days of witholding water were 49 and 57 mm; after 73 days the deficits were 56 and 62 mm.

Emergence was retarded by 5 days for seed planted into dry soil compared with that planted into moist soil. Tuber number was significantly lower in the plants grown in treatment (c), but this reduction was the result of lower stem numbers rather than differences in the numbers produced per stem. In all treatments the number of tubers per stem was considerably lower than previously found for irrigated glasshouse-grown potatoes. Tuber yield was 47 t/ha in the fully irrigated treatment (a), while the plants of treatment (b) and (c) which had water withheld until 73 days after planting, yielded 44 and 39 t/ha respectively.

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

Potato: light interception and growth

The pattern and amount of light interception during the season were examined, together with measurements of crop growth, in an experiment on the effects of different levels of N supply. Cv. Maris Piper was grown in a plot of low residual N, and pre-planting applications of 0, 4, 8, 16, 24 g/m^2 of N (Nitrochalk) were designated as N0, N1, – – – – N4, respectively. A sixth treatment (N5) of 16 g/m^2 of N was applied as a 50:50 split dressing before planting and at tuber initiation.

By mid-September, harvest indices including the weight of dead material had reached 0.88, 0.87, 0.82, 0.80, 0.83 in treatments N0 – N5. Apparent harvest indices (ignoring the weight of dead material), which are more usually measured, were 0.90, 0.91, 0.89, 0.85, 0.82, 0.85 respectively.

Rates of canopy expansion, total dry matter production and yield all showed that the largest difference was between N0 and the other treatments. Both the N0 and N1 treatments and to a lesser extent the N2, gave the appearance of being stressed for N (yellow-green leaves and poor canopy development). Maximum levels of light interception recorded were 0.76, 0.81, 0.85, 0.93, 0.95, 0.89 in treatments N0 to N5 respectively.

By the end of the season the integrated totals of intercepted radiation in the several treatments were ranked N0<N1<N2<N5<N3 = N4. Total dry matter production, tuber dry matter production and yield gave the same ranking.

The light conversion coefficients (the slope of the relationship between total dry weight and total intercepted light) in the treatments N1, N2,

and N5 were greater than in the higher pre-planting N treatments N3 and N4. The lowest value for the light conversion coefficient was in the N0 treatment. These results suggest that, while applications of N at and beyond the rate which is currently recommended may lead to prolonged interception of light and to increases in dry matter production, the consequent light conversion coefficient is lower.

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

Potato: canopy expansion in the field

Further field experiments examined on the influence of nitrogen application on canopy expansion in field crops of potato using two rates, 0 and 240 kg N/ha (Nitrochalk) at planting. The rate of appearance of leaves was similar at both N levels. The duration of expansion of individual leaves up to leaf 10 was similar between treatments and then increased for leaves 11 – 19. This increase was greater for 0 kg N.

In a second experiment tubers were planted at mid-April, late May and late June to correspond with average temperatures of 12, 16 and 20°C for the periods over which leaves were anticipated to appear. Initial results appear to confirm that the rate of leaf appearance is influenced mainly by temperature.

(W. W. Kirk, B. Marshall)

Potato: leaf development in controlled environments

Unsprouted tubers of cv. Maris Piper, previously stored at 2°C, were sprouted in the light at temperatures of 10, 15, 20, 25 and 30°C. Tubers were unwatered throughout the experiment, and were removed at intervals, the apical and lateral buds excised, and the number of leaf primordia on the main sprout counted.

The maximum number of leaf primordia initiated at all temperatures was 24.5. Scanning electron microscopy indicated that the transition of the sprout apex from a morphologically vegetative to a reroductive state was not the factor limiting the initiation of additional leaf primordia. The rate of initiation of leaf primordia declined steadily with time at each temperature although the rate of development at any given stage was a linear function of temperature.

(W. W. Kirk[1], H. V. Davies, 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

In 1983 the PMB sponsored a 2-year survey, the aim which was to couple environmental measurements with measurements of potato growth and development on a range of farms, in order to indicate sources of yield variation from site to site and the origins of the differences between

[1] Research Student

potential and achieved yields. In 1984 the survey of farm crops was extended to cover over 100 widely separated sites throughout the United Kingdom, in addition to 10 local sites studied as in 1983. These sites were selected to include fields on which yields were expected to be good, and others where poor yields were anticipated from past experience.

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 have 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, allow for a closer definition of reasons for shortfalls in yield.

The results suggested that crops grown from healthy unsprouted seed showed no decrease below potential during the first phase of growth, but an advantage of using chitted seed was to bring emergence forward by c. 9 days, giving 15% average increase in potential yield. In the second phase of growth, average dates of canopy closure differed for unsprouted and chitted seed within each of the PMB regions, but each of these matched very well with their respective predicted dates. The accuracy of the model to predict the emergence and canopy closure times allows comparison of the potentials in one year with those of an 'average' year using current weather data and long term average weather data.

The measurements made throughout the life of each farm crop enabled comparisons to be made of the actual crop yields with the calculations of the potential yields. Average potentials for irrigated sites ranged from 69 t/ha in Scotland to 99 t/ha in South West England. The highest yielding crop of all those studied was in the PMB South West Region which yielded 88.1 t/ha and represented 79% of the yield potential of that site. The final observed total dry matter production of three Scottish crops, and one crop each in of the Northern and East Midland PMB Regions were within 90% of their potentials.

(T. D. Heilbronn[1], D. K. L. MacKerron)

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

Potato: hexose metabolism in developing tubers

In their early stages of growth tubers of cv. Maris Piper have a high ratio of glucose:fructose. Experiments with ^{14}C-labelled sugars have indicated that fructose is preferred to glucose as a substrate for starch biosynthesis while more ^{14}C is released as $^{14}CO_2$ from glucose than from fructose. The rapid turnover of fructose appears to be related to the presence of a fructose-specific hexokinase.

(H. V. Davies, K. J. Oparka)

[1]Research Assistant

Potato: tuber growth and carbon partitioning

The growth rates of individual tubers were examined in observation chambers in which the roots were grown in different environments from the tubers. There were four rooting environments: UC compost, sieved field soil, Perlite (low N status), Perlite (high N status). The Perlite treatments were watered at weekly intervals with complete nutrient solution. The tubers of all treatments were grown in dry, finely-sieved sand.

The formation of tubers was delayed by about 2 weeks in the compost treatment, although these plants produced a greater total tuber number and total volume than the other treatments.

The relationship between tuber growth rate and within-tuber assimilate partitioning was examined following labelling of the haulms with $^{14}CO_2$. There was a good correlation between tuber growth rates and ^{14}C import rates, and rapidly-growing tubers which formed late had the highest turnover of soluble ^{14}C into ^{14}C starch. Slow-growing tubers had low import rates and low ^{14}C starch:soluble ratios. Reducing sugar levels were high in small tubers which had stopped growing and also in newly formed tubers.

(K. J. Oparka)

Potato: translocation within and between stems

Assimilates exported from the leaves of evenly illuminated potato plants remained confined to the same side of the stem as the source leaf, in a pattern consistent with the internal vasculature of the plant. Consequently, when a single leaf was fed, ^{14}C import into the tubers bore little relationship to tuber growth rates. However, alteration of source/sink relations by pruning to a single source leaf per stem resulted in an even distribution of ^{14}C throughout the vascular bundles of the stem and ^{14}C import into the tubers bore a closer relationship to tuber growth rates than to the phyllotactic relationship of the tubers to the source leaf. The sink demand of rapidly-growing tubers appears to be met by lateral redistribution of assimilates in the stem through vascular rechannelling at leaf nodes.

Labelling a single stem of a potato plant resulted in little or no movement of ^{14}C into tubers on unlabelled stems. However, removal of the unlabelled stems at ground level induced a significant movement of ^{14}C from the labelled stem to the tubers on unlabelled stems, this movement occurring via the mother tuber. Shading the unlabelled stems had less effect than did stem removal.

^{14}C sucrose injected into single daughter tubers was translocated to other tubers on the same stem and also to tubers on a second stem at the opposite end of the mother tuber. The sucrose was converted into starch in these tubers.

(K. J. Oparka, H. V. Davies)

Potato: influence of applied N on carbon partitioning

Carbon partitioning in a field crop of cv. Maris Piper was examined in relation to high (240 kg/ha basal dressing of N) and low (no applied N) nitrogen nutrition. Plants were labelled with $^{14}CO_2$ before tuber initiation and at four further dates during the tuber bulking period. Groups of plants were harvested 24 h after labelling to obtain an estimate of current assimilate partitioning, and then at intervals to determine the long-term partitioning of ^{14}C between haulm and tubers. The partitioning ratio (^{14}C activity in tubers/total ^{14}C activity) was significantly higher in the low N treatment. However, by the final harvest the differences between treatments were reduced.

(K. J. Oparka, B. Marshall)

Potato: the formation of adventitious buds on sprouts

Tubers of cv. Maris Piper were chitted at 10°C for 28 days either in the light or dark. The scale leaves at the base of the sprout were marked with liquid paper and tubers planted in pots containing field soil. After 28 days an average of three adventitious buds were present per sprout. The buds developed below the lowest scale leaf. From the lack of chlorophyll in adventitious buds from light-chitted tubers it is assumed that the buds developed after planting. Ten per cent of adventitious buds formed stolons compared with 90% of below ground axillary buds.

(H. A. Ross, H. V. Davies)

PU 7(c) Study the physiological basis of intersprout competition in the potato during the pre-emergence phase

Potato: intra plant competition

The effects of water and nutrition on plant competition were examined using single-sprouted cores taken from tubers of cv. Maris Piper. These were planted singly and in groups of four at 30 x 75 cm spacing. Three treatments were applied: (a) unirrigated control (b) trickle irrigated to maintain the soil moisture deficit below 25 mm, and (c) as (b) with the addition of JI liquid feed (54 g/m^2) at 14 day intervals; these treatments were applied from planting at the end of April until 21 June when the LAI in irrigated four-stemmed plants was approximately 3. During this period rainfall was only 56 mm (30 year mean = 103 mm).

The rate of leaf expansion was lower in the control plots than in the irrigated from soon after emergence. However, this did not affect the stage of development at which competition between stems occurred, which was between LAI 0.4 and 0.8 for four-stemmed plants. There were no differences in leaf area between treatments (b) and (c) during the period up to 30 days after emergence.

(P. A. Gill, P. D. Waister)

PU 7 (f) Examine (with MISR) the effects of mineral nutrition on growth and development of potatoes

Potato: physiological responses to nitrogen fertilisation

The physiological responses of the potato plant to applied nitrogen (0 and 240 kg/ha) were determined in a field crop. The fourth and fifth leaves from the top of the plant were analysed throughout growth.

Nitrate reductase activity (*in vivo* method) was 50% higher in the high N treatment although the development of enzyme activity followed a similar pattern in both treatments, increasing to a max. 90 days after planting and decreasing from day 100 onwards. The decrease of activity coincided with a marked fall in the concentration of nitrate in the petiole sap, which was always lower, c. eightfold, in the low N treatment. Leaf nitrate concentrations decreased in both treatments from the first harvest at day 66 onwards, and higher levels were again found in the high N treatment. The concentration of sugar in the petiole sap was similar in both treatments until day 130 when that in the low N plots fell substantially, and this coincided with a decrease in the rate of tuber bulking. The fall in the concentration of sugars in the petiole sap of the high N treatment was delayed by 20 days and this appeared, at least in part, to account for the difference in tuber yield between the treatments at the final harvest. The use of sugar levels in petiole sap as an indicator of tuber maturity and processing potential is under investigation.

(H. V. Davies, H. A. Ross)

Potato: screening for chocolate spot in tubers

Certain cultivars are highly susceptible to the physiological disorder known as chocolate spot which is believed to result from a deficiency of calcium. A reliable screen is required when breeding new cultivars and a preliminary investigation has shown that symptoms identical to those found in the field can be induced by manipulating the phasing of calcium supply to tubers growing in Perlite and watered with nutrient solution.

A reduction in the concentration of calcium in the solution approximately half way through the bulking period proved more effective than long term exposure of the plants to a low supply of the ion.

(H. V. Davies, H. A. Ross)

Potato: calcium distribution in the tuber

Tubers of cv. Maris Piper were grown in the presence of ^{45}Ca and the distribution of radiolabel was mapped by autoradiography. Areas of high activity included the periderm, the vascular ring (primarily composed of xylem) and regions occupied by phloem bundles internal and external to the ring; this raises the possibility of calcium movement into the tuber through the phloem. Uptake through the periderm accounted for only 30% of total tuber calcium. Microauto radiography indicated that there was little ^{45}Ca associated with cell walls. Much more was located in the

cytoplasm/vacuole. Some cells with very high activity contained calcium oxalate crystals but the frequency of such cells was extremely low. Chemical fractionation of the calcium tended to corroborate these findings in that 75% was associated with the fraction believed to contain soluble calcium compounds, e.g. organic acids, nitrates, and chlorides, and only 20% with the fraction believed to contain calcium previously bound as pectate. The fraction believed to contain calcium oxalate therefore accounted for a very small percentage of the total calcium.

(H. V. Davies, 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

Detailed examinations of early shoot, stolon and tuber growth have been made to try to understand the mechanism controlling the marked increase in tuber number of plants grown in MM conditions compared with those grown in ordinary soil.

The cultivars Maris Piper, Pentland Squire, Record, Cara, Foxton, Kennebec, Maris Bard and Pentland Javelin were grown in MM, high input or normal field soil plots. MM plots comprise a sand/peat mixture of high nutrient status and are well supplied with water and liquid nutrients. High input field soil plots receive similar treatments, but the normal input field soil treatment corresponds to good commercial practice but without irrigation. Total yields averaged over cultivars were similar for the MM plot and high input soil treatment at about 100 t/ha, whilst that for the normal input soil was 32 t/ha. These differences are of the same order as those found previously. Final tuber numbers were again greatest from the MM plot with 3.7 tubers per stem compared with 2.9 tubers per stem for the two soil treatments.

When averaged over cultivars, the number of stolon origins on 25 June was similar for the three treatments with a mean of 7.2 stolon bases per stem. At the same date numbers of stolon tips were 13.4 and 7.5 per stem for the MM plot and two soil plots respectively, indicating substantial amounts of branching in the MM plot. Corresponding values for total potential tuber sites at this time (i.e. stolon tips + tubers) was 19.1 and 11.4 per stem.

(R. Thompson, H. Taylor)

Potato: tuber growth and harvest index of cv. Record

Seed of Record was planted at 0.2 x 0.75 m on 30 April and grown either with normal commercial inputs with or without irrigation, or with irrigation and high levels of nutrients applied in the irrigation water. The crop was harvested on seven occasions between 10 July and 2 November,

[1]MISR

tubers were graded into 5 mm size classes and the fresh weight and number of tubers in each class recorded. Total plant and tuber dry weights were also obtained for the estimation of harvest index (ratio of tuber dry weight : total plant dry weight).

Tuber fresh weights reached constant levels for the non-irrigated (27 t/ha) about 10 August and for the irrigated plot (55 t/ha) about 20 August; final yield for the high input treatment increased throughout the period of observation and reached 70 t/ha.

Harvest indices for the non-irrigated and irrigated treatments were not significantly different from each other at any of the seven harvests and increased from c. 0.62 on 10 July to 0.92 on 2 November. The values for the high input treatment were significantly lower than for either of the other two treatments, increasing from 0.45 on 10 July to 0.88 on 2 November. Final dry matter contents of the tubers were 27, 25 and 21% for the non-irrigated, irrigated, and high input treatments respectively.

Tuber size grade distributions, when expressed as fractions by weight within a weight class, could be described by the normal distribution with minor modifications. The distributions are characterised by two parameters, μ and σ which describes the location and width of the distribution respectively. Linear relations were found between σ and μ and also between μ and yield. Treatment had little, if any, effect. The relation between σ and μ was similar to that reported by other workers for a different cultivar and indicates an increasing spread in the distribution of tuber weights with time, which is proportional to μ, and hence yield. There was no significant difference in tuber number between treatments with 85, 86 and 90 tubers/m^2 for non-irrigated, irrigated and high input treatments respectively. Therefore effects of different tuber number on the relation between μ and yield could not be explored in this experiment.

(R. Thompson, H. Taylor, B. Marshall)

Potato: influence of nodal origin on tuber growth

Samples from the above experiment were used for more detailed analysis of the origin of tubers. The number and fresh weight of tubers arising from each node of a potato stem were examined at two harvest dates for the cultivars Maris Piper, Record, Foxton and Kennebec, the latter two cultivars being known to differ markedly in tuber number and tuber size.

The mean number of below-ground nodes was Maris Piper 5.3, Record 6.3, Foxton 7.9, Kennebec 5.2, and there were no significant differences in node number between the sand/peat and soil treatments. In Maris Piper tuber fresh weight per node was evenly distributed across nodes 1 – 4 (nodes numbered from mother tuber to soil level) while in the other cultivars tuber fresh weight per node declined at nodes closer to soil level and the larger tubers were associated with nodes 1 and 2. In all cultivars the total number of potential tuber bearing sites (all stolon tips,

including those tuberised) was greater at the upper nodes (nodes 4–6) and declined at lower nodes. However, the percentage of sites which successfully formed tubers above 1 g was 60–70% at node 1, declining to 20–30% by node 6. When averaged over all the cultivars there was a 51% increase in the number of potential tuber-bearing sites in plants grown in sand/peat compared with soil and an 18% increase in the number of those sites which successfully formed tubers above 1 g fresh weight. The increase was brought about by branching of the primary stolon (rather than production of second-order stolons) and occurred at all nodes.

(K. J. Oparka)

Potato: small set performance

The effects of seed sizes ranging from 10 to 100 g on yield and size grade distribution have been examined with the cultivars Maris Piper and Pentland Crown. As in previous years the most important difference between sizes was found to be the numbers of stems per tuber produced. If this is accounted for adequately, any remaining effects of mother tuber size are small, with the possible exception of that for tubers <20 g. It still remains, however, to determine the reasons for the large between-year differences in stem numbers.

(R. Thompson, H. Taylor)

Potato: origin of seed on performance

The percentage dry matter content of tubers from three different levels of inputs in the measured maximum (MM) yield experiments have consistently differed greatly, so that it would not be surprising if their performance as seed also differed. Tubers of the cultivars Maris Piper, Pentland Squire, Record and Maris Bard were selected for planting from crops grown in MM conditions (high input + compost), high input field soil plots or normal input field soil conditions. The percentage dry matter contents from these three sources averaged over cultivar were 24, 20 and 17% respectively. Despite such large differences there were no effects on stem number, tuber number or yield.

(R. Thompson, H. Taylor)

Potato: effects of planting date of mother crop on seed tuber performance

Tubers of cv. Maris Piper were produced from crops planted in April, May, July and August 1983 to provide progeny with a wide range in tuber initiation dates, and hence potential effects on seed performance. Seed tubers weighing about 10 g were selected from all planting dates, and weighing 80 g from the first three dates, and after storage at 2°C tubers were planted at 15 and 30 cm spacings respectively, in 78 cm drills. This attempt to achieve similar stem densities by adjusting the spacing for each set size was only partly successful with averages of 12

stems/m^2 and 17 stems/m^2 for the small and large sets respectively. The crops were harvested on 22 August and 16 October, but there were no interactions between harvest date and other factors, so only averages over harvest dates are quoted.

The number of stems per tuber was similar for the small sets from each mother crop planting date with an average of 1.4 stems per tuber; but values for the large sets increased with delay in planting date of the mother crop with 3.6, 3.9 and 4.4 stems per tuber for those with April, May and July planting dates respectively.

The only effect of planting date of the mother crop on total yield was that small seed from the last planting date produced 49 t/ha compared with an average of 56 t/ha for the earlier plantings. Each of the three mother crop planting dates gave similar yields for the larger seed tubers with an average of 62.7 t/ha.

(R. Thompson, H. Taylor)

Potato: plant breeding M4 clone assessment

Some 70 clones from the M4 and later generations of the SCRI potato breeding programme were grown at two spacings in 76 cm drills with 15 or 30 cm within row spacings, to establish the range in response of a wide range of genotypes to competition in terms of yield and size grade distributions.

The rank order for yield differed for the two spacings, which in turn differed from the order using interpolated values for 20 stems/m^2. As expected, clones differed in responsiveness to changes in stem density in terms of yield, however, there was no relationship between total yield per unit area and responsiveness to changes in stem density. For example clone 13578.2 was the highest yielding with 87 t/ha at 20 stems/m^2 and showed the third greatest response to changing density with 24.4 g/m^2 per unit change in stem number at a stem density of 20 stems/m^2. In contrast clone 135546 A1 was the second highest yielding at 20 stems/m^2 with 86 t/ha, but was amongst the least responsive to density, its yield altering by 10.3 g/m^2 per unit change in density at 20 stems/m^2. Rate of change in average tuber weight at 20 stems/m^2 also varied between clones ranging from 4.5 g/stem/m^2 to 0.11 g/stem/m^2.

(R.Thompson, H. Taylor)

Potato: haulm desiccant evaluation

In two successive years, haulm desiccation with diquat or metoxuron had no adverse effect on the sprouting or subsequent field performance of chitted or unchitted tubers of cv. Maris Piper. Treatment with glufosinate inhibited the subsequent chitting of tubers and severely affected emergence and growth of tubers planted in the field. This chemical is not suitable as a desiccant for seed potato crops.

(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 SCRI model of potato growth (*Ann. Rep. 1983,* 160 – 161) has proved to be valuable tool in the analysis of an extensive PMB funded survey of farm crops grown throughout the UK (see p. 151). The predicted date of emergence for unsprouted tubers was on average 1 day earlier than the observed date. However, for pre-sprouted tubers the predicted date was too early and a function is to be developed when results from controlled temperature experiments have been analysed (see p. 148). The predicted time of canopy closure (leaf area index of 3), using the observed emergence date, was on average less than 1 day different from the observed date. However, during the period from emergence to canopy closure, the estimated total dry matter was less than that for crops grown to their full potential. As a first step to improving the estimate, a logistic function describing the fraction of radiation intercepted as a function of thermal time (base temperature 0°C) has been fitted to data from well-irrigated crops. The base temperature of 0°C is still to be confirmed by developmental observations of leaf growth in controlled environments. Finally, the potential value of the light conversion coefficient, that is the quantity of dry matter produced per unit of radiation intercepted, was again shown to be around 1.85 g/MJ (total solar radiation) by crops grown with non-limiting water and nutrient supply (see p. 150).

Work is now in progress to develop time dependent relations between tuber yield and total dry matter. Initially this will be at an empirical level using regression analysis. However, it is hoped that a more mechanistic sub-model can be developed from partitioning experiments using carbon 14 (see p. 154). An evaluation of mathematical and statistical functions to describe tuber size distributions is also underway.

The SCRI model is being used in collaboration with R. E. Thornton[1], and D. Nelson[2].

(B. Marshall)

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

Growth and yield were markedly checked by drought giving a much reduced range in both maturity and yield compared with that found

[1]Co-operative Extension, Washington State University, USA
[2]CIP, Peru

previously. The large seeded Minica was again amongst the earliest to mature and higher yielding with 2.7 t/ha. Similar in maturity to Minica with yields of 2.6 t/ha were two small seeded breeding lines ETS 64/16 and ETS 131/5 derived from the SCRI/PBI breeding programme for early maturity. The higher yielding cultivars with intermediate maturity included TG Long Pod (2.6 t/ha) from PBI, with a greater ovule number per pod than normal for small seeded types, and ETS 105/8 (2.8 t/ha) and Syn 2 (2.9 t/ha) which were also derived from the SCRI/PBI programme.

Maris Bead was 6 days later than Minica and gave a yield of 2.6 t/ha.

(R. Thompson, H. Taylor)

Fodder pea: cultivar trial

Of the 15 cultivars of fodder pea examined five were semi-leafless. The highest yields were produced by the conventional cultivars Belinda (3.6 t/ha), Bohatyr (3.5 t/ha), Smaragd (3.4 t/ha) and Dukat with 3.4 t/ha. The control cv. Birte produced 3.3 t/ha, and the highest yielding leafless type, HJA 51792 gave 2.9 t/ha. The dry weather reduced haulm growth compared with that produced in a normal season but some late lodging occurred. There were large differences in haulm length which ranged from 51 cm for Belinda to 124 cm for 159/5.

The earliest cultivars Heron and Birte reached an estimated 14% m.c. on 2 August. This was 6 days earlier than Progreta and 5 days earlier than Maro, which were the latest.

(R. Thompson, H. Taylor)

FRUIT CROPS

PU 11(a) Study physiological factors affecting the maturation and quality of raspberry fruits

Although the raspberry fruit nearly quadruples in size during the last 10 days of its development its solute potential as measured by the osmolality of its juice changed little as berries passed from under ripe to the over ripe stage of maturity. This resulted from the increase in sugar concentration being balanced by decreases in the other main osmotica, organic acids and potassium.

A comparison of the juice from nine cultivars showed that a high percentage of citric acid was usually accompanied by a low percentage of sugar e.g. Glen Isla and Glen Prosen; but in Malling Delight there was a low acid and high sugar content.

Differences in berry weight between cultivars were positively correlated with both the number of pyrenes per berry and drupelet size. This indicated that drupelet number (which is mainly genetically determined) is just as important as drupelet size (which is partly physiological controlled) as a component of berry weight.

Little is known about the changes which occur in a raspberry after it has been picked. Assuming that moulds do not occur it is the amount of post-harvest deterioration which determines when berries are no longer saleable.

To obtain more information on this topic ripe berries of cv. Malling Jewel were stored individually in open glass tubes in a refrigerator at c. 5°C or at the ambient temperature of c. 22°C.

After 8 days storage, berries at 5°C lost about 5% of their initial weight whereas those at 22°C lost about 25%. The percentage of reducing sugar in the berries increased during storage at both temperatures but although the actual amount per berry increased at 5°C it decreased at 22°C. The concentration and quantity per berry of non-reducing sugar decreased at both temperatures although the changes were less severe at the lower temperarure. The concentration and amount per berry of citric acid were relatively stable at 5°C but both decreased at 22°C.

Shelf life was terminated by juice leakage from the berries, which occurred at more than 8 days at 5°C, and after about 5 days at the ambient temperature.

(D. T. Mason)

PU 11(b) Study dry matter partitioning and compensation between yield components in cane fruits

The vegetative (primo) canes of the raspberry plant arise from the bases the fruiting canes and because they share the same root system and grow close to each other they are in competition for both water and light. The nature of this competition was studied by either removing the primo canes completely or by training them horizontally so that they were still in competition with the fruiting canes for water but not for light. Both treatments increased berry size in the same way as biennial cropping which removes primo canes, or cane vigour control which delays the development of primo canes. Changes in the percentage of acid and sugar in the berries were slight but both treatments increased the amounts of these substances per berry and this indicated that competition for light was more important than competition for water.

It is possible that assimilates can move from primo canes to fruiting canes or from one fruiting cane to another depending on the relative sink strengths of the various canes. To test whether this is likely single fruiting canes were completely defoliated on plants with or without primo canes. Spawn removal had effects similar to those described earlier and the defoliated canes behaved in a similar fashion irrespective of the presence or absence of primo canes. Defoliation decreased berry weight and the percentage of reducing sugar and to a lesser extent the percentage of non-reducing sugar; the percentage of citric acid was

virtually unchanged. The amounts of sugar and acids per berry were severely reduced by defoliation. It therefore appears unlikely that significant amounts of assimilates can pass freely from cane to cane.

Berries from the upper part of a fruiting cane have a higher percentage of soluble solids than those harvested at the same degree of ripeness, from lower down the plant (*Ann. Rep. 1982,* 168). This difference in berry composition due to position was investigated by recording the effects of removing berries from the upper, or from the upper and middle laterals, on the composition of the basal berries.

Removal of the top berries had little effect on the composition and size of the basal berries but removing both the top and the mid berries increased berry weight by 16%, the amount of reducing sugars by 45% and that of non-reducing sugar by 146%.

The results suggest that assimilates can move out of laterals where the berries have been removed into laterals still bearing fruit.

(D. T. Mason)

PU 12(a) Study physiological and cultural factors affecting the mechanical harvesting of soft fruits

RASPBERRY

Residual effects of mechanical harvesting

A plantation of cv. Malling Jewel part of which had been harvested by machine and part by hand in 1983 was hand picked in 1984 to measure residual effects. Fruit yields and mean berry weights from both hand and machine-picked plots were also similar. It seems likely that the dry weather conditions at and after the 1983 harvest were not conducive to the development of the cane blight fungus (*Leptosphaeria coniothyrium*) which can devastate machine-damaged canes.

(M. R. Cormack)

Hand and machine harvesting

Machine picking with the Littau harvester was compared with hand picking in a plantation of two cultivars and two selections, Malling Jewel, Glen Prosen, 33R40 and 14/106.

Hand picked yields were about 9 t/ha from Malling Jewel, Glen Prosen and 33R40 and over 12 t/ha from 14/106. The machine picked 77% of these weights from Glen Prosen, 70% from Malling Jewel and 33R40 and 65% from 14/106. Machine picked Malling Jewel contained 9.1% by weight of fruit with stalk attached, Glen Prosen 6.4%, 33R40 4.7% and 14/106 2.5%. Each sample contained about 2% mouldy or mummified fruit.

Potential yield was calculated from berry numbers stripped from a small sample of two canes per plot (12 canes per cultivar) shortly before

picking started. Hand pickers achieved about 60% of potential and the machine about 40%.

The picking season in 1984 was unusually warm and dry (as it was in 1983 and 1982) and the quality of the fruit picked by machine was good with little mould in evidence. Also, the proportion of fruit picked by machine from Malling Jewel compared to hand, and the low proportion of stalked fruit in machine picked 14/106, was consistent with previous experience.

(M. R. Cormack)

Fruit sorting

Preliminary trials with a simple sloping belt sorter (*Ann. Rep. 1983,* 165) were sufficiently encouraging to merit further investigation. The belt was fitted with a device to maintain slope at pre-set value and mounted to provide stability on the deck of the Littau machine.

In a plantation of cv. Malling Jewel the machine picked 5 t/ha of which 82% was in the ripe category, 11% was ripe + stalk, 4% was under-ripe and 3% was mouldy or mummified. The belt separated 53% of the ripe fruit into the IQF category, and the proportion of unacceptable fruit in this grade was 8%, which was reduced to 3% by one hand sorter. When the sloping belt was used at the same setting for a number of cultivars significantly better results were obtained with fruit of Glen Prosen than of Malling Jewel.

(M. R. Cormack)

Mechanical harvesting of a farm crop

In 1982 a comparison was made between machine harvesting with the Littau harvester and commercial hand picking on a grower's holding of cv. Malling Jewel (*Ann. Rep. 1982,* 167). All rows were hand picked in 1983, and then the machine and hand pick comparison was repeated in 1984. The hot dry weather concentrated the picking season and with the the smaller numbers of pickers available made it difficult to pick as frequently as required. Under these circumstances the machine harvested rather more than the pickers.

The machine picked 55% of the estimated potential yield calculated from fruit stripped and counted from a small sample of canes prior to harvest, and hand pickers 53%.

(M. R. Cormack)

PU 12(b) Select cultivars and devise production methods for soft fruit crops in northern Britain

Cane vigour control in raspberry

Application of dinoseb-in-oil to remove the first flush of vegetative canes in cultivars Glen Moy and Glen Prosen again resulted in inadequate

production of replacement canes, despite the plantations being in their fourth growing season and apparently very vigorous. Investigations are in progress on the size of the cane bud reservoir in established stools of these cultivars and its reaction to the removal of first-flush canes.

Evaluation of paclobutrazole and mefluidide in raspberry has indicated that these growth regulators are unlikely to be suitable for control of cane growth. Paclobutrazole temporarily stunted the growth of some, but not all, young canes emerged at the time of treatment (15 cm high), while treatment with mefluidide scorched cane foliage, killed some growing points and resulted in branching of affected canes.

(H. M. Lawson, M. E. Halford[1], J. S. Wiseman)

National Fruit Trial of raspberries, 1980

Selection 731/53 cropped at 16.8 t/ha, cv. Glen Moy at 15.7 t/ha and selections 33R40 and 3650/6, and cv. Joy, cv. Glen Clova and selection 7515C5 all produced more than 14 t/ha. Both early and late cultivars are represented in this high yielding group.

(M. R. Cormack)

Yield trials of Strawberry selections

Since planting in spring 1983, a trial of SCRI selections has suffered two unusually dry growing seasons and the yields in 1984, the first fruiting year, were low. Only four selections exceeded 10 t/ha, the highest being 69DB54 (12.5 t/ha) and 69DK60 (11.5 t/ha). Both are early season selections, ripening at least as early as cv. Cambridge Vigour which produced the same yield as cv. Cambridge Favourite (9.2 t/ha).

(M. R. Cormack)

Vaccinium species

Yields were similar from the two cultivars Bluecrop and Berkeley and averaged 11.1 t/ha in irrigated plots and 3.7 t/ha in non-irrigated plots. Mean berry weight of irrigated Bluecrop was 1.65 g and non-irrigated 1.24 g and in Berkeley 1.28 g and 0.83 g respectively.

Vegetative growth was more vigorous in the irrigated plots.

(M. R. Cormack)

WEED INVESTIGATIONS

PU 1(b) Study weed biology and herbicide activity in crop rotations

Weed seed banks in arable soils

Preliminary examinations of data on the weed seed content of soils from 20 upland swede fields has indicated that cropping sequence and soil characteristics influence the distribution of several weed species. A total of 60 species was recorded, of which 12 species were of major importance,

[1]Crop Division, ESCA

forming 91% of all seeds recovered from the 20 fields. Unexpectedly, since they are seldom seen as weeds in upland swedes, *Juncus* spp. ranked third in overall numbers of seeds recovered from soil samples, after *Spergula arvensis* L. and *Stellaria media* (L.) Vill.

(H. M. Lawson)

Use of image analysis to identify weed seeds

Preliminary investigations have shown that simple image analysis techniques involving use of shape parameters can reliably identify seeds of a range of common arable weed species. Certain species whose ranges of size and shape characteristics overlap will require the use of more complex parameters than those employed so far.

(H. M. Lawson, P. Smith[1])

PU 9(a) Study herbicide tolerance and control of weeds in arable crops

Herbicide evaluation: potato

Pendimethalin, CME 12701 and fluorochloridone applied post-planting or at 10% emergence had no adverse effect on yield of cv. Maris Piper in the dry spring and summer conditions of 1984. Pendimethalin again caused leaf cupping and malformation of emerged foliage, while CME 12701 caused transient leaf scorch and flourochloridone completely bleached emerged foliage. Subsequent growth did not show these symptoms. Tubers from plots treated with these herbicides in 1983 showed no adverse effects of earlier treatment on sprout development in store. EL 107, evaluated for the first time in 1984, caused no foliar effects when applied at 10% emergence and had no adverse effect on yield or size distribution of tubers.

Applications of bentazone or metribuzin when potato foliage was 15 cm high caused foliar scorch. However plots treated with bentazone at 1.4 kg a.i./ha (± Actipron) showed no reduction in tuber yields, while metribuzin at half the normal dose recommended for less sensitive cultivars reduced seed tuber yield in cv. Maris Piper by 22%.

A trials programme was initiated in 1984 to assess and quantify the effects of clopyralid contamination of seed potatoes as a result of soil residues, spray drift or inadequately cleaned spray tanks. Preliminary results have shown that relatively high levels of contamination are needed to produce foliar symptoms in the crop and to reduce tuber yield significantly. Foliage, tubers and soil are being analysed for clopyralid residues. Stored tubers will be chitted and subsequently planted in the field for the assessment of possible residual effects on the growth and yield of the next crop.

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

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[1] Data Processing Department

PU 10(f) Study herbicide tolerance and the ecology and control of weeds in soft fruit crops

Information retrieval systems for herbicide information

The HORTIHERB file was extended to include information on top fruit, flower bulbs, hardy ornamentals, container grown stock, herbaceous and bedding plants and a number of herbs. Costs of recommended rates of herbicides (relative to simazine) were included in the herbicide section. A range of BASIC programs has been devised to facilitate the extension, editing and updating of the file. These have been incorporated into a HORTIHERB editing manual.

(H. M. Lawson, P. Smith[1])

PU 4(f) Study herbicide tolerance and the control of weeds in forage brassica crops

Herbicide evaluation: swede

EL 107 (pre-emergence) and pyridate (various stages post-emergence) showed inadequate margins of safety to swede cv. Marian.

Benazolin was again examined as a post-emergence treatment at a range of doses and growth stages. Crop tolerance was satisfactory but the limited weed control range of this herbicide will require its use in mixtures.

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

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[1]Data Processing Department

CHEMISTRY

M. J. ALLISON

As in previous years, the main work of the Chemistry Department concerns the routine estimation of quality factors important in plant breeding, although the number of routine samples analysed was less than in previous years. Routine chemical estimations included SMCO in brassica (740 samples); thiocyanates in brassica (440 samples); the malting quality of barley (1,000 samples); nitrogen content (770 barley and brassica samples); the digestibility of kale (1,000 samples) and the total glycoalkaloids of potato tubers (19 samples).

During the year, a Gilson HPLC gradient system was acquired to enable the separation and measurement of individual anthocyanins in black currant extracts. This method has proved to be successful and can now be applied to the breeding material. In addition, individual glucosinolates in brassica material were separated on HPLC and identified with the help of standards, and preliminary studies indicated that a reverse phase HPLC system is a more sensitive tool for barley cultivar identification than SDS PAGE electrophoresis.

Further studies this year on the malting quality of barley have revealed that all of the cultivars currently in use that malt most readily, including winter barleys, also have a very low milling energy. This finding has rekindled interest in the biochemistry and genetics of the factors that influence this characteristic.

Progress was also made this year in shortening the analysis time required for the estimation of SMCO content of brassica, and consequently, the rate of sample throughput has been doubled.

Work continued on the possibility of rapidly estimating cellulase digestibility of kale using NIR. However, the main absorbance peaks for the new marrow stem kale population differed from those observed for the previous polycross population. Thus, the work required for recurring calibration to generate specific prediction equations may not be worthwhile. Collaborative work with the MAFF Stored Products Laboratory on the estimation of mite infestation in animal feeds by NIR continued to be successful due in part to the addition to the Neotec software of a Principal Components Analysis, although it became necessary to make a more extensive use of EMAS to cope with the calculations.

The application of Principal Components Analysis and other new software to NIR analysis seems to be a valid and successful means of

wavelength selection for prediction equations. New possible applications of NIR can now be tested thoroughly from the point of view of calibration and prediction of sample values. It is hoped that these advances will result in more of the Department's routine work being estimated by NIR.

PU 1(a) Develop NIR analyses to predict specific biochemical components in crops and pathogens

During the year collaborative work with J. W. McNicol[1] continued on the development of a new software package for use with NIR analysis. This system was incorporated with existing NIR techniques and extensively tested. Preliminary results indicate that the Principal Components Analysis provides a reliable method for identifying spectral variation that relates to sample composition. Regression models based on Principal Components Analysis worked equally as well as those based on reflectance values at specific wavelengths, and were more readily derived. Progress was also made in relating spectral variation to sample composition. This technique also showed clearly, often in the first component, the effects of particle size variation between the samples.

The collaborative study on mite infestation in animal feeds, with the MAFF Stored Products Laboratory, continued to be successful with the calibration equation obtained in 1983, predicting the mite numbers in 1984 samples (NIR versus visual scores, $r>0.90$). Preliminary investigation on the estimation of protein and starch contents in potato (with H. V. Davies[2]) indicated that these characteristics could be measured with sufficient accuracy for use in breeding programmes.

(I. A. Cowe)

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

The main proteins, the B and C hordeins, in barley endosperm separated by SDA PAGE electrophoresis, proved useful as markers in crosses because of their extensive polymorphism and relatively simple genetic control. This year a reverse phase HPLC system was modified using a Gilson gradient chromatogram to give a resolution of B and C hordeins that is superior to that achieved using unidirectional electrophoresis. This increase in resolution proved to be a sensitive aid to cultivar identification and promises to be a sensitive tool for the detection of protein variants in barley.

(H. Bain, M. J. Allison)

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[1] Data Processing Department

[2] Physiology and Crop Production Department

PU 2(f) Develop, and use, automated tests for malting, distilling, brewing and milling quality

Further studies were made on the correlations between hot water extracts from micromalts, and scores of grain modifications using the Carlsberg malt Modification Analyser this year. These correlations have been reasonably high over the past 2 years, so that the Carlsberg block test could be introduced as an effective screening method that takes account of malt enzyme production, especially when supported by other screening systems. Recent work on the milling energy of current barley cultivars has shown that both spring and winter barley cultivars, with very high malting quality, also have a very low milling energy. Because of this observation, a refurbishment of the Comparamill has been given a high priority.

The need for careful sample preparation was emphasised this year, when NIR analysis revealed that differences in grain moistures, which, in turn, led to differences in hot water extract, were due to varying drying rates of two grain dryers.

(K. Taylor)

PU 5(l) Develop, and use, screening tests for important compounds in brassica breeding material

An attempt was made this year to increase the rate of analysis of SMCO in brassica because the autoanalyser method is too slow to provide an effective screening system. Removal of the ion exchange column from the autoanalyser system, so that 10 or more samples could be run simultaneously with autoanalysis of the appropriate column effluent, resulted in a doubling of throughput to 300 samples per week. Column to column variation was acceptably low, and thus the loss in accuracy appeared to be negligible.

As in previous years, thiocyanates were estimated as a measure of the indole glucosinolates in kale. In addition, a good qualitative separation of all of the individual glucosinolates was achieved using HPLC. This new system can be used to estimate the goitrogens in brassica, but it is too slow (seven chromatograms per day) to provide a screening system for the goitrogenic glucosinolates.

(D. W. Griffiths)

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

Four main anthocyanins, and several lesser peaks due to acylated anthocyanin have been resolved from black currant extracts injected into an HPLC gradient system. Although not strictly quantitative, accurate estimations can be made of the delphinidin 3-rutinoside to cyanidin 3-rutinoside (main anthocyanins in black currant) ratios in these

extracts which also vary in the acylated anthocyanins. Preliminary investigations of current breeding material have revealed a wide range of pigment ratios, and so this technique can be used to match up anthocyanin ratio in the presence or absence of acylated peaks to pigment stability which is an important aspect of black currant juice quality.

(H. Bain)

DATA PROCESSING

P. B. TOPHAM

The year saw much appraisal of our computing service in the light of developments in the AFRC and the need for planning. Our present use of the ERCC mainframes has developed over many years and allows scientists access to a first class modern computing facility with support for training, programming, hardware acquisition, software applications, graphics, text-processing and networking. Notable features are the inexpensive local equipment and the low staffing commitments at SCRI. We have ready access to AGRENET and other networks. The ERCC facility seems acceptable to users (82 registered users at SCRI as against 69 last year). The system appears no more expensive than equivalent on-site facilities and considerably more flexible.

COMPUTER USAGE 1984

Department or Division	Users	2988 Logons	%	Graphs	%
Cereal Breeding	7	766	11.2	0	0
Chemistry	5	516	7.2	35	3.2
Data Processing	9	1395	20.3	241	21.5
Estate	1	28	0.4	0	0
Forage Brassica Breeding	5	236	3.4	0	0
Information Services	3	289	4.2	26	2.3
Mycology and Bacteriology	10	487	7.1	310	27.6
Physiology and Crop Production	16	1223	17.8	447	39.9
Potato Breeding	14	1274	18.6	0	0
Soft Fruit Breeding	3	173	2.5	7	0.6
Virology	2	46	0.7	19	1.7
Zoology	7	434	6.3	36	3.2
TOTAL	82	6867	100	1121	100

The programming team functioned well although it still has members at both sites. Shortage of resources prevented much development with BBC microcomputers and they are used as inexpensive work stations and graphics terminals. Work on the Epson HX20 as a hand-held terminal for data entry attracted outside attention and a suite of programs was

released to the BAPB. An Institute policy for restricted software release to AFRS institutes was formulated; it should permit informal but controlled distribution of such programs as CHIP, the plant breeding data base package developed by the Potato Breeding Department.

After a period of planning, applications for the Image Analysis System are being developed. Experience shows that they are most successful when there is close collaboration with the scientist to adjust procedures and evaluate results.

Hardware

The Terminal Control Processor (TCP) at Pentlandfield, a PDP11/10 which connected the eight interactive terminals and lineprinter to the ERCC network was replaced by a Camtec Packet Assembler-Disassembler (PAD). The PAD allows 16 devices to be connected to the network and to communicate directly with each other without involving any mainframe at ERCC, so that files can be transferred between microcomputers of different makes.

The BBC microcomputer at Pentlandfield proved particularly effective as a graphics terminal using the Tektronix 4010 emulation option provided by the Sussex workstation chip.

The Epson HX20 replaced the M50f hand-held data terminals at Pentlandfield. The only problem arose from the keyboard which is occasionally susceptible to dust and strong fingers. Clingfilm or a polythene fronted case provides some protection.

At Mylnefield the cardreader and paper tape punch were disconnected from the RJE early in the year. D. Walker[1] wrote a loader program for the RJE terminal so that it could be loaded from a BBC microcomputer. The new procedure has been more reliable than paper tape. The paper tape reader is now rarely used.

Three departments have BBC microcomputers in laboratories which are used as workstations. Each has twin disk drives and a printer, and all those at Mylnefield have sideways Read Only Memory (ROM) sockets on the keyboard for portability of software.

(R. J. Clark, J. W. McNicol)

Software

A system to monitor controlled environment chambers was developed on a Sirius 1 microcomputer under UCSD Pascal. Four Link-On analogue to digital multiplexors, connected to the Sirius through an RS-232 port, interrogate light, temperature and humidity (wet bulb) sensors in each of 21 cabinets. Day and night set-temperatures are stored along with inner and outer limits. A warning message is printed if the temperature exceeds

[1]ERCC

the inner limits, and an alarm is triggered if the outer limits are exceeded. Daily and weekly summary statistics are available for the sensors in each cabinet. The hours of use of the fluorescent tubes in any cabinet can also be requested. Other features include a screen display of all sensor readings, a one hour rolling log of all sensors, and an hourly summary of any faults in the system.

The range of data capture software for the Epson HX20 was extended. A second general purpose program was written to handle data sets for which the number of observations per sample is not known in advance, and for unbalanced designs, and another to transfer these Epson files to the UCSD environment. A new program records the readings produced by the Chemistry Department's Technicon 300 Infralyser which measures nitrogen, acid-soluble beta glucan and moisture contents in barley samples, and nitrogen content in brassica samples. Previously the readings were transferred by hand to a microcomputer or mainframe file from a printout.

Programs were written for the routine clubroot screening work in the Mycology and Bacteriology Department. A UCSD program produces labels and pot tags. Data recorded on an Epson HX20 are transferred to an Apple microcomputer where they are summarised, and a file created for more detailed statistical analysis which is carried out on the mainframe using GENSTAT.

A UCSD Pascal program was written with the Zoology Department to display the effects of varying parameter values in several models describing growth of potato cyst nematodes.

All the general purpose UCSD programs were updated during the year; in particular, the label and bar code printing programs were generalised to use all the printers available at both sites.

A program for inverse estimation of nucleic acid or protein molecular weights from electrophoretic measurements was written to display graphically estimates and tolerance limits on the Tektronix 4051.

(J. W. McNicol, R. Kidger, J. B. Cowan)

Data Management

Two processes were obtained on the AFRC Computing Centre VAX 11/780; one for electronic mail and the other to allow virologists to access the DNA and protein sequencing programs.

Access was obtained via the British Telecom network to the Health and Safety Executive Information Retrieval system (HSE-Line) running on a mainframe in Italy, which allows databases to be searched for literature on health and safety topics.

A simple data management system, 'Starbase,' proved useful on the BBC microcomputers in the following applications which are still under development:

Vehicle inventory and maintenance record
General maintenance inventory
Recording maintenance requests from departments
Virus-free stocks of narcissus
Hardware and consumable stores records

Aspects of setting up a brassica genetics database for J. R. T. Hodgkin[1], using Dbase II, formed a student project at Dundee College of Technology.

The HORTIHERB program providing advisory information on herbicides was extended to more crop species. Through demonstrations at meetings and seminars it continued to attract more users, particularly as networks, such as AGRENET and IPSS, become more available. Use of bibliographic information retrieval files continued to grow with most departments maintaining their own in specialist subject areas. The black currant bibliography is updated periodically.

Large address lists with a worldwide distribution have been converted to run on the LABS program on EMAS, the advantage being greater standardisation and protection of files.

Both sites now use three ERCC graphics packages, Easygraph, Notice and GPLayout. The first two allow a single graph to be produced, whereas the third allows several graphs to be reduced or enlarged, and laid side by side. Graphs produced can be displayed on the BBC microcomputer screen using TVIEW, another ERCC program. Once the graph has been altered to the user's satisfaction a hard copy can be obtained from the graph plotter at Mylnefield or at ERCC.

(R. J. Clark, R. Kidger)

Statistics

Further collaborative work with the Chemistry Department involved analysing the sample spectra produced by the Neotec 6350 scanning infra-red composition analyser. An experiment was carried out with samples consisting of controlled mixtures of four chemicals. Examination of the spectra of these led to clear interpretations of the wavelength calibration equations and to a method for interpreting the correlation graphs relating wavelength reflectance energies to sample determinations. This method of interpretation is particularly helpful when an 'interfering' effect such as particle size is highly correlated with the constituent of interest. The experiment also indicated that calibration models based on principal components might provide a more accurate estimate of the standard error of prediction than models based on wavelengths.

Analysis began of cereal breeders' trials for the years 1980-84 with AFRC Unit of Statistics and the Cereal Breeding Department. Of particular interest will be a comparison with the results of a similar exercise carried out by AFRC Unit of Statistics on trials having the same type of design but much larger plot sizes.

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[1]Forage Brassica Breeding Department

Prediction of maturity date of calabrese crops was investigated with R. Thompson[1] and H. Taylor[1] using multiple regression. The meteorological measurements used as independent variables including accumulated heat units, accumulated radiation, soil temperature, day-length and day number. A computer program was written to give updated predictions from current and long-term average meteorological data. The predictions are being compared with those from chronological time (day number) only and from 'physiological time' (measured by accumulated heat units) only.

Other statistical collaborations included various aspects of nematode ecology: the effect of varying sampling intensity on measures of aggregation; the association between species estimated from their joint occurrence within survey samples; an examination of the similarities between the longidorid nematofauna of several European countries. In addition studies continued on the effect of crop density on the weed flora using diversity indices and principal component analysis.

P. I. Dugard[2] helped to use cluster analysis of pathogenicity scores to study discontinuities in the response of strawberry cultivars to isolates of *P. fragariae* causing red core disease.

(J. W. McNicol. P. Smith, P. B. Topham)

Image Analysis and Digitisation

Use of the Quantimet 900 image analysis system is increasing. Applications, developed with the end users, included measurements of: potato leaflet areas, with automatic correction for insect damage; areas of foliage from infra-red photographs of cereal crops; projected areas of powders for near infra-red scanning. Feeding in salmon using radiographs of fish fed on food containing iron particles is being investigated with C. Talbot[3] and M. Miles[3]. Optical density measurements of neutral density filters showed a linear relationship over a range of 1.8 units and development started of routines to quantify stained cell and tissue components in stained sections, and of routines for auto-radiographs of nucleic acid hybridisations.

File transfer from the Quantimet to an Apple microcomputer was developed.

The Tektronix 4051 microcomputer was used regularly to make measurements with a digitising tablet for a variety of applications, including: virus and nucleic acid particle lengths drawn from plates; pollen tube measurements; estimation of percentage foliage ground cover from area measurements; nematode measurement and identification; nematode avoidance behaviour in plate tests with nematicidal chemicals.

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[1]Physiological and Crop Production Department
[2]Dundee College of Technology
[3]DAFS Fisheries Research Laboratory

A point-counting method was developed to estimate the percentage ground cover of potato crops grown in beds from wide-angle (f = 16 mm) or fish-eye (f = 8 mm) photographs when the standard technique, which measures coincidence of foliage at the perimeter of a circle, gave unsatisfactory results due to the bed layout. Coincidence was detected of foliage in the projected 35 mm slides and points in a circular chart, the points being chosen randomly but so distributed as to give uniform areal density 'on the ground' for each lens. This is because the fish-eye lens does not give equal area representation. A Tektronix program was written to plot suitable charts with 100 random points per chart. The percentage ground cover estimated from point coincidence was highly correlated (r = 0.90) with the estimate of the fraction of light intercepted measured by tube solarimeters on 21 occasions in the PMB Survey 1983, using samples of 900 points (with T. D. Heilbronn[1]).

The program for nematode measurement and identification is being re-written with B. Boag[2] and P. B. Topham for the BBC microcomputer to use inexpensive equipment, and to improve the identification techniques.

(P. Smith)

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[1] Research Assistant

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VIROLOGY

B. D. HARRISON

Virologists often take great pains to separate viruses that occur naturally in mixtures, as a preliminary to determining the properties of each component of the complex. It is becoming increasingly evident that this practice can delay the discovery of unexpected, and in some instances very important, interactions between different viruses. These interactions are of many kinds. Some involve the dependence of one virus on another for providing a means of transmission from plant to plant by vectors, notably aphids. This year's report describes fresh evidence of a resemblance in general properties between two such dependent viruses, groundnut rosette and carrot mottle, each of which has a luteovirus (groundnut rosette assistor and carrot red leaf viruses respectively) as its helper. Thus groundnut rosette, one of Africa's most important virus diseases, is caused by a combination of viruses similar to that causing carrot motley dwarf disease in Britain, a subject of our previous and continuing research. In one, and probably both, of these pairs of viruses, the dependent virus is transmitted when its nucleic acid is assembled into particles that have an outer shell containing coat protein of the helper virus. In another system, also studied in the past year, the aphid transmission of a heracleum virus seems to depend on its particles becoming linked individually to a particle of a helper virus in doubly infected plants. A different kind of interaction is illustrated by the greatly increased accumulation of black raspberry necrosis, a virus prevalent in red raspberry crops, when propagated in herbaceous test plants also infected with solanum nodiflorum mottle virus. This has enabled the raspberry virus to be purified in amounts adequate for antiserum production and a promising first serodiagnostic test for it has been introduced.

Among other results of particular note are the use of virus-specific double-stranded RNA as an aid to the detection and diagnosis of several viruses, the production of antiserum to a virus associated with narcissus late season yellows, the detailed characterization of a form of resistance to potato leafroll virus that results in very restricted accumulation of the virus particles in potato leaf tissue, and evidence that a fungus-transmitted virus has a bipartite genome.

During the year a replacement scintillation counter was bought, and two glasshouse cubicles were upgraded with the aid of an ODA grant to make them suitable for research on cassava viruses.

PU 1(j) Study molecular aspects of the biological properties of viruses especially nepoviruses and tobraviruses

Genome and serological relationships among geminiviruses

Serological and nucleic acid hybridization tests were used in attempts to detect geminiviruses in leaves supplied by V. Muniyappa[1] containing a range of Indian whitefly-transmitted agents.* In immunosorbent electron microscopy (ISEM) tests using antiserum to squash leaf curl virus (SLCV) from North America, many bisegmented particles typical of geminiviruses were found in extracts of leaves of lima bean (*Phaseolus lunatus*) with yellow mosaic, bean (*Phaseolus vulgaris* cv. Topcrop) with yellow mosaic, *Dolichos lab-lab* with yellow mosaic and okra (*Abelmoschus esculentus*) with yellow vein mosaic symptoms. Similar but fewer particles were found in leaf extracts from horsegram (*Dolichos biflorus*) with yellow mosaic and from tomato with leaf curl. In contrast, antiserum to bean golden mosaic virus, also from America, failed to trap particles from the samples of horsegram or Topcrop bean and trapped relatively few particles from the samples of lima bean or *D. lab-lab*. This indicates that these plants were infected with whitefly-transmitted geminiviruses, and that the viruses are serologically related to geminiviruses from America but probably not closely to bean golden mosaic virus.

In spot hybridization tests with cloned cDNA probes for the two genome segments of African cassava mosaic virus (ACMV), the DNA-1 probe reacted with samples from tomato plants with leaf curl and *Ageratum conyzoides* with yellow mosaic. Other samples, including those examined by ISEM, gave only weak reactions or none. The DNA-2 probe reacted with an *A. conyzoides* sample in one test but not with any of the other samples. These results therefore provide further examples of serological relationships among geminiviruses transmitted by the whitefly *Bemisia tabaci* and of the greater variation between viruses in DNA-2 than in DNA-1 and its coat protein gene.

Samples of mosaic-affected cassava leaves from India† yielded a few geminate particles in ISEM tests using antiserum to the western Kenyan type strain of ACMV. Leaf extracts also reacted weakly with the ACMV DNA-1 probe but did not react with the DNA-2 probe. Similar tests on cassava leaves infected with the Kenya coast strain of ACMV* supplied by I. A. D. Robertson[2] detected many particles by ISEM, showed a strong reaction with ACMV antibody in ELISA, and reacted strongly with the ACMV DNA-1 probe in spot hybridization tests and weakly with the DNA-2 probe. In contrast an isolate from Ghana reacted

*Imported under DAFS licence

[1]University of Agricultural Sciences, Bangalore, India

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[2]Commonwealth Institute of Biological Control, Muguga, Kenya

strongly with both probes. These results point to a possible similarity between ACMV strains in India and coastal Kenya, the apparent difference between the two perhaps being caused by a difference in virus concentration in infected leaves.

(B. D. Harrison, I. M. Roberts, D. J. Robinson)

Solanum apical leaf curling (SALCV)*, a virus described recently from Peru, resembles geminiviruses in particle morphology except that many of the particles have three segments instead of two. In ISEM tests on samples supplied by L. F. Salazar[1], many virus particles were trapped by homologous antiserum but no reaction was detected with antisera to ACMV, SLCV, beet curly top virus or three other leafhopper-transmitted geminiviruses. Similarly, no reaction was detected with probes for ACMV DNA-1 or DNA-2 in spot hybridization tests. However, nucleic acid extracted from partially purified SALCV particles contained circular molecules of c. 3200 nucleotides, estimated by measurements of molecules in electron micrographs. SALCV therefore has properties typical of geminiviruses but seems not closely related to other well characterized members of the group.

(B. D. Harrison, G. H. Duncan, I. M. Roberts, D. J. Robinson)

Properties and relationships of Indian and African isolates of peanut clump virus

A locally serious disease of groundnuts in India is caused by a soil-borne, probably *Polymyxa*-transmitted, virus with rod-shaped particles and properties of the same general type as those of soil-borne wheat mosaic and potato mop-top viruses. However, no serological relationship was detected in ISEM tests at SCRI between this virus, called Indian peanut clump*, and any of several other viruses including the two named above and an isolate of peanut clump virus (PCV) from West Africa supplied by J. C. Thouvenel[2]. Moreover, further work in India has shown that three isolates from groundnut plants from different parts of the country, isolates B, H, and L, have little or no serological relationship to one another. In experiments at SCRI, the nucleotide sequence relationships between the RNA genomes of these three Indian isolates and of the isolate from West Africa were assessed in hybridization tests using complementary DNA copies. RNA preparations from all four isolates had substantial sequences in common, but RNA from each Indian isolate had more homology with that from other Indian isolates than with that from the West African isolate. Thus, although virus isolates that cause peanut clump disease in India are serologically distinct from PCV from

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[1]International Potato Center, Lima, Peru

[2]ORSTOM, Adiopodoumé, Ivory Coast

West Africa, they should be regarded as isolates of the same virus. This pattern of variation, in which substantial genome homology exists among isolates with little or no serological relationship resembles that found in previous work at SCRI with tobacco rattle virus.

The rod-shaped particles of isolate L were of two predominant lengths, c. 175 and 235 nm, and respectively contained RNA species of mol.wt. 1.35×10^6 (RNA-2) and 1.84×10^6 (RNA-1), estimated by gel electrophoresis in denaturing conditions. Both species were needed for local lesion production in *Phaseolus vulgaris*, indicating that the virus has two genome parts. Infectivity of virus RNA was affected little by protease treatment.

(D. V. R. Reddy[2], D. J. Robinson, I. M. Roberts, B. D. Harrison)

When RNA from isolate L was translated in reticulocyte lysates the largest polypeptide made had a mol.wt. of about 195,000 and the main products had mol.wt. of about 143,000 and 24,500. The 24,500 mol.wt. product co-migrated with virus coat protein in acrylamide gel electrophoresis and reacted specifically with antiserum to isolate L. Translation of the separated RNA species showed that the 195,000 and 143,000 mol.wt. polypeptides arose by translation of RNA-1, and that RNA-2 was translated to give only the 24,500 mol.wt. coat protein. When gel fractions containing RNA smaller than RNA-2 were added to reticulocyte lysate, the RNA of mol.wt. 0.5 to 0.9×10^6 gave a polypeptide of 50,000 mol.wt. corresponding to a product found when unfractionated RNA was translated.

In its translation, PCV therefore resembles tobacco rattle virus in having the gene for its coat protein on the smaller of the two main RNA species, and in that much of the RNA-2 is untranslated *in vitro* whereas most of RNA-1 is translated to give overlapping polypeptides of mol.wt. about 195,000 and 143,000.

(M. A. Mayo, D. V. R. Reddy[2])

Antigenic variants of raspberry ringspot virus (RRV)

Isolates of RRV infecting artichokes in Turkey (RRV-T*) and in Greece (RRV-G*), supplied by G. P. Martelli[1], were found to be only distantly related serologically to the English (RRV-E) and Scottish (RRV-S) type isolates. In agarose gel double diffusion serological tests, the reaction end points of antisera to either RRV-E or RRV-S (both with homologous titres of 1/512) were 1/32 and 1/16 to RRV-T, and 1/64 and 1/32 to RRV-G, respectively. The artichoke isolates were distantly related to an RRV isolate from grapevine* in Germany, reacting with its antiserum only at dilutions of 1/16 or less (homologous titre 1/256). An isolate of

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[1]Istituto di Patologia Vegetale, Bari, Italy

[2]Visiting Worker

RRV from cherry trees affected with Pfeffinger disease in Switzerland was serologically distinguishable from all the other five RRV isolates. Antigenic variation in RRV therefore seems greater than previously recognised.

(A. T. Jones)

Properties of the raspberry bushy dwarf virus (RBDV) genome

When preparations of dsRNA from RBDV-infected *Chenopodium quinoa* leaves were examined by electrophoresis in polyacrylamide gels, two main components of estimated mol.wt. 3.6×10^6 (5.2 kbp) and 1.7×10^6 (2.4 kbp) were found. These presumably are the replicative forms of two of the RNA species found in the virus particles, RNA-1 (mol.wt. 2.0×10^6; 5.8 kb) and RNA-2 (mol.wt. 0.8×10^6; 2.3 kb). Several additional minor dsRNA components were also observed, of which one (mol.wt. 0.3×10^6; 0.4 kbp) also occurred in extracts from healthy *C. quinoa* leaves. None of them corresponded to a double-stranded form of RNA-3 (mol.wt. 0.36; 1.0 kb).

(A. F. Murant, J. H. Raschké)

Previous work showed that the main product of translation of RBDV RNA in wheat germ extracts is a protein of mol.wt. c. 30,000 which reacts with RBDV antiserum. In further work, the separate RNA species of RBDV were translated in reticulocyte lysates. Translation of RNA-1 (5.8 kb) gave many polypeptides, the largest of which had a mol.wt. of about 190,000 and would account for nearly all of the coding potential of the RNA. Translation of RNA-2 (2.3 kb) also gave several polypeptides but the predominant one was of mol.wt. 46,000. Translation of RNA-3 (1 kb) gave little except the polypeptide of mol.wt. c. 30,000, which represents all the coding capacity of this RNA species.

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

PU 1(i) To elucidate mechanisms of virus transmission by aphids

Heracleum latent virus (HLV) and heracleum virus 6 (HV6)

In previous work on the mechanism of dependence of the 'short' closterovirus, HLV (particles 730 nm long), on a 'long' closterovirus, HV6 (particles 1650 nm long) (for transmission by aphids *Cavariella* spp.), extracts from doubly infected coriander (*Coriandrum sativum*) were found to contain particles that could be coated along part of their length with antibody to HLV and along the rest of their length with antibody to HV6. Further tests were made to improve the preservation of such particles for electron microscopy. HLV particles from extracts of singly infected coriander were very flexuous in 2% PTA, pH 7, but much straighter in 2% PTA, pH 3.5; HV6 particles were moderately flexuous over a range of pH values but appeared to be preserved best in 2% PTA, pH 6. For examination of the composite particles in mixed infections, 2% PTA, pH

4.25, was used as a compromise. On grids coated with HLV antiserum (the HV6 antiserum proved unsuitable for use in ISEM), many particles were found in which a short straight portion was joined to a longer moderately flexuous portion. The straight portion could be coated with HLV antibody and the moderately flexuous portion with HV6 antibody. The straight 'HLV' portion was approximately the same length as the particles of HLV in single infections. The flexuous 'HV6' portion was very variable in length (probably a result of breakage) but in some instances was as long as the particles of HV6 in single infections. More than 30% of HLV particles in mixed infections were associated in this way with HV6 particles or particle fragments. Some further improvement in the preservation of the 'HV6' portion was achieved by making leaf extracts directly in 1% glutaraldehyde. The present evidence suggests that the mixedly coated particles result from end-to-end attachment of a single particle of HLV to a single particle of HV6 (chains of alternating HLV and HV6 particles have not been found). However, the possibility that there is some kind of phenotypic mixing, perhaps along only a very short length of one of the particles, cannot be excluded. The end-to-end attachment cannot be simply a matter of particle aggregation because composite particles are not formed when extracts from singly infected plants are mixed together; they seem to be produced only in doubly infected plants, presumably during particle assembly. The results strongly suggest that this unique kind of particle association explains the dependence of HLV on HV6 for transmission by aphids.

(A. F. Murant, G. H. Duncan)

Further tests were made to ascertain whether other 'short' closteroviruses are dependent on 'long' ones for aphid transmission. However, no antigenically composite particles were found in extracts from *Chenopodium quinoa* mixedly infected with beet yellows virus (BYV; 'long' closterovirus) and HLV, or from sugar beet mixedly infected with BYV and apple chlorotic leafspot virus (ACLSV; 'short' closterovirus). This is in line with our earlier report that BYV did not assist the transmission of HLV or ACLSV by *Myzus persicae*. Nevertheless, to obtain clues as to which other closteroviruses might be helper or dependent viruses, ISEM and antibody coating experiments were done with HLV, HV6 and antisera to a wide range of closteroviruses. No relationship was detected between these two viruses or between either of them and ACLSV, BYV, beet yellow stunt, carnation necrotic fleck, citrus tristeza, festuca necrosis, lilac chlorotic leaf spot or wheat yellow leaf viruses (or apple stem grooving or potato T viruses, which are no longer regarded as closteroviruses). However, a serological relationship was detected between HLV and grapevine virus A (GVA)* (another 'short' closterovirus) in both

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kinds of test. This relationship suggests that GVA may, like HLV, depend on a 'long' closterovirus for transmission by a vector. However, the tests provide no clue to the identity of such a helper virus.

(A. F. Murant, G. H. Duncan, I. M. Roberts)

Groundnut rosette virus (GRV)

Studies on GRV*, which depends on a luteovirus, groundnut rosette assistor virus (GRAV*), for transmission by *Aphis craccivora*, were continued. An isolate from Nigerian groundnut plants with the chlorotic form of rosette (GRV(C)), infected nine out of 32 species in three out of nine plant families by manual inoculation, causing local lesions in *Chenopodium* spp., especially *C. amaranticolor*, and systemic symptoms in *Glycine max*, *Nicotiana benthamiana* and *N. clevelandii*. An isolate from a Nigerian groundnut plant with symptoms of green rosette gave local lesions similar to GRV(C) in *C. amaranticolor* but milder symptoms in *N. benthamiana* and *N. clevelandii*.

Infectivity of GRV(C) in *N. clevelandii* leaf extracts survived for 1 day at room temperature and for 15 days at 4°C but was lost after 1 day at −20°C or after dilution to 10^{-4}; the infectivity and longevity *in vitro* were not altered in the presence of 1 mg/litre bentonite. Treatment of leaf extracts with pancreatic ribonuclease at up to 100 ng/ml did not abolish infectivity although there was a reversible decrease in lesion number on *C. amaranticolor*, probably caused by the well-established ability of this enzyme to act as an inhibitor of infection. Infectivity of GRV(C) was abolished by treatment of leaf extracts with ether, butanol or chloroform; in attempts at purification by more gentle methods the infective material was found to sediment like virus but to purify with a cell membrane fraction which, however, contained no virus-like particles.

The infectivity of nucleic acid preparations made directly from GRV(C)-infected *N. clevelandii* leaves was inactivated totally by treatment with ribonuclease at low and high ionic strength and is therefore attributed to ssRNA. When such nucleic acid preparations were electrophoresed in gels, no virus-specific bands were distinguishable from the ribosomal RNA bands but, judging from the position of the infectivity, the infective ssRNA had an apparent mol.wt. of 1.55×10^6. A similar mol.wt. was indicated by the rate of sedimentation of the infective RNA in sucrose gradients. Preparations of dsRNA made from GRV(C)-infected *N. clevelandii* leaves contained a species of mol.wt. c. 3.0×10^6; in addition, some dsRNA preparations contained an abundant dsRNA component of mol.wt. c. 0.6×10^6, together with several other minor components of intermediate mol.wt. Similar patterns of bands were found in dsRNA preparations from *N. clevelandii* infected with a GRV isolate from Malawi, as well as from Nigerian-grown groundnut material infected with GRV(C) alone, GRV(C) + GRAV, or with GRV(G) + GRAV.

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The properties of GRV closely resemble those of two other viruses that depend on luteoviruses for transmission by aphids, carrot mottle and lettuce speckles mottle viruses. They probably should be regarded as members of a new virus group.
(D. V. R. Reddy[1], A. F. Murant, J. H. Raschké, M. A. Mayo, O. A. Ansa[1])

Tobacco mottle virus (TMotV)*
TMotV is another virus that depends on a helper virus for transmission by aphids (*M. persicae*) in the persistent manner. Electrophoresis of dsRNA from TMotV-infected *N. tabacum* cv. White Burley detected two bands of mol.wt. 3.3×10^6 and 0.9×10^6, very similar in size to those found previously for carrot mottle virus.

(A. F. Murant, J. H. Raschké)

Characterisation of parsnip yellow fleck virus (PYFV)
A start was made on the further characterization of particles of the type isolates of the parsnip strain (P121) and the *Anthriscus sylvestris* strain (A421) of PYFV, which is a sap-transmissible virus that depends on anthriscus yellows virus for transmission by aphids.

Although particles of isolate P121 could be purified from infected spinach leaves by the 8.5% *n*-butanol or *n*-butanol/chloroform clarification procedures used previously, these methods were unsatisfactory for purifying particles of isolate A421 and extracts were clarified with ether instead. With this method, yields of about 2 mg virus nucleoprotein per 100 g leaf material were obtained for both isolates. The purified preparations were found to contain not only the c. 150 *S* particles of 30 nm diameter previously reported but also 30 nm particles of about 50 *S* which had an ultraviolet absorption spectrum characteristic of protein and could be penetrated by negative stain. They reacted with PYFV antiserum in gel-diffusion tests and were coated with PYFV antibody in immunoelectron microscopy tests. Apparently, they represent RNA-free protein shells ('top component') which are destroyed by the 8.5% *n*-butanol or *n*-butanol/chloroform clarification procedures used previously. The nucleoprotein particles ('bottom component') of isolate A421 had a buoyant density in CsCl of 1.52 g/cm^3.

Purified bottom component particles of isolates A 421 and P121 each contained a single RNA species, and the previously reported mol.wt. of 3.5×10^6 was confirmed for both isolates by electrophoresis of glyoxylated RNA in 0.75% agarose gels. RNA preparations induced about 100 lesions per leaf of *C. amaranticolor* at 1 μg/ml and, as found previously with purified virus particles, gave a good 'one-hit' dilution curve, suggesting that only one molecule of RNA is required for infection. The infective

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[1]Visiting Worker

RNA of isolate P121 bound to oligo-dT cellulose under high salt conditions, indicating that it contains polyadenylate.

When purified by the ether method, both the top component and the bottom component particles of isolate P121 contained three major proteins, of mol.wt. 31,000, 26,000 and 22,500, and two minor proteins of mol.wt. 50,000 and 28,000, estimated by SDS/polyacrylamide gel electrophoresis. The top and bottom component particles of isolate A421 contained three major proteins of mol.wt. 31,000, 26,000 and 24,000, and a single minor protein of mol.wt. 50,000, all of which were also found in preparations of bottom component after equilibrium centrifugation in CsCl. All these mol.wt. estimates were unaffected by gel strength. However, when isolate P121 was purified by the 8.5% *n*-butanol method, the 31,000 mol.wt. protein was absent and an additional minor protein of mol.wt. 18,000 was found. Treatment of ether-purified particles of isolates A421 and P121 with 8.5% *n*-butanol had no effect on their protein composition, indicating that its effect during clarification of spinach leaf sap may result from an interaction with some plant component.

(S. K. Hemida[2], A. F. Murant)

In ISEM tests, no relationship was detected between PYFV and anthriscus yellows virus or between either of these and maize chlorotic dwarf, radish radish yellow edge, rice tungro spherical or rice tungro bacilliform viruses.

(A. F. Murant, G. H. Duncan)

Infectivity of plant viruses for insect cells

In collaboration with 11N. F. Moore and colleagues[1], attempts were made

to infect cultured lines of insect cells with African cassava mosaic (ACMV) and potato leafroll viruses. Cells of two lepidopterans (*Mamestra brassicae* and *Spodoptera frugiperda*) and two dipterans (*Aedes albopictus* and *Drosophila melanogaster*) were inoculated with purified particles of each virus. ACMV particles attached to the cells readily but neither virus infected any of the types of cell as judged by fluorescent antibody staining or ELISA, by inspection for cytopathic effects, or by examining the pattern of ^{35}S-methionine – containing polypeptides produced in cells inoculated with material given two blind passages in similar cells.

(B. D. Harrison, H. Barker, D. J. Robinson)

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PU 1(l) Devise methods for detecting specific bacteria, viruses and their strains

Detection of tobacco rattle virus (TRV) infections by spot hybridization

Because of the antigenic diversity of particle-producing (M-type) isolates of TRV, and the frequent occurrence of NM-type isolates, which do not produce nucleoprotein particles, serological tests are unreliable for the diagnosis of TRV infections. Previous work showed that a solution hybridization test using DNA complementary to TRV RNA-1 could detect all isolates of TRV so far encountered, but this test could not readily be applied to large numbers of samples. A spot hybridization test was therefore devised using a ^{32}P-labelled probe prepared by nick-translation of a DNA clone (provided by M. Boccara[1]) containing a sequence complementary to part of the RNA-1 sequence of TRV strain SYM.

In preliminary experiments, M-type TRV strains SYM and ORY* were detected with equal efficiency in phosphate buffer extracts of infected *Nicotiana clevelandii* leaves. Treatment of the extracts with dilute alkali or with Pronase did not enhance the sensitivity of detection. Detection of an NM-type isolate of strain SYM was between ten- and one hundredfold less sensitive, and hybridization occurred mostly at the edge of the spot, leaving a clear centre. The reason for this unusual behaviour is not known.

The test was applied to a range of field-grown narcissus plants, including eight that had been shown to be TRV-infected in 1982. Seven of these reacted positively in the spot hybridization test, but the eighth, which had contained a very low concentration of TRV in 1982, now seemed free of the virus as judged both by spot hybridization and by inoculation of sap to indicator plants. Of a further 24 plants of cv. Golden Harvest with leaf symptoms suggestive of TRV infection, 22 were positive and two were negative in both spot hybridization and infectivity tests. In contrast, only four out of 24 plants of cv. Dutch Master with similar symptoms were positive in both tests. Sap from one other plant was barely infective, but did not react in spot hybridization, and 19 plants were negative in both tests. At least 20 of the plants in this group contained narcissus mosaic virus, and one contained cucumber mosaic virus. As in previous work with narcissus, all the TRV isolates were of the M-type. Thus the spot hybridization test seems to be a reliable method of detecting TRV infections, at least with M-type isolates, and could be applied to large numbers of samples.

(D. J. Robinson)

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[1]PBI

Simplified enzyme immunoassay for plant virus detection and identification

A simple and rapid procedure of enzyme immunoassay was used to detect viruses in individual plants. Virus particles in crude sap extracts were adsorbed directly to a solid phase support, allowed to react with antivirus γ-globulin or unfractionated antiserum, and the antigen-antibody complex detected with a general purpose conjugate of protein A and enzyme. Virus antigen was adsorbed best when sap extracted in carbonate buffer at pH 9.6 was placed in high bonding polystyrene or polyvinylchloride microtitre plates. Virus-specific reactions were obtained in <2 h with extracts from narcissus leaves using protein A-horseradish peroxidase conjugate and 3, 3′, 5, 5′ tetramethylbenzidine as substrate. The test was as sensitive as $F(ab')_2$ ELISA for narcissus tip necrosis tombusvirus (detection end-point 10^{-4}) but less so for narcissus mosaic potexvirus (10^{-4} cf. 10^{-6}). However, the method is not suitable for testing pooled leaf samples from different plants. Constituents of sap of some uninfected plant species, and of some infected plants, attached to the solid phase and oxidised the substrate 3, 3′, 5, 5′ tetramethylbenzidine. Treatment of attached material with HCl-PBS at pH 1.4 to 3 suppressed the non-specific reaction, but also abolished the antigenicity of some viruses. However, tests in which protein A-alkaline phosphatase conjugate was used with p-nitrophenylphosphate as substrate were free from such non-specific reactions.

Viruses identified by this method include narcissus latent (carlavirus), turnip mosaic, tulip chlorotic blotch (potyviruses), white clover mosaic, narcissus mosaic and tulip X (potexviruses), tobacco rattle, pea early-browning (tobraviruses), narcissus tip necrosis (tombusvirus), turnip yellow mosaic (tymovirus), cauliflower mosaic (caulimovirus), cucumber mosaic (cucumovirus) and parsnip yellow fleck. The method provides a ready means of detecting and identifying viruses in crude sap extracts with unfractionated antiserum where less sensitivity than is provided by double antibody sandwich (DAS) ELISA is acceptable. It is particularly useful in providing a method for identifying viruses with filamentous particles that is as simple as gel-diffusion serology.

(W. P. Mowat)

Analysis of dsRNA for detecting vicia cryptic virus (VCV)

VCV has isometric particles c. 28 nm in diameter which occur in low concentrations, and commonly, in several cultivars of *Vicia faba*. It is transmitted through seed to a high proportion of progeny but is not transmissible either mechanically or, apparently, by grafting and is not associated with any disease. When VCV particles from plants of cultivars Maris Bead and Stella were purified by sedimentation to equilibrium in CsCl solution, they formed a single band of density c. 1.36 – 1.37 g/cm^3.

Nucleic acid extracts from these particles contained dsRNA that migrated as three bands of estimated mol.wt. (using dsRNA of maize rough dwarf virus as a standard) of 1.37, 1.26 and 1.21×10^6. These dsRNA components were also readily and consistently detected in nucleic acid extracts from leaves of Maris Bead and Stella and they could be found in extracts from as little as 0.5 – 1.0 g of root, stem and flower tissue. In tests on 1 – 2 g leaf of 20 additional cultivars of *V. faba*, 16 were found to contain these or similar dsRNA components, including six cultivars in which VCV-like particles were found previously. However, no such dsRNA components or VCV particles were detected in extensive tests on cultivars Beryl and Minica nor in single samples of cultivars Banner and Optica. In general, the occurrence of VCV in plants was detected more reliably by dsRNA analysis than by ISEM. Some samples of many of the cultivars yielded additional dsRNA components, with mol.wt. of $1.5 - 2.0 \times 10^6$ and $2.4 - 2.9 \times 10^6$. The occurrence and number of the components in each of these categories differed between cultivars and between individual plants but they usually occurred in much smaller amounts than the dsRNA of mol.wt. $1.2 - 1.4 \times 10^6$. Neither VCV particles nor their dsRNA species were detected in Minica plants 6 wk after attachment of dodder shoots taken from parasitised VCV-infected plants of Maris Bead. The lack of symptoms in *V. faba* plants and the failure to transmit VCV experimentally from plant to plant, leaves the status of VCV as a plant virus open to question, especially as its morphology and dsRNA composition resemble those of mycoviruses. However, the characteristic dsRNA components of VCV were detected in extracts of washed mesophyll protoplasts from VCV-containing plants of Maris Bead and cv. The Sutton.

Cytoplasmic male sterility (CMS) in *V. faba* has been reported to be associated with a much larger dsRNA species that was transmissible using dodder. However, analysis of nucleic acid either from CMS-affected *V. faba* plants or from CMS maintainer plants (each supplied by D. A. Bond[1]) failed to detect dsRNA components similar in size to the components associated with VCV, suggesting that VCV is not involved in inducing CMS.

(M. A. Abou-Elnasr[2], A. T. Jones, M. A. Mayo, I. M. Roberts)

Association of dsRNA with yellows diseases of black currant

Yellows symptoms in leaves of some black currant cultivars and selections have been attributed to three causes: (a) genetic, (b) infection with black currant yellows (BY) agent, or (c) infection with an infectious variegation (IV) agent. The nature of these casual agents and their mode of spread are not known; evidence of their existence comes only from graft inoculation tests to sensitive black currant cultivars. However, when

[1] PBI

[2] Visiting Worker

dsRNA from plants with and without yellowing symptoms was examined, a component of estimated mol.wt. 2.92×10^6 was found both in plants of cv. Baldwin affected with BY and in those of cv. Daniel's September, which are all affected by IV. No such component was detected in nucleic acid from healthy stock plants of other black currant cultivars, or in green or yellow clones of an SCRI *Ribes* selection. If the 2.92×10^6 dsRNA is produced by the causal agents or BY and IV, these agents are evidently very similar if not the same. Analysis of dsRNA in leaf extracts from infected plants seems a promising approach to the detection and characterization of otherwise intractable viruses.

(M. A. Abou-Elnasr[3], A. T. Jones, M. A. Mayo)

*Assay for circular RNA-2 molecules from particles of velvet tobacco mottle virus (VTMoV)**

In earlier reports, the occurrence of small circular molecules of satellite RNA (RNA-2) in particles of lucerne transient streak* (LTSV) and solanum nodiflorum mottle viruses*, was shown to change the type of lesion induced by LTSV RNA-1 in *Chenopodium amaranticolor* leaves from chlorotic to necrotic. This proved to be a very sensitive assay for these RNA-2 molecules. Further studies have shown that the similar RNA-2 molecules from particles of another virus, VTMoV* (supplied by D. Zimmern[1]) also have this ability, and can therefore be assayed in the same way.

(A. T. Jones, M. A. Mayo)

Serological relationship between hydrangea mosaic (HyMV) and elm mottle (EMotV) viruses

A virus isolated from diseased hydrangea plants in England and described as HyMV shows many properties of the virus described previously in Scotland as EMotV. In agarose gel double diffusion serological tests using infective sap of *C. quinoa* as antigen, HyMV (supplied by B. J. Thomas[2]) and EMotV each reacted with each other's antiserum. When the two viruses were placed in adjacent wells, the precipitin lines joined without forming a spur, indicating that HyMV is antigenically very similar to EMotV, if not identical.

(A. T. Jones)

Detection and characterisation of cassava viruses

A 3-year project, financed by ODA, was started with the objectives of characterising previously undescribed cassava viruses and devising methods for their detection and diagnosis.

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*Held under DAFS licence

[1]MRC Laboratory of Molecular Biology, Cambridge

[2]GCRI

[3]Visiting Worker

In previous work, an Angolan isolate of African cassava mosaic virus* (ACMV) was detected in cassava leaf sap by standard DAS-ELISA using antibody to the West Kenyan type strain. In further tests, an antigenic variant, the Kenya coast strain*, was detected by this method in each of several cassava clones. Isolates from Western Kenya* and Nigeria* were readily detected in *N. benthamiana* sap as also was an isolate of euphorbia mosaic virus* from the USA supplied by R. W. Fulton[1]. In contrast, extracts from cassava leaves affected by three Colombian diseases, 'Caribbean mosaic' 'latente' and 'frogskin,' did not react. ACMV was also detected in cassava with equal sensitivity by standard DAS-ELISA and by DAS-ELISA on nitrocellulose membranes. Clarification of cassava leaf extracts with *n*-butanol (1:1, v/v) improved ACMV detection in some samples tested by conventional DAS-ELISA, but was detrimental for membrane ELISA.

A potexvirus* was transmitted by mechanical inoculation from the cassava plants from Colombia with frogskin, an important disease that prevents the tubers swelling without decreasing shoot growth. It infected *N. benthamiana* and *Ricinus communis* systemically, and produced countable local lesions in *C. quinoa*. The virus particles had a modal length of c. 480 nm. Infection was readily detected in cassava by DAS-ELISA and less readily by ISEM using homologous antibody. A relationship to potato X and cactus X viruses was detected by ISEM, but very little to none to cassava common mosaic virus, another potexvirus. The virus was also detected in apparently healthy plants from fields where frogskin occurred and its role in the etiology of this disease is not yet clear.

A virus with flexuous filamentous particles was transmitted by mechanical inoculation to *N. debneyi* from several Kenyan clones of cassava with brown streak disease*. In ISEM tests no relationship was detected to cowpea mild mottle or sweet potato mild mottle viruses.

Cassava leaves with mild green mosaic symptoms sent from the Solomon Islands by B. Smith[2] contained a virus that is readily sap-transmissible to *C. quinoa, Cucumis sativus, N. clevelandii* and *Phaseolus vulgaris*, all of which were infected systemically. The virus has isometric particles *c.* 30 nm in diameter and seems to be undescribed previously.

(A. M. Lennon, M. M. Aiton, B. D. Harrison)

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*Held under DAFS licence

[1]Department of Plant Pathology, University of Wisconsin, USA

[2]Ministry of Agriculture, Honiara, Solomon Islands

PU 1(k) Devise methods for the electron microscopy of viruses, fungi and bacteria

Improved extraction and preservation of virus particles from tissues

The micro-mortar extraction method (*Ann. Rep. 1979,* 108) was improved to give efficient extraction from refractory tissues and to allow the extracts to be prepared more rapidly. The glass grinding rod was replaced by a small hand-held electric motor, which was fitted with steel arbors or disposable wooden cocktail sticks to grind the tissue. As before, Carborundum powder was usually included to aid grinding. This method proved very effective in releasing virus particles from all kinds of tissue, particularly woody material or leaves which contain glutinous substances. It was not suitable for the very long particles of closteroviruses, which are notoriously fragile and usually were severely damaged.

Extraction in buffer containing 1% (v/v) glutaraldehyde without using the motorised grinder improved preservation of the filamentous particles of closteroviruses and some other viruses. Extracts prepared in this way were stable for several days at room temperature and remained free from bacterial growth. Extracts containing 1% glutaraldehyde were also used for immunoelectron microscopy. In many instances ISEM trapped large numbers of particles, although somewhat fewer than from unfixed extracts. Fixed virus particles were coated with antibody somewhat more slowly than unfixed particles, but strong reactions were obtained and the results were easily scored.

(I. M. Roberts, G. H. Duncan)

Attempt to improve detection of particles of a potyvirus

Trapping virus particles by conventional ISEM fails with some viruses that have filamentous particles, such as tulip chlorotic blotch virus (TCBV, potyvirus group), even when antibody is available that gives reliable results in conventional ELISA and in simplified enzyme immunoassay (see p. 188). Attempts were therefore made to simulate the conditions used in these tests when performing ISEM. Electron microscope grids were coated with polystyrene films made from a solution of pieces of microtitre plate in amyl acetate, purified γ-globulin was used instead of unfractionated antiserum, and the same buffers were used as in conventional ELISA and its variants.

With grid films not coated with antibody, the number of virus particles found in samples on polystyrene films was not greater than that on carbon films. Similarly, conventional ISEM using antiserum-coated films of carbon or polystyrene gave only slight increases in particle numbers compared with control grids (untreated films). ISEM performed under conditions used in ELISA gave even fewer whole particles relative to

control grids, although possible fragments of TCBV particles were more numerous.

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

Improved shadowing of nucleic acid molecules

The platinum/tungsten source used for shadowing nucleic acid molecules (*SHRI Ann. Rep. 1978,* 111) was replaced with an uranium evaporation source (*SHRI Ann. Rep. 1975,* 79). This is much less expensive to use, offers more control of metal deposition and gives better resolution and contrast for a given thickness of metal.

(G. H. Duncan)

PU 1(n) Study the biological activity of DNA copies of virus RNA genes and the effects of their incorporation in plant genomes

In continuation of work in collaboration with D. Baulcombe[1] and M. Bevan[1], further samples of genome RNA of cucumber mosaic and tobacco rattle viruses were supplied. DNA copies of the satellite RNA of cucumber mosaic virus, and RNA transcripts of this DNA, were tested for biological activity but none was found. The activity of modified constructs will be tested as they become available.

(B. D. Harrison, M. A. Mayo, D. J. Robinson)

PU 4(e) Study virus diseases of forage brassica crops and devise methods for their control

Turnip yellow mosaic virus was detected in two of five *Brassica campestris* plants with virus-like symptoms found in the Forage Brassica Breeding Department's genotype collection. This again raises the question of whether these occasional virus infections in plant breeders' material result from transmission of virus through seed, something not known to occur with the common brassica viruses, or from sporadic field infections. The possible occurrence of seed transmission will be tested by examining progeny from self-pollinated infected plants.

(W. P. Mowat, J. R. T. Hodgkin[2])

PU 9(k) Study mechanisms of virus resistance in potato

Tests for potato virus Y (PVY) in cultivars with extreme resistance

Potato cultivars Pirola and Corine have extreme resistance to PVY whereas cv. Maris Piper is susceptible. Extracts obtained from Maris Piper leaves 12 days after they were manually inoculated with PVY° were very infective and contained numerous full-length particles that were detectable by ISEM. In contrast, extracts from Pirola and Corine leaves

[1]PBI

[2]Forage Brassica Breeding Department

had little or no infectivity and contained only a few particles, nearly all of which were fragmented. These damaged particles probably are remnants of the inoculum virus. Extracts from non-inoculated tip leaves of Pirola and Corine were not infective. These results support the notion that PVY replicates little if at all in these two cultivars.

(H. Barker, I. M. Roberts)

Polygenic resistance to potato leafroll virus (PLRV)

Three different types of resistance to PLRV have now been found in potato. The first type (*Ann. Rep. 1983,* 194) is expressed as an abnormally low concentration of PLRV antigen in leaf extracts, as determined by ELISA, and is found in several potato cultivars and clones with high field resistance ratings. Young leaves of field grown plants of resistant potato genotypes with primary infection induced by either graft- or aphid-inoculation, or with secondary infection, contained only 2 – 10% of the amount of PLRV antigen found in susceptible genotypes. Most genotypes with low virus contents developed only mild primary and secondary symptoms whereas those with normal virus contents developed more pronounced symptoms. However, one genotype (G7461(4)) with a low PLRV content was very severely affected. Tests in which fluorescein-conjugated antibody to PLRV particles was used to stain sections of young leaf vein tissue showed that individual phloem companion cells in a cultivar with low virus content contained as much antigen as those in a control cultivar but the infected cells were ten- to twentyfold less numerous. The difference in virus content can therefore be attributed to a failure of most companion cells to become infected in the cultivar with the low virus content.

In older leaves, differences in virus concentration between genotypes with high and low field resistance ratings were at least as pronounced as those in younger leaves. However, in petiole and stem tissue, the differences were smaller, and the PLRV contents of root, stolon and tuber tissue were essentially independent of field resistance rating. Aphids (*Myzus persicae*) fed on leaves of cultivars with low virus contents acquired little PLRV and transmitted it infrequently to *Physalis floridana* test plants. For example in one test, 58% of aphids that fed for 4 days on infected plants of cv. Maris Piper transmitted the virus but none of those fed on cv. Pentland Crown, a cultivar with a low virus content did so.

The second type of resistance was demonstrated in glasshouse and field experiments in which plants of genotypes with different field resistance ratings were inoculated with PLRV-carrying *M. persicae*. The proportion of plants infected was directly related to the field resistance rating. For example, in one field experiment, 50% of Pentland Crown plants became infected (using ELISA to detect PLRV in the foliage) compared with 100% of Maris Piper plants.

A third type of resistance was found in a glasshouse experiment in which plants of clone G7445(1) (the genotype with the highest field resistance rating) were inoculated with PLRV-carrying aphids. The foliage of several such plants became infected, as indicated by ELISA. However, when the tubers produced by these plants were grown on, about half of the infected mother plants were found to have produced uninfected progeny plants. In contrast, all infected Pentland Crown and Maris Piper mother plants produced infected progeny. Thus it seems that in clone G7445(1) the passage of PLRV through the tubers to progeny plants is impaired. As a result, when PLRV resistance was assessed on the basis of number of progeny plants infected, clone G7445(1) was more resistant than Pentland Crown.

The relative importance of these three types of resistance in minimising virus spread has yet to be determined. However, it is already clear that they occur in a variety of combinations in genotypes selected for PLRV resistance in field exposure trials. The kinds of resistance that are most valuable to farmers will differ in different regions. In places where the infection pressure on ware crops is great, and schemes for producing virus-free stocks are not available, all kinds of resistance will be helpful. However, in areas where seed potatoes are produced, cultivars that do not develop obvious symptoms when infected, even if they are poor sources of virus for aphids, will pose new problems for growers.

(H. Barker, B. D. Harrison)

PU 9(l) Study detection methods, properties, transmission and spread of potato viruses

Monoclonal antibodies to potato leafroll virus (PLRV)

Work was begun to prepare monoclonal antibodies to a Scottish isolate of PLRV. Spleen cells from immunized BALB/C mice were fused with NSO/U mouse myeloma cells, provided by G. Galfre[1], and hybridoma supernatant fluids were screened for PLRV antibody by ELISA. For ELISA, microtitre plates were coated with purified PLRV particles, then hybridoma supernatant fluid was added and bound antibody was detected using rabbit anti-mouse IgG, conjugated to horseradish peroxidase. Crude sap of PLRV-infected *Physalis floridana* could not be substituted for purified virus. In the first fusion, 75 of 480 wells contained hybridomas, and 10 of these wells contained PLRV antibody. After cloning at limiting dilution, two hybridomas continued to secrete PLRV antibody, which in both instances was of the IgG1 sub-type. Further experiments are under way to produce a panel of monoclonal antibodies to PLRV.

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[1]IAP

Two monoclonal antibodies to a Canadian isolate of PLRV, provided by R. Martin[1], were used in tests on 22 different PLRV-infected potato cultivars collected in Scotland. In ELISA, each monoclonal antibody reacted about half as strongly as antibody from a polyclonal antiserum to a Scottish isolate of the virus. No important antigenic differences were detected between the 22 isolates by comparing their relative reactivity with the two monoclonal antibodies and with the polyclonal antibodies.

(P. R. Massalski, B. D. Harrison)

Weeds in the ecology of potato leafroll virus (PLRV)

PLRV was detected by ELISA in 2% (5/274) of shepherd's purse (*Capsella bursa-pastoris*) seedlings growing in a field plot containing PLRV-infected potato plants. In ISEM, more virus particles were trapped by antiserum to PLRV than by antiserum to beet western yellows virus (BWYV). The virus in the shepherd's purse plants was also detected by ELISA, using the two Canadian monoclonal antibodies; these are specific for PLRV and fail to detect BWYV. In the glasshouse, PLRV was transmitted by *Myzus persicae* from PLRV-infected potato to 80% (40/50) of glasshouse-grown shepherd's purse seedlings which, however, remained symptomless. The virus was also transmitted in the glasshouse from PLRV-infected shepherd's purse to potato in each of three trials, suggesting a possible role for weeds in the ecology of PLRV in the field.

(P. R. Massalski, B. D. Harrison)

PU 10(i) Study the properties, spread and control of *Rubus* viruses

Outbreaks of nematode-transmitted viruses

Symptoms in cv. Glen Clova raspberry resembling those associated with raspberry ringspot virus (RRV) (*Ann. Rep. 1983,* 197) were found at several sites in England, Wales and N. Ireland. These symptoms were caused not by RRV but by arabis mosaic virus (AMV), and they were more severe and prevalent than raspberry ringspot disease is in Glen Clova in Scotland. Some crops of cv. Malling Admiral were also severely affected. Lasting chemical control of the nematode vector of AMV is not easy, suggesting that increased attention to breeding raspberry cultivars immune from AMV may be necessary, especially as only three of the more modern cultivars are graft-immune from the virus. As an interim measure, field experiments have been planted at sites of RRV and AMV outbreaks to detect any field resistance to, or tolerance of, infection with these viruses in the newer raspberry cultivars.

(A. T. Jones)

Properties of a cucumber mosaic virus (CMV) isolate from Rubus

The isolate of CMV from a raspberry cultivar that is resistant to *Ampho-*

[1]Agriculture Canada Research Station, Vancouver, B.C.

rophora idaei (*Ann. Rep. 1983,* 197) was readily transmitted by *A. idaei* from *N. clevelandii* to *N. clevelandii* but apparently not to cv. Malling Jewel or cv. Glen Moy raspberry plants. Particles of the virus purified from infected *N. clevelandii* leaves had physicochemical properties similar to those of other CMV isolates. However, its serological detection by conventional methods was difficult. In gel diffusion precipitin tests, an antiserum with a homologous titre of 1/128 against purified virus particles fixed with 0.2% formaldehyde failed to react with sap from CMV-infected *N. clevelandii* plants, even when the gel and sap contained 0.005 M borate buffer (pH 9) + 0.005 M EDTA, conditions which were necessary for the reaction of another CMV isolate from *Rubus* in previous tests. Detection in *N. clevelandii* sap by $F(ab')_2$ ELISA using a horseradish peroxidase system or by standard DAS-ELISA using an alkaline phosphatase system was also inefficient and/or unreliable, although some improvement was effected in DAS-ELISA by mixing the enzyme-globulin conjugate directly with sap extracts. However, the best results were achieved using the simplified enzyme immunoassay (see p.188). The difficulty in detecting this CMV isolate is attributed to the fragility of its particles in plant sap.

(M. A. Abou-Elnasr[1], A. T. Jones)

Black raspberry necrosis (BRNV) and raspberry leaf spot (RLSV) viruses
As reported previously (*Ann. Rep. 1983,* 196), the concentration of BRNV particles in *N. clevelandii* was greatly increased when the plants also contained a second virus. This fortuitous contaminant was identified as solanum nodiflorum mottle* (SNMV), a virus which is not indigenous in the UK and is not known to infect *Rubus*. Using sap of *N. clevelandii* infected with the mixed culture as inoculum, BRNV was transmitted to several new hosts, including *N. benthamiana*, *N. rustica* and *N. tabacum* cv. Samsun NN. BRNV particles in purified preparations of the mixed culture sedimented slightly faster than the 116 *S* particles of SNMV and in immunoelectrophoresis they migrated towards the anode considerably more slowly than those of SNMV.

Using antiserum to the mixed culture in $F(ab')_2$ ELISA, BRNV was detected in a range of naturally infected raspberry cultivars growing in the field, and in experimentally infected raspberry cultivars, *Rubus* species and *Rubus* hybrids growing in the glasshouse. These included glasshouse-grown Malling Jewel raspberry plants infected with BRNV by means of the aphid *A. idaei*. Natural or experimental infection of BRNV-infected raspberry with nepoviruses, raspberry bushy dwarf virus or other aphid-borne viruses seemed not to interfere with BRNV detection. However, in some tests, particularly on field grown plants, high background readings were obtained. BRNV gave the highest readings in

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[1]Visiting Worker

ELISA in samples from glasshouse-grown plants tested in April-May and in those from field-grown plants tested in June. In field-grown plants, BRNV was most readily detected in the young tip leaves of first year cane and was rarely detected in older leaves. Further work is needed before ELISA can be considered a reliable routine test for BRNV in field-grown plants throughout the growing season.

(A. T. Jones, M. J. Mitchell)

BRNV has some similarities to RLSV and raspberry leaf mottle virus (RLMV). Although all three can occur in the same plant, it is not known whether they are related. However, no reaction was obtained in ELISA when sap extracts from some raspberry plants thought to be infected with RLMV or RLSV alone were tested for BRNV. When the dsRNA components in leaf extracts of these and other plants were examined, those infected with BRNV yielded one main component and two subsidiary components of estimated mol.wt. ($\times 10^{-6}$) of 0.62, 1.80 and 2.10 respectively. No dsRNA components were obtained from RLMV-infected plants but an RSLV-infected plant, in which BRNV could not be detected by ELISA, yielded components of the same size as the two larger ones found in BRNV-infected plants. The usefulness of dsRNA analysis as a diagnostic procedure for these viruses is being explored.

(A. T. Jones, M. J. Mitchell, M. A. Abou-Elnasr[1], M. A. Mayo)

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, four imported black raspberry selections* from Canada and 27 raspberry selections from the SCRI *Rubus* breeding programme were indexed for virus infection. In addition, three imported *Ribes* selections* and four selections from the SCRI *Ribes* breeding programme were indexed for mechanically transmissible viruses. Only one of the imported plants was virus-infected; this black raspberry plant was infected with raspberry bushy dwarf virus, which was readily detected using ELISA but was not transmitted by mechanical inoculation of sap to herbaceous test plants. This isolate therefore resembles other black raspberry isolates of raspberry bushy dwarf virus in being difficult to transmit mechanically.

ELISA was used for the first time to screen plants for infection with black raspberry necrosis virus (BRNV). The value of this rapid test was shown when BRNV infection was detected at an early stage of propagation in some English stocks of red raspberry destined for entry into the MAFF certification scheme. ELISA also proved useful for screening propagants following heat treatment to eradicate aphid-borne viruses from three genotypes produced in the SCRI *Rubus* breeding programme.

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[1]Visiting Worker

The early detection of BRNV infections decreased considerably the number of propagants that needed to be graft indexed to *Rubus* indicator plants.

At the request of MAFF, clones of Loganberry were screened for virus infection with a view to providing healthy foundation material for a certification scheme for this crop.

(A. T. Jones, M. J. Mitchell)

PU 16(a) Study the detection, properties and epidemiology of narcissus and tulip viruses

Serological detection of a potyvirus in narcissus with late season yellows

Many maincrop narcissus cultivars are infected, probably totally, with one or more uncharacterized potyviruses. Some of the plants develop leaf yellowing late in the growing season but this symptom does not always develop and detection has relied on examination of leaf extracts by electron microscopy in several successive years. Even this is difficult because the virus-like particles occur in very low concentrations and cannot be found reliably.

Particles of this type were purified from a clone (BA3-8) of cv. Golden Harvest, and found to have a single modal length of 725 nm. An antiserum was prepared that reacted specifically in $F(ab')_2$ ELISA and in simplified enzyme immunoassay (see p. 188) with leaf sap from plants of clone BA3-8. Positive reactions were also obtained with plants of several other clones of Golden Harvest with late season yellows, with plants of cultivars Dutch Master, Golden Ducat, Sempre Avanti and Rembrandt and with two supposedly virus-tested mother plants (Dutch Master and Rembrandt) which were obtained by meristem-tip culture in 1977 and first developed late season yellows in 1984. However, no reaction was obtained with sap from plants of cv. Corinthian showing similar symptoms.

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

Detection of narcissus latent virus

A substantial improvement in sensitivity of ELISA for detecting narcissus latent virus in narcissus was obtained by absorbing the virus antiserum with leaf sap from virus-free narcissus and then using the $F(ab')_2$ form of ELISA. With this procedure, the virus was detected in composite samples of one infected and 24 virus-free leaf pieces.

(W. P. Mowat)

Incidence of viruses in commercial narcissus stocks

Continuing the survey of the incidence of narcissus tip necrosis (NTNV) and narcissus mosaic (NMV) viruses in Scottish grown commercial stocks (*Ann. Rep. 1983,* 199), six stocks of cv. Sempre Avanti were tested. All

stocks were infected by both viruses; the incidence of NTNV ranged from 67–97% and that of NMV from 50–73%. Thus stocks of Sempre Avanti were infected with NMV to about the same extent as those of cv. Carlton sampled in 1983 but more so with NTNV. It is surprising, however, that such incidences of infection have not led to total infection of some stocks. Therefore the possibility was tested that the viruses may fail to invade all newly formed daughter bulbs. However, in clones of Carlton, no evidence was obtained that either virus sometimes fails to pass from mother to daughter bulbs.

(W. P. Mowat)

PU 16(b) Produce and maintain virus-free stocks of narcissus

Virus-free clones released

In 1984, the ninth annual batch of virus-free clones was released by SCRI to SNSA (FB) Ltd for further rapid multiplication by ESCA and NSCA. These clones comprised 23 kg bulbs of Golden Harvest, King Alfred and Fortune, the first time these cultivars have been released. A total of 91 virus-free clones representing 13 cultivars are now held at SCRI, of which 37 clones representing five cultivars are undergoing field propagation by SNSA (FB) Ltd.

(W. P. Mowat)

Data on all VT clones and their management in the different stages of the propagation scheme were stored on disc using the Starbase programme on a BBC Microsystem computer. This permits ready access to, and up-dating of, the voluminous data which have accumulated since all stages of the scheme first became functional in 1979.

(R. J. Clark[1], W. P. Mowat)

Virus-indexing of virus-tested clones

In 1984, no infection with narcissus mosaic or narcissus tip necrosis viruses was found in leaf samples from 1000 plants from the sixth annual issue made by ESCA and NSCA to SNSA (FB) Ltd for field propagation. Similar tests were made on 500 plants from each of the first and second issues in their fifth and fourth year, respectively, of field propagation. Again neither virus was detected. In addition, further tests were made on plants of a VT clone of cv. Carlton, grown for three years in a trial sited within a commercial planting of narcissus. Of the eight viruses commonly occurring in commercial narcissus stocks in Scotland, only narcissus tip necrosis was found, and this only in one plant. Field spread of narcissus tip necrosis virus has not been recorded before.

(W. P. Mowat)

[1]Data Processing Department

ESTATE

W. I. A. JACK

Mylnefield

The area of the farms suitable for field trials has been identified as 173.4 ha; all are of uniform status showing neither residual effects from previous cropping or chemical treatment, nor perennial weed problems.

During the year there were many changes in land area due to the following circumstances. Improvements to the A85 and A972 trunk roads started in May and have resulted in the loss of 2 ha of North Bullion field, and 4.5 ha of what remained of Lade and Haugh fields have been lost to cropping until completion of the work which includes re-grading, re-draining and landscaping. Also 21.8 ha of the land at Ninewells was surrendered for the creation of The Dundee Technology Park. To off-set the loss of land the SCRI took the tenancy of 1 ha of land known as Carselea in February and purchased 7.8 ha of land known as Lonsdale in May.

As the meteorological records show, 1984 was a year of extreme weather conditions. The main features were the above average rainfall in January, March, September to November, and extremely dry conditions from April to the end of August. These conditions had a marked effect on crop yield and quality resulting in the lowest average yields recorded at the Institute.

Farm crops and field experiments

Farm crops decreased by 32.2 ha this year due to the changes outlined above and included 68 ha barley, 28.5 ha winter wheat, 8.1 ha grass, 4.9 ha raspberries, 3 ha potatoes, 2 ha field beans and 10.8 ha fallow.

Barley cv. Golden Promise sowing started on 9 March into average seedbed conditions and continued until the 21 March when adverse weather intervened; sowing was resumed on the 4 April and was eventually completed on the 27 April. Germination and established plant populations were satisfactory but subsequent growth was poor due to the drought conditions that prevailed through to harvest; mildew (*Erysiphe graminis*) was evident in all fields in May and required two spray applications of triadiamenol with fuberidazole (Bayleton) and tridemorph (Calixin) before the disease was controlled. Harvesting started on 30 July and was completed under excellent conditions on the 14 August. The yield of 4.2 t/ha was down 0.7 t/ha on the previous year with grain

samples generally of poor quality with a high proportion of screenings, a high average nitrogen content, and with a moisture content averaging 14.8%; only c. 60% of the crop was sold for malting.

Winter wheat cv. Avalon which was sown in the autumn of 1983 over-wintered well and plant populations were satisfactory in the spring. A high-input and rigorous pest and disease control strategy was practised for the crop. Harvesting started on 15 August and was completed on 21 August. The yield of 6.6 t/ha was down 0.5 t/ha from the previous year, the grain samples were of good quality and with a protein value averaging 11.5%. All was sold for milling.

Grass grew well in the early spring but was then affected by drought conditions and failed to bulk up. Hay was cut on 8 June, drying was rapid and baling was completed on 16 June in excellent weather conditions; the yield of 6.4 t/ha was down 0.2 t/ha compared with the previous year. A second cut was taken on the 7 August and although it was of fair quality it yielded extremely poorly.

Field bean cv. Herz Freya was sown on 7 March into excellent seedbed conditions; however both the plant population and pod number per plant were below average due to the drought. The crop ripened rapidly and was combined on 21 August giving a good sample of beans at 14% moisture content; the yield of 1.5 t/ha was down 1.3 t/ha compared with the previous year.

Soil conditions were perfect at potato planting time. However the continuing dry weather made chemical weed control difficult and in some areas impossible; nevertheless the growth of the crops that were irrigated progressed satisfactorily. Sprays were applied fortnightly against pest and diseases. Lifting started on 2 August and lasted until the 13 December with frequent interruptions due to heavy rain and hampered by difficult ground conditions. Tuber quality, size and yield of the harvested crop was variable ranging between 28.8 t/ha for the non-irrigated and 32.4 t/ha for the irrigated crops.

Fruit picking started with strawberries on 21 June, followed by raspberries 10 July, Tayberries 14 July, black currants 18 July, blackberries 13 August and blueberries 24 August. The weather was excellent throughout the fruit season with only 3 days lost through rain, and losses through disease was negligible. However, crops never realised their potential due to the drought conditions; although fruit was on the small size, the quality was generally high. There was a shortage of pickers throughout the season with the result that some of the raspberry and a large proportion of the black currant crops had to be abandoned. The fruit crops sold included 37.5 t raspberries, 3.6 t strawberries, 0.3 t black currants and 0.4 t of other fruits. This was an increase 21.1 t compared with 1983 but was due to the 4.9 ha of raspberries grown at Lonsdale.

There was a total of 239 field experiments and off-station trials, an

increase of five compared with 1983. Thirty four different crop species were grown, using 77 management schemes with many special requirements utilizing 28 fertilizer and trace element formulations, 45 herbicides, 23 pesticides, 16 fungicides, and 8 experimental chemicals supplied by sponsors of field trials. The experimental crops grown included 11.5 ha raspberries, 9 ha brassicas, 8.2 ha potatoes, 5.6 ha black currants, 1.8 ha strawberries, 1 ha black- and hybrid-berries, 1 ha field beans and peas, 0.8 ha cereals, 0.3 ha bulbs, with a miscellany of minor crops occupying a further 3.1 ha. This was an overall increase of 3 ha on the previous year.

The Estate Division has benefited from the introduction of a microcomputer for many aspects of management. G. Wood has developed a system using a microcomputer program that accommodates all management data for the crops and field experiments/trials at the Institute. The system aids man-management and forwarding planning, stock control of consumables, and reduces the need for numerous individually handwritten instructions to staff, as work sheets and 'action lists' are printed out. The arduous task of manual record keeping is also much reduced, and sponsors now receive printed reports for each experiment at the end of the cropping year showing intended and actual treatments, together with costings of the services provided.

In addition, in conjunction with P. Smith[1], G. Wood has initiated and developed a computer graphics program which produces the best arrangement for field experiments within a defined land area. It has proved particularly useful with annual crops (especially brassicas, cereals, potatoes) where large numbers of experiments are required to be sited within limited areas of land. Wheras previously it could easily take days to produce just one plan, a variety of plans can now be produced in hours.

An early August harvest and continuing dry weather enabled the routine programme of stubble hygeine, sub-soiling and ploughing for winter cereals to be completed in good time. Winter barley trials were sown by 26 September, 33.5 ha of winter wheat was sown by 11 October, and both crops established well and entered the winter in fine fettle. Seven hectares was sown with grass in preparation for the site being used for the multiplication of cereal pure stocks in 1986.

Estate work was confined to fencing and the planting of windbreaks. This work included re-fencing at Carselea, and at Gourdie farm the erection of a further 900 m of security and vermin proof fence on the north and west boundaries of Highland and Reservoir fields; 700 m of windbreaks/amenity planting of *Cupressocyparis leylandii* was carried out along the east and south boundary fences of Home Park South and Gowrie East fields.

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[1]Data Processing Department

New farm equipment acquired during the year included a M.F. 265 four wheel drive tractor, a fertilizer distributor and a set of tractor-mounted rollers.

Glasshouses

The year has been a momentous one in many ways for the unit. In particular the recently completed Virology and Zoology Department glasshouse complexes provided more heated glasshouse bench space and stimulated more experimentation. More plants were therefore required and a new stock peak for the Institute was reached with 72,000 plants in containers at any one time.

Glasshouse accommodation was reduced by the removal of 345m^2 of heated glass and 86m^2 of gauze house to allow for the clearance of the site for the building of the new propagation houses and potting shed, which started in January; 64 additional polythene tunnels were constructed and irrigation laid-on in South Bullionfield, and one gauze house was erected within the glasshouse area.

Plant production at 141,345 units was up 17,345 on the 1983 total; Departmental totals were 56,025 Virology, 27,347 for Soft Fruit Breeding, 17,328 for Forage Brassica Breeding, 12,943 for Mycology and Bacteriology, 12,646 for Zoology, 12,031 for Estate, 2,364 for ODA and 785 for Physiology and Crop Production.

Other projects included the preparation of plants of some of the Institute's recently introduced black currant cultivars for the Royal Show; several Tayberry plants were prepared for the Ayr and Perth Shows, and root material from 11 cultivars of raspberry were despatched to NSDO to produce 18,950 pot canes.

Pests and diseases gave few problems following prompt and regular control measures; however, red spider mite was rather persistent where routine pest control measures could not be applied. Several new chemical pesticides were tried and it was found that three fungicides, metalaxyl with mancozeb (Fubol 58WP), bupirimate (Nimrod) and fenarimol (Rubigan), gave good control of mildew and are therefore added to the extensive list of chemicals now used under glass.

Investigations were initiated into finding a heat source other than the manually operated spirit lamp for vapourising nicotine fumigant compound for pest control. Particular success was achieved by the use of an electro-thermal 400-500V heating mantle linked to a time clock, allowing fumigation to take place automatically when the optimum temperature was reached outwith the normal working day.

(W. I. A. Jack)

The Murrays Farm

The 29.3 ha of commercial wheat cultivars Norman, Longbow and Armada which were sown in Folly, Crow, Crow reserve and Sunnyside

reserve fields overwintered well although the plant density was low. It received a top dressing of 20:10:10 fertilizer at the rate of 375 kg/ha in March. A second top dressing of nitrogen (Nitram) at the rate of 75 kg/ha was applied in April/May. The crop, harvested in late August and early September averaged 11.2 t/ha and was sold into EEC Intervention Store. Some straw was chopped and ploughed in following spike Rotavator incorporation.

Commercial spring barley totalling 40 ha was sown of the cultivars Tweed, Golden Promise and Triumph, mainly in Sunnyside, Longriggs and Cottage fields. Drilling started mid March and finished in mid April; sowing was delayed by the torrential rains of late March. Fertilizer (20:10:10) at the rate of 514 kg/ha was broadcast prior to poorer seedbed cultivations. Soil capping was a problem on heavy land necessitating Cambridge rolling to break the crust to aid emergence of the early sown material. Golden Promise and Triumph required routine fungicide applications. The extremely dry and hot summer made for an easy harvest although yields were disappointing averaging 5.6 t/ha. The grain was sold for malting and the straw baled and sold for stock bedding.

1255 kg/ha of fertilizer (15:15:20) was broadcast on the potato land before ridging and planting. Planting began on 20th March with early experimental and breeding material in Toll field and was completed with the main crop material in late April. Aphicide sprays were applied at fortnightly intervals following inspection if required; one fungicide application was required late in the season. Lifting of the early material was delayed by the dry weather, starting in early August. Maincrop lifting took place in September and early October.

Cereals for cultivar multiplication occupying c. 5 ha were grown in Potato Shed West field. Cereal breeding and trial plots occupied the 12.7 ha of the Wee Murrays field.

Trial plots of kale, swede and rape, along with NSDO spring and winter cereal demonstration plots were sited in the eastern half of Hollow field. Whitehills and Loan fields were grazed through the season by stock from the East of Scotland College of Agriculture. Hay yielding 9.4 t/ha was produced in Wall field, and the crop was sold in June. The aftermath was grazed prior to spraying off and ploughing for winter cereal trial plots and for cereal multiplication and testing in spring 1985.

Sunnyside, Sunnyside Reserve, Potato Shed and Whitehills fields were ploughed in good condition in early September. Winter wheat cultivars Renard, Galahad, and Longbow were drilled in late September and early October.

A Massey Ferguson 835 combine harvester was the one major new item of farm equipment purchased during the year.

(I. M. Chapman)

INFORMATION SERVICES

R. J. A. EXLEY

As part of the continuing development of Mylnefield, the building of an extension to the administration accommodation was started which required the library to be temporarily dispersed. Thus, the library office, current literature and reference sections were re-located in the Old Canteen which formerly provided alternative accommodation for meetings, and was also the only facility on the Institute readily available for meetings which were too large to be accommodated in the Seminar Room.

In order to harmonise the list of journals to which the Library subscribes with the research interests of staff, the requirements of the readership are surveyed every few years. Such a survey has just been completed but on this occasion the information it will provide will reflect changes due to the recent reorganisation of the research programme, and information which will be essential for the rational assessment of subscription priorities if the demand for economies becomes stringent.

LIBRARY

Mylnefield

The Mylnefield library moved into temporary and dispersed accommodation in August as indicated above. The office, current literature and reference section were moved to the Old Canteen, the bookstock and the bulk of the 'core' periodicals were moved to a room previously used as the Library up to 1975, and other periodicals and literature were placed in offices in the research departments. All other material was stored in the mobile shelving in the Library, and protected as far as possible from damp and dust. The transfer was accomplished within a fortnight, and it is estimated that 20 tonnes of volumes were packed, moved and reshelved. The library users were kept advised throughout the move of the location of services and literature by a computerised list, as well as conventional means.

By the end of the year 25 staff at Mylnefield were recipients of the Institutes Current Awareness Bulletin, 71 received circulated journals, and 209 journal titles were listed as being circulated either as parts or as contents pages. During the year, 655 items were borrowed from the library's own stock and 1057 items were obtained by inter-library loan. This is a slight decrease over previous years. In addition, almost 80

books were purchased or received by donation, besides other items such as MAFF or Scottish Agricultural College pamphlets. Thirty-four literature searches and several additional short on-line enquiries were made for library users. U. M. McKean and M. Mitchell both attended the National Library of Scotland (NLS) Interlibrary Lending Seminar at the NLS in October, and U. M. McKean attended a meeting of the Scottish Agricultural Librarians' Group in the spring, and the biennial AFRC Librarians Conference in September which was held at the PRC.

(U. M. McKean)

Pentlandfield

Inter-library loans during the year totalled 158, of which 114 were from the British Library. There were 346 internal loans. Subscriptions were taken out to *Journal Contents in Quantitative Methods* and to *Research and Development in Agriculture*, and were cancelled to *Electronic Library* and *Current Contents*. There were 17 literature searches, and 28 other on-line enquiries were made. Seventy-one books were purchased. Thirty-six users were registered as recipients of the Institute's Current Awareness Bulletin by the end of the year.

The Institutes Current Awareness Bulletin is now produced at Mylnefield due to the Librarians post at Pentlandfield now being part-time.

Five meetings were attended, including a Dialog training session and meetings of the Scottish Agricultural Librarians' Group.

(E. W. Vandome)

VISUAL AIDS

During the year there was an increased demand for photography and graphics, especially for publication purposes.

	PHOTOGRAPHY					GRAPHICS	
	Jobs	Colour	Monochrome	Diazo	EM/Prints	Jobs	Graphics
1983	1931	6365	8933	617	2437	146	485
1984	2012	6706	9354	814	2076	194	611

Novel to the Institute was the use of shortwave u.v.-light photography to record the results of electrophoretic separations of virus RNA. Specialised photography included the use of longwave u.v.-light photography to map the distribution of damsyl-amino acid derivatives on TLC plates, and to follow the movement of phloem-mobile fluorescent dyes through potato plants: time-lapse photography, using a 16 mm cine camera with colour film, was employed to study the development of chocolate spot lesions caused by infection of field bean leaflets by fungal pathogen *Botrytis fabae* under different air humidity regimes: and to study the motility of bacteria a multiple exposure photographic technique

using stroboscopic Xenon arc lamp and dark field illumination was assessed, and a suitable flashing rate and exposure time were determined to record the track as a series of images across the photograph.

A high power studio flash system was purchased in order to achieve a more even illumination when photographing large plant material and a greater depth of focus for macrophotography by enabling a smaller aperture to be used.

T. G. Geoghegan and G. Cruickshank attended the 6th AFRC Photographers and Graphics Officer Conference 11-13 September at GRI.

(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.

A Fruit Walk for members and guests was held during July, and this was followed by a successful Forage Brassica Meeting during September. The proceedings of the latter have been published in SCRI Bulletin No. 4, the contents of which are noted at the end of this section. Copies of the Bulletin were circulated to members, and a few are still available from the Secretary of the Society

During the year the Society made a number of grants for various purposes as listed below:—

(i) From General Funds:

(a) £200 in support of a visit to Pentlandfield by Mr Bogdan Flis from the Polish Potato Research Institute, the balance of the cost of this visit being met by the British Council.

(b) £75 towards the cost of a visit to Holland by Mr J. W. McNicol of the SCRI Data Processing Department.

(c) £75 towards the cost of the 'Better Brassicas '84' Conference organised by the SCRI which was held at St. Andrews during September.

(ii) From the Thyne Bequest:

£350 towards the cost of a visit to Switzerland by Dr H. Barker of the SCRI Virology Department to attend the 9th Triennial Conference of the European Association for Potato Research.

Mr J. Arbuckle, C.B.E., resigned from office as a Trustee of the Society on account of ill-health. He had held various offices in the Society, including the Chairmanship, continuously from 1961.

The 1984 Society Lecture was given on 29th March by Mr A. Q. Hitchcock, Chairman of the Potato Marketing Board. The theme of the Lecture was 'A Forward Look at the Potato Industry and the Potato Marketing Board.'

SCRI Bulletin No. 4 (December 1984)

Forage Brassicas

Mylnefield

Though the year will probably be remembered for its dry summer the total rainfall for the year (845.7 mm) represented 124% of the average and made this the fourth wettest year in our records.

Wind

Windspeeds were generally low in 1984 with the total windrun for the year being only 91% of the average. In particular, during the months of May and September the lowest average windspeeds were experienced for these months since recording began at the Institute.

Rainfall

For the third consecutive year there was an abnormal distribution of rainfall. The spring and summer period, April-August was the driest such period on our records (39% of the average) while January to March and September to November were the wettest (186 and 215% of their respective averages).

Estimated soil moisture deficits from early July to the end of August were greater than previously recorded over the same period.

Temperature

During the period May to August soil temperatures at 10 cm depth were generally the warmest on record at SCRI and average maximum air temperatures over July and August were close to the record values, only being exceeded in the summer of 1955. The 3 days of ground frost in June were unusual and presumably were associated with the fine weather and clear skies at the time.

Sunshine and Solar Radiation

Patterns of bright sunshine and solar radiation complemented the periods of high rainfall. The period April to August had the longest duration of sunshine and the second highest receipt of solar radiation that has been recorded, while September to November was the second dullest autumn (after 1968) and had the lowest receipt of radiation recorded for that period.

(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 degree days Above 6°C	Accumulated degree days Below 6°C	Days ground frost	Potential evap-oration mm	Rainfall Total mm	Rainfall DFA *	Bright sunshine hours Total	Bright sunshine hours DFA *	Mean daily solar radiation mWh/cm²	Windspeed Mean km/h	Windspeed DFA †
January	3·8	−1·7	−2·5	−2·5	0·9	−0·6	2·6	+0·1	3·1	163·1	28	4·3	137·1	+ 74·3	51·8	− 1·3	53‡	14·4	+1·5
February	5·6	0·0	0·9	+0·9	2·0	+0·4	3·0	+0·4	3·4	82·8	24	10·5	41·7	− 6·3	57·4	−14·2	91‡	11·7	−0·5
March	7·1	−0·8	2·0	+0·3	3·4	+0·1	5·0	+0·7	14·4	60·6	18	27·4	118·6	+ 69·7	81·7	−23·6	181‡	12·2	−2·7
April	10·9	−0·1	3·5	+0·2	7·3	+1·0	7·1	+0·2	63·1	27·9	15	55·5	5·1	− 35·0	163·5	+ 6·1	353	11·9	−2·3
May	14·0	+0·3	5·3	−0·5	12·7	+2·5	10·6	+0·5	125·4	11·9	11	92·2	20·8	− 34·8	233·0	+50·8	514	9·0	−3·5
June	17·9	+1·0	9·7	+1·0	15·9	+2·0	13·6	+0·1	234·5	0·3	3	102·6	38·9	− 11·4	192·0	+13·6	479	11·8	0·0
July	20·8	+2·4	11·5	+1·3	19·1	+3·8	16·1	+1·0	316·0	0·2	0	108·9	31·5	− 30·0	239·3	+64·4	520‡	8·9	−1·8
August	20·5	+2·2	11·5	+1·4	17·0	+2·6	15·9	+1·0	310·8	0·0	0	80·7	11·2	− 54·4	185·1	+31·3	401‡	9·3	−0·5
September	15·1	−0·8	8·7	+0·1	11·5	0·0	13·2	+0·5	178·9	1·2	0	42·0	117·9	+ 54·8	101·8	−16·3	223	8·1	−3·2
October	13·0	+0·5	5·9	−0·3	7·7	−0·4	9·9	+0·2	4·1	52·0	9	21·6	90·9	+ 29·2	80·8	− 9·9	125‡	11·9	+0·3
November	9·1	+0·8	5·0	+2·8	5·8	+1·7	7·6	+1·7	17·7	40·6	8	10·3	180·3	+124·3	34·0	−33·0	44	13·6	+1·5
December	7·4	+1·1	2·5	+1·7	3·8	+1·5	5·9	+2·3	11·6	73·6	20	0·3	51·7	− 18·1	56·8	+12·9	30	11·0	−1·7

*DFA Deviation from 1954-83 average

†DFA Deviation from 1959-83 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	3·9	−2·4	0·9	*	21	24	115·8	14
February	5·4	0·4	1·8	*	11	15	32·4	8
March	6·0	1·5	3·1	3·3	7	13	106·4	12
April	11·4	2·8	7·6	6·6	6	13	10·6	2
May	13·6	4·1	12·5	10·9	1	8	34·3	9
June	16·7	8·8	15·2	13·9	0	0	52·1	7
July	20·5	10·0	18·9	17·3	0	0	28·0	7
August	20·1	10·4	16·7	15·7	0	0	25·6	5
September	14·7	8·9	12·1	11·8	0	0	59·1	11
October	13·0	6·6	8·5	8·4	0	2	66·4	13
November	8·6	4·8	5·6	6·1	1	4	169·7	14
December	7·3	2·4	3·3	3·8	5	14	41·1	8
Annual total	—	—	—	*	52	93	741·5	110
Annual mean (365 days)	11·8	4·9	8·9	*	—	—	—	—

*Recording thermometer broken. Data available from 1 January to 16 January (inc.) and 3 February to 29 February (inc.)

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LIST OF ABBREVIATIONS

Countries and Organisations

AAB	Association of Applied Biologists
ADAS	Agricultural Development and Advisory Service
AFRC	Agricultural and Food Research Council
ASS	Agricultural Scientific Services (DAFS)
ATB	Agricultural Training Board
BAPB	British Association of Plant Breeders
CARI	Cyprus Agricultural Research Institute
CIP	Centro Internacional de la Papa (Peru)
COSAC	Council of Scottish Agricultural Colleges
CNR	Consiglio Nazionale delle Ricerche
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
ECRE	Edinburgh Centre for Rural Economy
EMBO	European Molecular Biology Organisation
EMRS	East Malling Research Station
ERCC	Edinburgh Regional Computing Centre
ESCA	East of Scotland College of Agriculture
GRI	Grassland Research Institute
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
INRA	Institut National de la Recherche Agronomique
ISHS	International Society for Horticultural Science
JII	John Innes Institute
MAFF	Ministry of Agriculture, Fisheries and Food
MISR	Macaulay Institute for Soil Research
MRC	Medical Research Council
NIAB	National Institute of Agricultural Botany
NERC	Natural Environment Research Council
NSCA	North of Scotland College of Agriculture
NSDO	National Seed Development Organisation
NVRS	National Vegetable Research Station
ODA	Overseas Development Administration
PRC	Poultry Research Centre
RASE	Royal Agricultural Society of England
RES	Rothamsted Experimental Station
ROSPA	Royal Society for the Prevention of Accidents
PBI	Plant Breeding Institute
PMB	Potato Marketing Board
SERC	Science and Engineering Research Council
SHRI	Scottish Horticultural Research Institute
SNSA	Scottish Nuclear Stocks Association
SPBS	Scottish Plant Breeding Station
SSPDC	Scottish Seed Potato Development Council
UC	University of California
UK	United Kingdom
USA	United States of America
USSR	Union of Soviet Socialist Republics

WPBS	Welsh Plant Breeding Station
WRO	Weed Research Organisation
WSAC	West of Scotland Agricultural College

Others

c.	about
cv.	cultivar
DM	dry matter
EHF	Experimental Husbandry Farm
EHS	Experimental Husbandry Station
ELISA	enzyme-linked immunosorbent assay
EMAS	Edinburgh Multiple Access (Computer) System
JMT	joint main trial
LAI	leaf area index
NAC	National Agricutural Centre
NFT	National Fruit Trials
NIR	near infra-red
NLT	National List Trial
NPL	National Physical Laboratory
PCN	potato cyst nematode
RCCA	Research Council Co-operative Award
r.h.	relative humidity
SE	standard equivalent
SEC	scanning electron microscope
SMCO	S-methyl cysteine sulphoxide
sp.	species
u.v.	ultra violet
VTSC	virus tested stem cutting

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

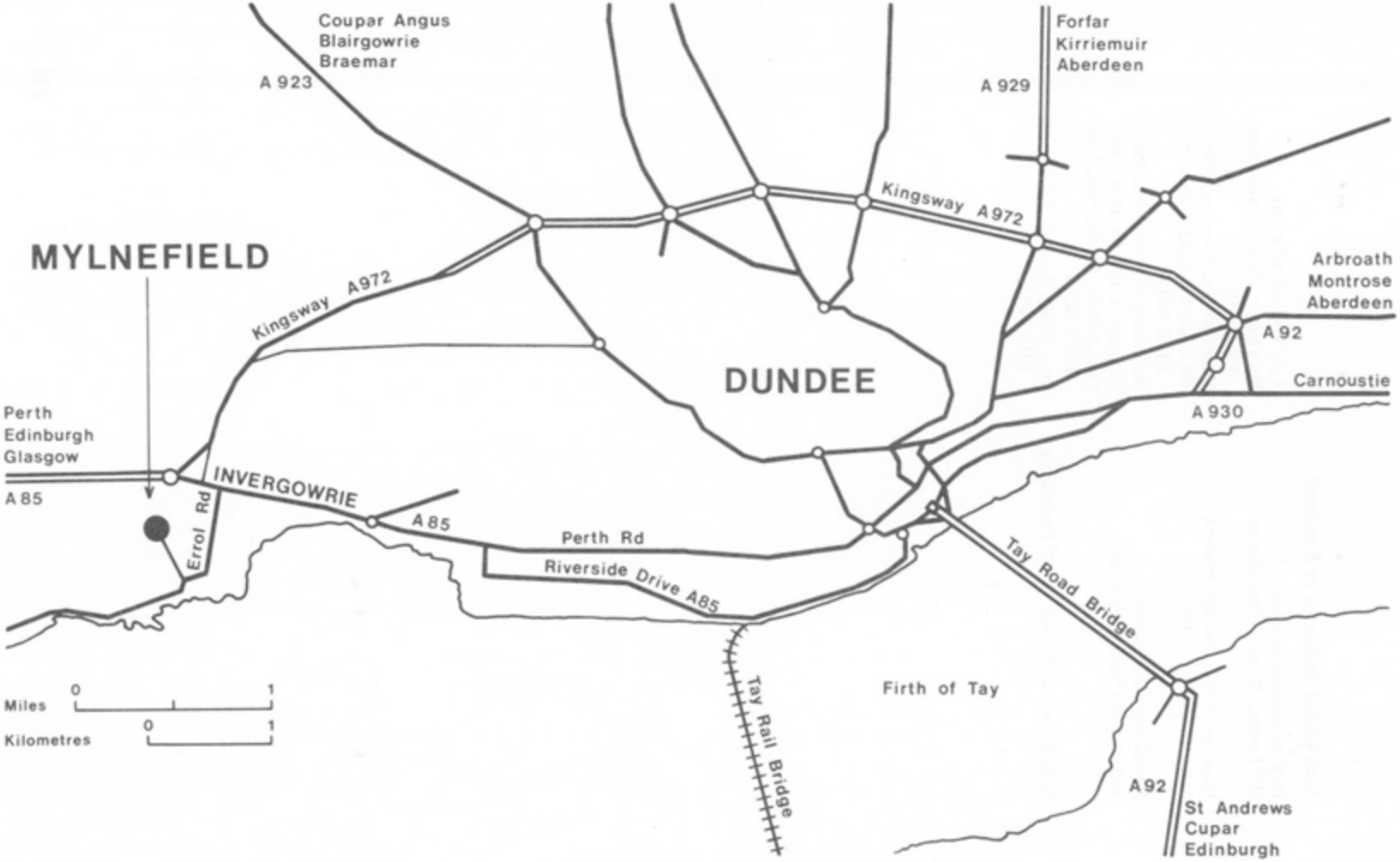
Animal Breeding Research Organisation	King's Buildings, West Mains Road, Edinburgh, EH9 3JQ
Food Research Institute	Colney Lane, Norwich, NR4 7UA
Institute of Animal Physiology	Babraham, Cambridge, CB2 4AT
Institute for Research on Animal Diseases	Compton, Newbury, Berks., RG16 0NN
Letcombe Laboratory	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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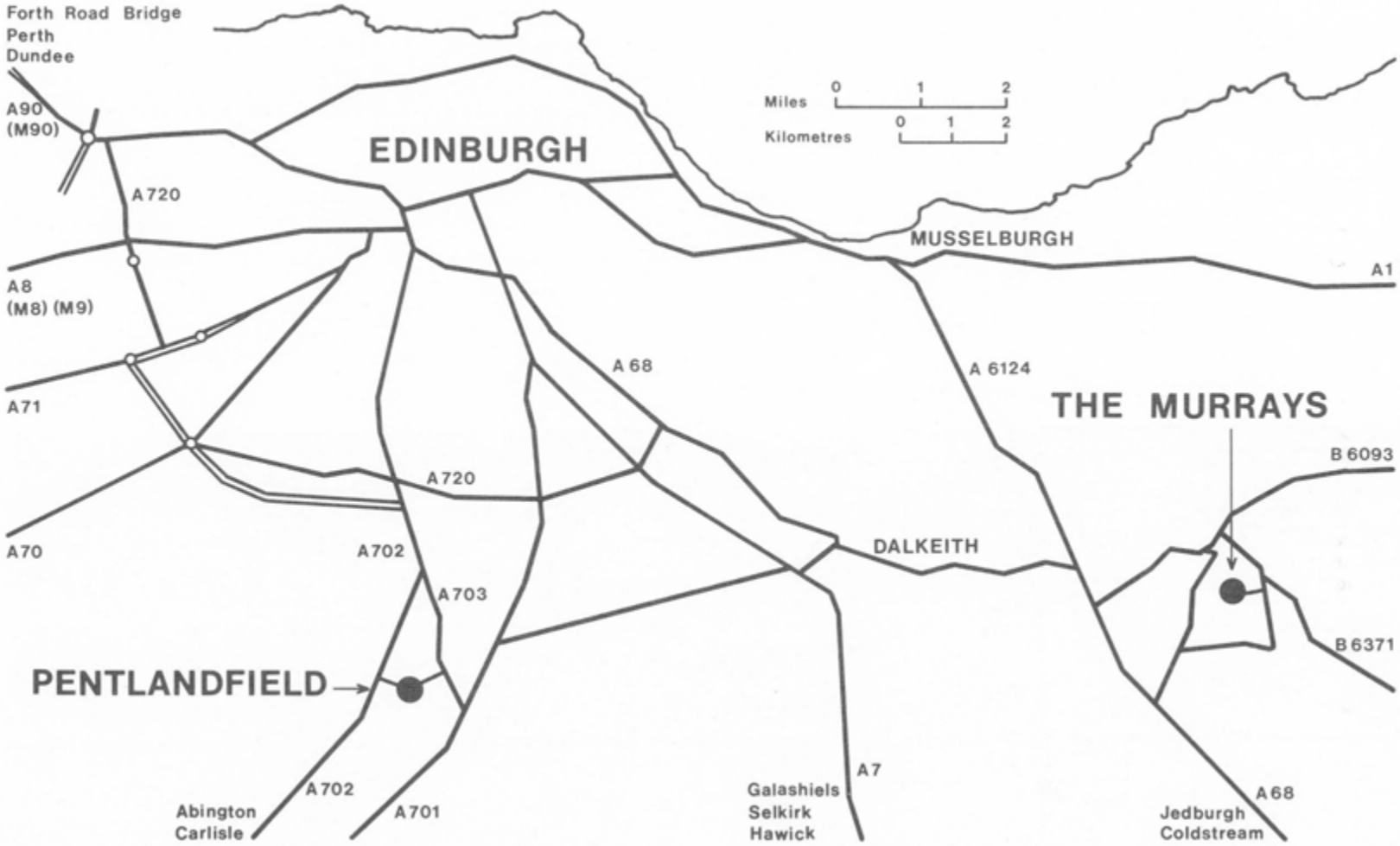
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