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ANNUAL

THE SCOTTISH HORTICULTURAL RESEARCH INSTITUTE

1979

The Scottish Horticultural Research Institute

26th Annual Report for the year 1979

The Scottish Horticultural Research Institute
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† Honorary Senior Lecturer in the University of St Andrews.

General Report

C. E. TAYLOR

In the 1978 Annual Report reference was made to the review of the future requirements for state-funded plant breeding and crop research in Scotland, undertaken by the Working Party set up by the Secretary of State for Scotland. The Working Party recommended the amalgamation of the Scottish Plant Breeding Station at Pentlandfield with the Scottish Horticultural Research Institute at Invergowrie. From the time of publication of the Working Party Report, and throughout 1979, views on this recommendation were expressed by the Governing Bodies of the two Institutes, the Agricultural Research Council, Directors and Staff. In the House of Commons on 19 December, 1979, the Secretary of State announced his decision to accept the recommendations of the Working Party and the following paper was subsequently laid in the Library of the House.

New Organisation for Plant Breeding and Crop Research

'I have accepted the recommendation of a working party which reported at the end of last year that Scotland's two premier crop research institutes should be amalgamated on one site near Dundee.

The effect of this decision will be to bring together under one governing body the work of the Scottish Horticultural Research Institute, Mylnefield, Dundee, and the Scottish Plant Breeding Station, Pentlandfield, near Edinburgh.

The amalgamation will be phased over a period of years. It will also involve the transfer of the farm of Gourdie, presently held by Tayside Health Board, but surplus to their requirements, to the new combined Institute, and a development programme to support the amalgamation and develop the existing facilities at Mylnefield will be put in hand as soon as possible.

A Working Party on the future of state-funded plant breeding and crop research in Scotland was set up in July, 1978, by the then Secretary of State. It reported in November last year. Consultations with Governing Bodies, staff and the Agricultural Research Council followed. Lord Mansfield, Minister of State at the Scottish Office, recently met the Chairmen of the Governing Bodies and representatives of the Staff Side of the Agricultural Research Service at separate meetings to hear their views before I reached my decision.

In terms of society's needs and resources for the future, the development of crop production is vitally important. It is our intention to develop and improve the facilities for carrying out plant breeding and research work in Scotland. At present we have two separate institutes which while working on different projects and having distinct functions do have common interests and a common need for certain scientific disciplines and resources. The combining and reinforcement of such resources will enhance the scope for collaboration between the plant breeders and those engaged in fundamental research.

Provision of improved facilities is of the highest importance: in particular the land which will be available to the combined Institute is more suitable than the land currently held by the Scottish Plant Breeding Station. The overall objective is to obtain for the agricultural and horticultural industry the maximum benefit from the programme of development which is now required.

The Working Party comprised three well-known Scottish farmers (including the Chairmen of the two Institutes), two professors and one civil servant. Its recommendations are supported by the Directors and Governing Bodies of the Institutes and by the Agricultural Research Council, which is responsible for the scientific oversight of state-funded agricultural research in the UK. I have considered the Working Party's review very carefully along with Lord Mansfield, and having heard his reports of his meetings with those involved, I am in no doubt that this amalgamation and investment is necessary to release the full potential that exists for advancement of plant breeding and crop research in Scotland.

It will be necessary to arrange for the two Institutes to be brought under the control of one Governing Body. I understand the existing Governing Bodies have been giving tentative consideration to that question, and I shall be consulting them on that subject. In the meantime I am arranging for the transfer of the farm of Gourdie to the Scottish Horticultural Research Institute who will prepare the land for plant breeding and research work. Arrangements are also being made with the Agricultural Research Council for a review of the research programmes of both Institutes.

I fully understand the misgivings of the staff at Pentlandfield. Change is always difficult to accept, but we expect to be able to offer jobs at Mylnefield to all the scientific staff. As many of the support staff as can be accommodated at Mylnefield will be offered jobs there and we will do our best to find employment for the rest within the Edinburgh Centre of Rural Economy, of which the Scottish Plant Breeding Station is a member.

I wish to endorse strongly the Working Party's view that the staff at both Institutes should be associated at an early stage with the work of planning and phasing the move.

I am convinced that my acceptance of the Working Party's recommendation will offer staff at the combined Institute a more rewarding future with

prospects of more effective research than would be possible under the present organisational arrangements.'

The amalgamation will be brought into effect by an extension of facilities at SHRI, Invergowrie, including the acquisition of Gourdie farm, and the transfer of staff from Pentlandfield. The building of new facilities will take several years, but the present two institutes will come under the management of one Governing Body and one Director towards the end of 1980, by which time the name of the Scottish Horticultural Research Institute will have been changed to the Scottish Crop Research Institute to identify the new amalgamated institute.

In March, 1980, an Agricultural Research Council Programme Review Group, under the Chairmanship of Professor J. L. Jinks, will examine the research programmes of the two institutes with a view to making recommendations to the Department of Agriculture on the structure and content of the research programme for SCRI. It is expected that the research programme eventually identified for the new institute will demonstrate to the agricultural and horticultural industry the value of the development of the relevant sciences from the amalgamation of the resources of SHRI and SPBS.

Sir James Hamilton, Permanent Secretary at Department of Education and Science visited the Institute on 24 August. The Hon. L. Gandar, High Commissioner for New Zealand, with Mrs Gandar, and Mr Nelson, Trade Commissioner at New Zealand House visited the Institute on 7 November.

Mrs Winnie Ewing, European Member of Parliament for Moray and Nairn, with Mr Douglas Crawford, Member of Parliament for Perth and East Perthshire, paid a visit to the Institute in April, while Mr Bill Walker, Member of Parliament for Perth and East Perthshire, visited the Institute on 6 August.

Governing Body

With regret we note the death of Mr Robert L. Scarlett, CBE, VMH, on 5 June, 1979, at the age of 91 years. Mr Scarlett served as a member of the Governing Body from 1953 to 1958. He was one of the group of horticulturists involved in promoting the idea of a Scottish horticultural institute. After his retiral from the Governing Body he remained in close contact with the Institute and was much respected for his sound opinion and advice.

Appointments

Dr T. Tamada from the Hokkaido Central Agricultural Experiment Station, Japan, was appointed to a temporary post in the Virology Section from 17 April, 1979, for approximately 18 months, to undertake work on some aspects of the detection of aphid-borne viruses of potato.

Ursula M. McKean was appointed to the vacant Librarian post in February, 1979.

The following ASOs were appointed during 1979:

Mrs Carol Henry	Zoology Section
Carol Findlay	Zoology Section
Wendy F. Adams	Virology Section

New members of the Estate Section were I. D. Burge, E. A. Davidson, W. D. J. Jack and R. Keith.

Resignations

A. J. Hargreaves	HSO, Mycology Section
Mrs Sandra Husband	ASO, Zoology Section
Mrs Sylvia Dick	ASO, Zoology Section
A. Spink	EW, Estate Section
D. C. Cameron	EW, Estate Section
G. Wilson	EW, Estate Section

Promotions

R. A. Fox A. F. Murant	PSO to SPSO
D. J. Robinson	SSO to PSO
J. G. Harrison	HSO to SSO
R. J. Clark P. A. Gill	SO to HSO
Judith Thomson	ASO to SO

Awards

B. D. Harrison was elected Fellow of the Royal Society of Edinburgh.

L. Torrance — Ph.D., University of Dundee

Retirements

J. Chambers retired from the Virology Section after 27 years' service at the Institute. A. D. McDonald retired from the Estate Section after 23 years' service.

At the West of Scotland Unit, Janet B. Henry, Clerical Officer, retired on 31 December after 12 years' service.

Research Students

Helmy Wahdan (Horticultural Research Institute, Cairo) continued his three-year study of environmental effects on the growth and development of the strawberry. (Crops Research)

B. Elliot contined an ARC research studentship studying the cytogenetic relationships of Rubus species in the sub-genus Idaeobatus.

Jacqueline Weir was appointed to a Department of Agriculture for Scotland studentship for a similar study. (Plant Breeding)

D. R. Ellerton (ARC post-graduate student) continued his studies into the causes of failure to emerge of barley seeds of low vigour.

K. Forbes (SRC-CASE post-graduate student, jointly with the Institute of Animal Genetics, Edinburgh, and the University of Edinburgh) continued his studies on the genetics of *Erwinia carotovora.*

T. M. O'Neill (SRC-CASE post-graduate student, jointly with the University of Stirling) continued his studies on the epidemiology and biochemistry of host/pathogen interaction in smoulder of narcissus.

Christine J. Whitehart (SRC-CASE post-graduate student, jointly with the University of Aberdeen) commenced research on the epidemiology of cane spot of raspberry. (Mycology)

R. L. S. Forster, a New Zealand National Research Advisory Council post-graduate student, continued his studies on nepoviruses.

J. C. Sequeira, from the Eastacao Agronomica Nacional, Oeiras, Portugal, arrived in October to work on cassava latent virus as a post-graduate fellow of the Calouste Gulbenkian Foundation.

P. Waterhouse, an ARC research student, continued his studies on aphid-transmitted viruses of umbelliferous plants. (Virology)

C. A. Aveyard completed his studies on the control of potato aphids in relation to virus spread.

D. J. F. Brown continued his studies on an analysis of population differences on *Xiphinema diversicaudatum* in relation to morphology and virus transmission.

Miss L. M. Cotes continued her studies on the tolerance of potatoes to damage by potato cyst nematodes.

B. S. Griffiths commenced studies on the changes induced in root-tip galls by *Longidorus elongatus* and *Xiphinema diversicaudatum.* (Zoology)

Sandwich Course Students

Miss Patricia Dyce (Dundee College of Technology) assisted from April to September on the EEC joint field bean experiment. (Crops Research)

Stephen Grosset (Dundee College of Technology) from April to September assisted with studies on the feeding behaviour of Longidorus and Xiphinema. (Zoology)

Visiting Workers

Tang Deng-yin (Institute of Geography, Peking) arrived at the end of the year to spend 14 months studying water uptake and loss from crops. His visit is under an agreement between the Royal Society and the Chinese Academy of Sciences.

A. Nes (Kise Agricultural Research Station) completed a year's study on within-plant competition in black currants and returned to Norway in February.

Dr Shabaan Khalil of the Agricultural Research Centre, Legume Research Section, Giza, Egypt, spent 10 May until 25 September working on effects of competition on bud, flower and pod development in *Vicia faba.* (Crops Research)

P. Geerts, a plant breeding student of Wageningen University, Holland, worked for 6 months on plant breeding problems in Rubus and Ribes. (Plant Breeding)

Miriam Abbenhuis, from the Agricultural University, Wageningen, The Netherlands; Irene Majewicz, from the Scottish Plant Breeding Station, and Daphne Wright, ADAS, Cambridge, spent brief periods gaining experience of various techniques in plant virology.

Dr R. I. Hamilton completed his year's work on nepoviruses under a transfer of work arrangement, and returned to the Agriculture Canada Research Station, Vancouver, in August.

Mr A. Kurppa returned to the University of Helsinki in January, having studied tobraviruses for 6 months with financial support of the Kellogg Foundation.

Dr T. Tamada arrived in April from the Hokkaido National Agricultural Experiment Station, Japan, and is spending 18 months studying potato leafroll and allied viruses. His visit is aided by a travel grant from the Underwood Fund. (Virology)

Dr I. Spiegel (Volcani Centre, Israel) spent 5 weeks in July and August studying the adsorption of cationised ferretin on to nematode cuticle. (Zoology)

Visits Abroad

R. A. Fox visited the Institute ' De Haaf ', Wageningen, 2-4 May, to attend a meeting of the Council of the European Association for Potato Research and to discuss planning for the Association's next Triennial Conference.

H. J. Gooding spent 10 days in France during May visiting the Institut National de la Recherche Agronomique (INRA), the Centre Technique Inter-professional des Fruits et Legumes (CTIFL), nurserymen and growers.

D. L. Jennings visited the Institut National de la Recherche Agronomique at Angers and the Centre de Recherche de Dijon, France, in June.

D. L. Jennings visited the Research Institute of Pomology at Skierniewice, Poland, and several of its sub-stations in central and southern Poland from 3-12 September. His visit was sponsored partly by the Polish Institute and partly by NSDO.

A. T. Jones and A. F. Murant attended the Eleventh International Symposium on Fruit Tree Virus Diseases, held from 3-11 July at Budapest, Hungary.

M. C. M. Pérombelon visited the International Potato Centre (CIP), Peru, 11-14 June, to participate in a Planning Conference on bacterial diseases of potato and to formulate recommendations for future work. He also visited two CIP field stations and on his return journey spent 4 days at the Department of Plant Pathology, University of Wisconsin, USA.

D. A. Perry visited Denmark, 10-14 September, at the invitation of the State Plant Pathology Institute Copenhagen, to examine carrot crops and to discuss a research programme into the causes and control of cavity spot.

I. M. Roberts spent 8 weeks in October-December in Lima, Peru, at the invitation of the International Potato Center as consultant on electron microscopy. During this period he provided instruction on techniques for detecting and identifying plant viruses, and conducted research on potato viruses.

C. E. Taylor attended three meetings of the Consiglio Scientifico del Laboratorio di Nematologia agraria, Bari, Italy, on 14-16 March, 26-29 June and 24-26 September. During 10-15 September, he also attended the European Science Foundation Workshop on taxonomy of longidorid and trichodorid nematodes and survey techniques. At the invitation of the British Council, Dr Taylor joined a group and visited Jammu and Kashmir and also Himachal Pradesh research stations in India from 19 October to 2 November to explore, on behalf of the Overseas Development Administration, the possibilities of Indo-UK research collaboration in the field of temperate horticulture. As a guest of the Italian Society of Nematologists, he attended the inaugural meeting of the Society, held 21-30 November at Pisa, Italy, and presented a paper with D. J. F. Brown.

R. Thompson visited research workers between 10-20 September in several European countries, in connection with the EEC Protein Group activities on field beans. The itinerary included visits to Institut National de la Recherche Agronomique (INRA), Dijon, France; Station Federale de Recherches Agronomique de Changins, Nyon, Switzerland; University of Hohenheim, Germany; University of Gottingen, Germany; Foundation for Agricultural Plant Breeding, Wageningen, The Netherlands; Centre for Agrobiological Research, Wageningen, The Netherlands; Royal Veterinary and Agricultural University, Taastrup, Denmark, and Svalof A.B., Sweden.

Pauline B. Topham visited research workers in The Netherlands (Nijmegen), Belgium (Gembloux), West Germany (Saarbrucken), and Austria (Linz) to study computer methods applied to biogeographical data handling and mapping, from 5-9 March. She also attended the NATO Advanced Study Institute on Map Data Processing, Maratea, Italy, 18-29 June.

A. B. Wills visited the Western Washington Research and Advisory Center and attended the Crucifer Improvement Conference, Puyallup and Mount Vernon, Washington State, USA. In California he visited Moran Seeds, Inc., Salinas, the Asgrow Seed Company, San Juan de Batista, and Golsmiths Seeds Inc., Gilroy, from 24-27 July, for discussions on vegetable breeding and sib testing in F1 hybrids. His visit was sponsored by the American Seed Research Foundation.

A. B. Wills visited on 4 October the seed company of Sluis en Grott, Enkhuisen. His visit was sponsored by the Dutch Horticultural Seed Trade Association.

Eveline Wiseman visited The Netherlands from 7-16 May at the invitation of Bejo Zaden for consultations concerning the electrophoretic sib testing technique. She also visited the seed companies Royal Sluis and Sluis and Groot where the technique is being successfully applied to commercial seed stocks.

J. A. T. Woodford visited Brittany, 3-10 July, to study basic seed potato production and potato aphids.

Courses Attended

T. J. W. Alphey attended the SRC/ARC Middle Management Course II at the Elcot Park Hotel, Newbury, 5-9 March and 23-27 April.

D. J. F. Brown attended an ARC/SRC introduction to management course held in Newbury, 29 January-2 February.

D. J. F. Brown attended an FBPP methods in plant pathology course held at Leeds University, 17-20 December.

T. G. Geoghegan and S. F. Malecki attended a Kodak seminar on micro-filing techniques at Dundee on 16 February.

S. F. Malecki attended a meeting on lighting techniques for cinemicro- and macro-photography at Rothamsted Experimental Station on 16 December.

W. M. Robertson attended a course on the principles of Light Microscopy organised by Royal Microscopical Society at Brunel University, Uxbridge, 16-20 July.

D. L. Trudgill attended the ARC Training Course III at Middleton Hall, Corebridge, 4-8 June and 10-14 September.

Conferences at which papers were given

3 January	Society for General Microbiology Virus Group, Cardiff.	
	M. A. Mayo	Structural features of nepovirus RNA.
	M. A. Mayo	Effects of proteases on the RNA of nepoviruses.
16 January	ADAS Carrot Conference, King's Lynn.	
	D. A. Perry	Cavity spot of carrots.
17 January	The East of Scotland College of Agriculture, Fruit Growing Conference.	
	I. G. Montgomerie	Developments in control of red core in strawberries.
30 January	PMB Seed Potato Advisory Committee.	
	J. A. T. Woodford	Early haulm destruction to curtail the spread of potato leaf roll—would it decrease the virus content of Scottish seed potatoes?
20 February	Meeting on Bulb Research and Development, Lisse, Netherlands.	
	W. P. Mowat	Introduction of virus-free narcissus into commerce.
13-14 March	ADAS Conference: ' Factors affecting emergence of vegetable seeds '.	
	D. A. Perry	Seed vigour and field emergence.
3-6 April	Association of Applied Biologists/Federation of British Plant Pathologists, Cambridge.	
	B. D. Harrison	Mechanisms of virus variation and some factors affecting the success of variants.
	A. T. Jones	Performance of aphid-resistant raspberry cultivars.
	D. L. Jennings	Progress in breeding for virus resistance in raspberry.
25 May	Scottish Diagnostic Virology Group, Aberdeen.	
	H. Barker	Protoplasts in plant virology.
11-14 June	Eighteenth Planning Conference of the International Potato Center, Lima, Peru.	
	M. C. M. Perembelon	Ecology of soft rot erwinias in relation to potatoes.

23-27 June	European Invertebrate Survey, 4th International Symposium, Saarbrucken, Germany.	
	B. Boag	Computer Mapping Programmes for EIS Base Maps.
	B. Boag	Geographical distribution of *Xenocriconemella macrodora* in Britain and Spain and its relationship with oak.
26-29 June	International Seed Testing Association, Interconvention Meeting, Zurich.	
	D. A. Perry	Report of the Vigour Test Committee.
28 June	EEC Seminar on seed legumes, Cambridge.	
	A. T. Jones	Seed-borne viruses of *Vicia faba* and the possibility of producing seed free from broad bean stain virus and Echtes Ackerbohnen-mosaik-Virus.
2-5 July	Association of Applied Biologists (Plant Breeding Group) and Federation of British Plant Pathologists, Edinburgh.	
	P. A. Gill	Screening for low temperature tolerance in black currants and onions.
	H. J. Gooding	Screening for quality in strawberries.
	H. J. Gooding	Screening for resistance to strawberry mildew.
	I. G. Montgomerie	Definition of objectives in screening for resistance to red core in strawberry.
	A. B. Wills	Screening for convenience characters.
3-4 July	Second International Symposium on Small Fruit Virus Diseases, Budapest, Hungary.	
	A. T. Jones	Some effects of latent virus infection in red raspberry.
	A. F. Murant	Particles of raspberry vein chlorosis virus in the aphid vector, *Aphis idaei*.

11 July	Royal Microscopical Society, York.	
	I. M. Roberts	Virus/antibody interactions in electron microscope serology.
18-20 July	Crucifer Improvement Conference, Puyallup, Washington.	
	A. B. Wills	Testing F1 hybrids of *Brassica oleracea* for sibs by seed and seedling isoenzyme analysis.
29 August	ISHS Working Group on Vegetable Viruses, Bari, Italy.	
	A. F. Murant	Ecology of nematode-borne viruses affecting vegetable crops.
3-7 September	Section M, British Association Annual Meeting, Edinburgh.	
	P. D. Waister	Market specifications in relation to consumer needs.
	C. E. Taylor	Production for specific market requirements.
6 September	Symposium on virus diseases of ornamental plants, Prague, Czechoslovakia.	
	W. P. Mowat	A potexvirus from tulip.
10-15 September	European Science Foundation Workshop on Taxonomy of longidorid and trichodorid Nematodes and Survey Techniques, Wageningen, Holland.	
	T. J. W. Alphey	Data handling and computer mapping in surveys.
	B. Boag	Data handling and computer mapping in surveys—GIMMS computer programme.
	D. J. F. Brown	The effects of methods of killing, fixation and mounting on the morphometrics of *Xiphinema diversicaudatum*. Morphometrical variability between populations of *Xiphinema diversicaudatum*. Sampling and nematode extraction methodology used in nematode surveys.

13 September	Society for General Microbiology Virus Group, Oxford.	
	D. J. Robinson	Sequence homologies between RNA species of tobacco rattle virus strains.
17-21 September	Association of Applied Biologists 75th Anniversary Meeting: 'Advances in Crop Production and Crop Protection', Reading.	
	B. D. Harrison	A biologist's view of twenty-five years of plant virus research.
	H. M. Lawson	New weeds for old in perennial crops.
	A. F. Murant	Estimation of RNA molecular weights by gel electrophoresis.
	I. M. Roberts	Developments in electron microscopy.
	D. L. Trudgill	Effects of nematodes on plant growth.
	P. D. Waister	Cultural methods for soft fruits: the physiologist as innovator.
18-19 September	ARC Brassica Breeders' Conference, SPBS, Edinburgh.	
	A. B. Wills	DUS criteria and problems of stability.
1-3 October	Eucarpia 'Cruciferae 1979' Conference, Wageningen.	
	A. B. Wills	Comparative studies of isoenzyme genes in some Crucifer species.
3 October	Seventh Scottish Symposium on Electron Microscope Techniques, Edinburgh.	
	G. H. Duncan	A simple freeze-drying device for electron microscope specimens.
	I. M. Roberts	A method for providing comparative counts of small particles for electron microscopy.
10-12 October	European Weed Research Society Symposium on 'The Influence of Different Factors on the Development and Control of Weeds', Mainz, Germany.	
	H. M. Lawson	The influence of herbicides and crop management on weed control problems in raspberries.

30 October	ADAS Black currant study day, Luddington EHS.	
	A. Dale	Tolerance of black currants to spring frosts.
	P. A. Gill	Bud necrosis in black currants.
16 November	VTSC Growers' Conference, Aviemore.	
	J. A. T. Woodford	Potato aphids and viruses — past, present and future problems.
19 November	5th Dacamox Seminar, Brighton.	
	J. A. T. Woodford	Virus spread in seed potatoes.
20-22 November	1979 British Crop Protection Conference: ' Pests and Diseases ', Brighton.	
	D. L. Trudgill	Control of *Pratylenchus penetrans* and other replanting disorders in raspberries with dazomet.
	J. A. T. Woodford	Field trials for the control of raspberry cane midge in Scotland.
	I. G. Montgomerie	The effect of systemic and other fungicides on the control of red core disease and on the yield of treated strawberries.

Conferences Organised

C. E. Taylor with T. J. W. Alphey and B. Boag organised a Workshop on taxonomy of londidorid and trichodorid nematodes and survey techniques. The Workshop, financed by the European Science Foundation, was the first formal meeting of participants in the European Plant Parasitic Nematode Survey which is recognised as an 'Additional Activity' by the *ad hoc* Group of Biological Recording, Systematics and Taxonomy of the European Science Research Councils. It was held at the Laboratorium voor Nematologie, Landbouwhogeschool, Wageningen, September 10-13.

P. D. Waister (with I. M. Roberts and W. M. Robertson) organised a symposium and exhibition ' Microscopy Today ' on behalf of the Tayside and Fife Branch of the BA, in Dundee on 17 November.

Editorial Duties

R. A. Fox	Member of Board of Editors of Potato Research.
H. J. Gooding	Member of the Board of Editors of *Horticultural Research*.

B. D. Harrison	Editor of *Commonwealth Mycological Institute/ Association of Applied Biologists Descriptions of Plant Viruses.* Member of Editorial Board of *Journal of General Virology.* Member of Editorial Board of *Intervirology.*
M. A. Mayo	Member of Editorial Board of *Journal of General Virology.*
A. F. Murant	Member of Board of Editors of *Annals of Applied Biology.* Editor of *Commonwealth Mycological Institute/ Association of Applied Biologists Descriptions of Plant Viruses.*
D. J. Robinson	Member of Editorial Board of *Journal of Virological Methods.*
C. E. Taylor	Editor of *Nematologia Mediterranea.* Associate Editor of *Journal of Horticultural Science.* Member of the Board of Editors of *Horticultural Research.*
Pauline B. Topham	Assistant Editor of the *Lichenologist.* Editor of *Horticultural Research.*
P. D. Waister	Associate Editor of *Journal of Horticultural Science.*
A. B. Wills	Joint Editor of Cruciferae Newsletter.

Service on Committees

T. J. W. Alphey	UK representative on the European Plant Parasitic Nematode Survey Committee.
B. Boag	Nematology representative on the European Invertebrate Survey Committee.
A. Dale	NFT Scottish Soft Fruit Panel.
R. A. Fox	Council Member, European Association for Potato Research. Vice-Chairman, Pathology Section, EAPR. Chairman, Disease Assessment Group, EAPR.
H. J. Gooding	Fruit Working Group Committee. NFT Scottish Sub-Committee. NFT Strawberry Variety Assessment Panel.

B. D. Harrison	Association of Applied Biologists, President-Elect. JCO, Technical Secretary of Plant Science Committee. International Congress of Virology, Joint Vice-Chairman of Programme Committee.
D. L. Jennings	NFT Raspberry Panel. NFT Scottish Soft Fruit Panel. SNSA Adviser to Committee.
A. T. Jones	Virology Group of Federation of British Plant Pathologists, Member of Committee.
H. M. Lawson	Association of Applied Biologists — Weeds Group. ISHS Working Group on Weed Control in Vegetables. JCO Technical Secretary of Field Vegetables Committee.
R. J. McNicol	NFT Scottish Sub-Committee.
W. P. Mowat	Scottish Bulb Technical Committee, Convener.
A. F. Murant	International Society for Horticultural Science, Chairman of Working Group on Small Fruit Viruses.
D. A. Perry	Chairman, Vigour Test Committee, International Seed Testing Association.
C E. Taylor	Journal of Horticultural Science Publications Committee. University of Strathclyde/West of Scotland Degree Advisory Board. West of Scotland Agricultural College Glasshouse Advisory Committee. NFT Advisory Committee. SNSA — Adviser to Committee. SNSA (Flower Bulbs) — Adviser to Committee. NSDO Advisory Committee. Member of Scientific Council of the Laboratorio di Nematologia Agraria, University of Bari, Italy. SHRI/Scottish Colleges Liaison Group. ACAS Advisory Committee. Potato Marketing Board — Member of Research and Development Committee. Member of Board of Management of European Society of Nematologists.

R. Thompson	SHRI/Scottish Colleges Liaison Group.
Pauline B. Topham	ERCC Research Councils Users Group. ERCC Database and Data Facilities Working Party
P. D. Waister	JCO, Member of Fruit Committee. Tayside and Fife Branch Committee of the BA. HEA Scottish Branch. NFT Scottish Sub-Committee. Dundee University Botanic Garden Committee.
A. B. Wills	British Association of Plant Breeders Vegetable Crop Group.

Exhibitions

19 January	'New SHRI Strawberry Varieties' for the Institute of Biology, at the Royal Scottish Museum, Edinburgh.
21-24 March	Computer mapping of plant parasitic nematodes was demonstrated at an exhibition 'The Computer and your Future' organised by the Tayside and Fife Branch of the BA.
18 April	'New SHRI Strawberry Varieties' at the West of Scotland College of Agriculture Open Day.
21-23 August	'Blueberries' at Ayr Flower Show.
17-21 September	Several staff representing different Sections exhibited display boards at the Association of Applied Biologists 75th Anniversary Meeting 'Advances in Crop Production and Crop Protection,' Reading.
17 November	The Institute exhibited at 'Microscopy Today,' an educational meeting in Dundee organised by the BA.
13 December	The Institute exhibited at 'Careers in Biology,' a meeting in Dundee organised by the East of Scotland Biology Teachers' Association.
17-21 December	An exhibit showing nematode virus transmission test systems was displayed at the 'Methods in Plant Pathology' meeting organised by FBPP at Leeds University.

Radio and Television

M. R. Cormack spoke on soft fruit cultivars, particularly those bred at SHRI, on BBC TV's 'The Beechgrove Garden' on 19 October.

D. L. Jennings discussed the 'Tayberry' on 24 October in a programme recorded for the BBC External Service.

P. D. Waister discussed the effects of winter weather on the raspberry crop on 'Reporting Scotland' on BBC TV on 6 June.

Index to Projects

CROPS RESEARCH

P. D. WAISTER

Yields of field beans in Scotland have usually been as high or higher than in England, but still well below the potential if even only half of the flower initials are sustained through to maturity. Experiments this year have helped to identify the phasing and the profiles of loss of developing flowers and pods, and to distinguish the critical periods of competition for light. This is a useful step towards the objective of understanding the reasons for the present yield ceiling and hence what opportunities exist for raising it.

The analysis of samples from field experiments has been greatly aided by the opening of a crop handling building, equipped with grading lines, cold stores, growth analysis laboratories and drying ovens. This is the culmination of efforts to transfer recording from a multitude of points in the field and elsewhere to centralised facilities, while still retaining the capacity to deal with the differing requirements for fruit, vegetable, and arable crops. Every prospective user of this building was consulted at each stage of its design, which probably accounts for the smooth operation of the facilities in this first year of use.

01001 *Effects of weather conditions on growth, yield and quality of soft fruit crops*

Root environment of strawberries

In spring, 1979, an experiment was planted to examine the response of strawberries to raising the temperature of the rooting medium. Six treatments were included to separate the effects of ridging, mulching, soil sterilisation and changes in soil water content. Soil temperature was raised by covering the soil with black or clear polythene mulch.

Soil temperatures were measured at 10 cm depth at 9·00 GMT each day until July when a multipoint recorder was installed to measure temperature fluctuations. Ridging had no significant effect on soil temperature, black polythene raised it by an average of 0·6°C and clear polythene by 1·9°C.

Soil moisture potential was monitored in irrigated plots using Bourdon gauge tensiometers, irrigation being applied whenever potential reached −0·4 bar. Gypsum blocks were used in the later part of the season to

monitor soil moisture status in polythene-covered non-irrigated plots. At no time were potentials lower than – 1 bar observed. This may have been due in part to the relatively wet season and in part to redistribution of soil water beneath the polythene.

Plants were de-blossomed in early summer to aid establishment and there was no yield to be recorded. Runners were removed on 5 August and 21 September.

The clear polythene mulch produced a 66% increase in stolon number and a 76% increase in total dry weight of runners. Other treatments did not differ from the control.

(D. K. L. MacKerron, P. A. Gill, P. D. Waister)

Crop response to shelter

Strawberries were planted in 1978 to examine the response of the crop to shelter from wind when grown in matted rows. The Annual Report for 1978 reports that growth and crown production showed strong gradients along the length of the experiment, swamping any shelter effect. This gradient was again apparent in 1979, possibly masking responses in yield.

Exposed blocks yielded 15·4 t/ha while sheltered blocks gave 17·3 t/ha, an increase of 12%. Measurements of rooted crowns made at the end of the growing season showed no consistent differences between exposed and sheltered treatments—both had 103 crowns per m^2.

In view of the strong gradient evident on the site it was decided to terminate the experiment.

In another experiment, on an exposed site near Aberdeen, more positive results were obtained. Truss number was increased by 21%, the number of berries per truss was unaffected, and the number of rooted crowns was 39% greater in shelter at the end of the season.

(D. K. L. MacKerron)

Frost damage in black currants

Plants of cv. Ben Lomond, cv. Baldwin and the seedling N43/6 were artificially frosted to a temperature of – 3·5°C for 4 hours. This treatment was applied to three plants of each genotype from pre-grape to full flower.

The results confirmed that flower buds of Ben Lomond are inherently more hardy than those of Baldwin and N43/6 until after the grape stage at temperatures of – 3 to – 4°C. However, from first flower onwards the level of injury in all genotypes was similar at 30-40%. (See Plant Breeding Section report).

Bud necrosis in black currants

Bud necrosis was first observed at SHRI during the winter of 1977 in cv. Ben Lomond. Many overwintering buds had been lost leaving a stub of

tissue at the affected nodes. Of the buds that remained, those which were severely necrotic could be distinguished from healthy buds by their small size and pale, brown scales.

A plantation consisting of the cultivars Baldwin, Ben Lomond, Ben Nevis and the seedling 93/28, was sampled at weekly intervals from June onwards to determine the incidence of bud necrosis and its time of onset. The primary buds, from the current season's growth, were dissected and scored for signs of injury. Symptoms varied from a single necrotic leaf to the complete death of the bud. The tissue below the meristem appeared normal with no signs of disruption to the vascular tissue. Damaged buds occurred randomly along shoots, but were more prevalent towards the top of the bush. The necrosis began in all genotypes during mid-July and rapidly developed reaching a maximum by late August. Ben Lomond, Ben Nevis and 93/28 had a similar level of injury (60-70%) whilst Baldwin was less affected (45%). Only in the severely necrotic buds were flower buds killed. Prior to the onset of dormancy there were no visible signs of compensatory development of secondary buds.

Other genotypes were examined, and all showed necrosis to varying extents. The seedling 238/36/12 which appeared to have suffered badly in 1978/79, only showed 21% affected buds on the current year's growth.

Other sites in Perth and Angus were examined in co-operation with ESCA. The incidence was lower, but again Ben Lomond and Ben Nevis were worse than Baldwin. Results from one site at which there are consecutive plantings of Ben Lomond, seem to indicate that older plantations are more prone to bud necrosis.

At present, plant material from the main growing areas of England, collected with the help of ADAS, is being examined to assess the extent of the problem. Although only a few samples have been looked at, the two SHRI cultivars are worse than Baldwin.

The cause is as yet unknown. No pathogens (fungi, bacteria, viruses, nematodes or mites) have been found within affected plants, and soil and leaf analyses have not suggested a nutrient disorder.

(P. A. Gill, P. D. Waister)

01049 *Effects of weather conditions on growth, yield and a quality of vegetable crops*

Studies on canopy development and light environment in a bean crop

In experiments on measured maximum yields in field bean the yield increases have been less than expected from the increased growth of the plants. Yield appeared to be limited by the shedding of flowers and immature pods. A detailed investigation of the canopy structure provided data on the change in its form with time, and on the light environment

within it. This will allow a test of the hypothesis that flower and pod shedding in beans is related to the light environment within the canopy and so presumably to availability of assimilates.

Three cultivars were grown, Maris Bead, TI (terminal inflorescence) and CH421 (dwarf) each in field plots and in maximum yield plots (see page 38).

Growth analysis measurements made on 20 harvest occasions included heights to nodes, leaf area and weight at each node (giving leaf area profile), stem weight and area of each internode, node status (vegetative, flowering, etc.) and numbers and weights of flowers and beans.

The rate of production of leaves was remarkably constant for all cultivars and both soils, until node 16 was reached. At this stage TI produced its terminal inflorescence and leaf production ceased, and CH421 suffered a severe attack of chocolate spot which terminated growth after two further leaves had emerged. The conventional cultivar Maris Bead continued to produce leaves at a constant rate up to node 26, that is for a period of 100 days from emergence.

In Maris Bead and CH421 leaf area reached a maximum between 80 and 96 days from sowing and in TI between 75 and 82 days from sowing. At these times leaf area indices were respectively 7·1, 2·5 and 4·0 in the field plots and 8·3, 3·9 and 7·3 in the maximum yield plots.

The detailed changes in distribution of leaf area and of dry matter within the canopy and the development of the podding profile have still to be analysed as have records of light profiles within the canopy.

(D. K. L. MacKerron)

01004 *Germination and establishment of vegetable seeds in relation to moisture and temperature*

The influence of growth regulators on lucerne germination and growth under moisture stress

Previous work on the treatment of clover seeds under osmotic stress with different combinations of the growth regulators kinetin, gibberellic acid (GA_3) and Ethrel has shown that 2·0 mM Ethrel together with 0·3 mM kinetin added to solutions of polyethylene glycol 6000 (PEG) stimulated germination at the same water potentials as growth. To test the effects of these growth regulators further, lucerne seeds were germinated and grown in a range of solutions of PEG and of sodium chloride (NaCl) with or without Ethrel and kinetin. In both NaCl and PEG the water potential at which there was 50% germination inhibition (G50) was reduced from − 11·5 bar and − 7·6 bar respectively to a value of approximately − 17 bar in the presence of Ethrel and kinetin. The water potential at which 50% of the germinated seeds failed to grow (R50) after transfer to PEG solutions in the absence of growth regulators was − 16·4 bar, close to the G50 value in the presence of Ethrel and kinetin. A higher R50 value in NaCl

(−13·4 bar) was most likely due to the toxic effects of the salt. While germination was stimulated in the presence of Ethrel and kinetin, radicle growth after germination was severely reduced and R50 values in PEG and NaCl were −5·1 and −7·6 bar respectively.

Mitotic activity in lucerne root-tips

Cell division in lucerne seeds germinated in water and in PEG solutions at −6, −10 and −14 bar with or without ethrel (E) and kinetin (K) was investigated over a period of 7 days. The lengths of the radicles were measured prior to fixation in acetic-alcohol (1:3) and staining with aceto-orcein. In the presence and absence of E+K, root growth was reduced in all the PEG solutions. In comparison to the control seeds grown in the absence of E+K, root growth was significantly lower in the presence of E+K in water and −6 bar PEG 48 hours and 72 hours after the start of imbibition respectively. At −10 and −14 bar there was limited growth in the presence of E+K, but no growth in the control seeds at these water potentials. Examination of root-tip squash preparations showed that in the absence of E+K the initiation of mitotic activity was progressively delayed, and the level obtained progressively reduced at lower water potentials. There was no significant mitotic activity at −10 and −14 bar PEG in the absence of E+K. Mitotic activity in the presence of E+K was much less affected by water potential and at −14 bar reached a level half that attained at 0 and −6 bar. However, especially at 0 and −6 bar, mitosis was suppressed rapidly after germination in the presence of E+K. At lower water potentials in the absence of E+K there was a low level of mitotic activity, but no germination and in the presence of E+K germination occurred without any detectable mitotic activity initially.

Cell expansion during germination

Lucerne seeds were germinated in water and in −14 bar PEG with or without E+K and samples fixed when the root-tips had protruded approximately 1 mm from the seed coat in the water control and in the −14 bar treatment with growth regulators. Seeds grown in −14 bar PEG without E+K did not germinate, but samples were fixed after 60 hours when the E+K treated seeds had germinated. The root-tips were embedded in a monomer mixture of glycol methacrylate (GMA) in gelatin capsules, and 2 μ sections were stained and the length of the cortical cells in the zone of elongation measured. There was no significant difference between the length of cells from the E+K treated seeds and from the water control seeds (mean values of 28·5 and 26·5 μm respectively). The mean length of cortical cells from the ungerminated seeds held in −14 bar PEG without E+K was 14.8 μm, almost half the length of those from other treatments indicating that E+K was stimulating germination under osmotic stress by its influence on cell expansion.

(Heather A. Ross)

01051 *Effects of soil structure on germination and emergence of vegetable seeds*

Compaction by press wheels

Seeds of calabrese (cv. Rex) and onion (cv. Hyduro) were sown in the field on nine occasions between April and July. Three levels of compaction (0, 60 and 95N) were appplied to the soil surface in combination with 0 and 86N compaction at seed depth either before or after sowing. Compaction treatments were applied with a weighted press wheel of 15·5 cm diameter, 7·5 cm wide for surface treatments and 2·5 cm wide for seed depth treatments. The plots were left exposed to natural rainfall.

Soil integral impedance was measured with a penetrometer when the seedlings began to emerge. Integral impedance increased with increasing surface compaction force within sowing dates. It was also positively related to rainfall amount and negatively related to soil moisture content at the time of testing.

Seedling emergence was negatively correlated with integral impedance for both crops, but calabrese was more sensitive than onion. However, surface compaction only significantly reduced calabrese seedling emergence on the first two sowing dates in comparison with the uncompacted treatment.

Compaction at seed depth, particularly after sowing, reduced seedling emergence although other workers have reported improved emergence. It is probable that the decrease in emergence found in this experiment was connected with the high level of soil moisture, which was never below 14% at seed depth on the day of sowing. (Field capacity of this soil is about 25%.) There were indications of an interaction between sowing date and the compaction treatments with emergence being reduced most when the soil was cold and wet.

The rate of emergence was also significantly reduced by the compaction treatments, but the differences were too small to be important.

(K. N. Weaver)

WEED INVESTIGATIONS

01021 *Weed ecology and control in soft fruit*

Herbicide evaluation

Investigations continued into the formulation of programmes for season-long control of weeds in young strawberries. Lenacil/ethofumesate, propochlor/chlorthal dimethyl and phenmedipham/ethofumesate, as tank mixtures, again gave high levels of control of annual weeds. Pentanochlor alone and in tank mixtures with other herbicides injured both maiden and established crops and is unlikely to be a useful component of herbicide

programmes. The crop tolerance limits of several new herbicides (for the control of perennial weeds) were examined in weed-free rows of established strawberries and raspberries, treated in May. Both crops appeared highly tolerant to alloxydim sodium, but oxadiazan caused severe injury to young raspberry canes and to strawberry plants. 3, 6-dichloropicolinic acid produced leaf malformation in both crops, but the margin of safety appeared to be sufficiently high in raspberry to merit further investigation.

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

01029 *Weed control in crop rotations*

Volunteer crops

Germination of seeds from potato berries planted outdoors in pots at 2·5 cm depth in autumn was greatly increased by soil disturbance in the following April and further stimulated by a second soil disturbance in July, in comparison with that from seeds undisturbed during spring and summer. Regardless of soil treatment, emergence did not commence until early May and was virtually complete by late September. Further soil disturbance in October did not result in late autumn emergence of seedlings. Potato berries peeled or quartered before planting in pots in autumn produced many more seedlings during the next growing season than berries planted intact or seeds planted after the removal of pulp and skin. Most of the ungerminated seeds were recovered and found to be viable one year after planting intact berries, but where separated seeds had been sown very few viable seeds remained.

Yields of potato berries from a range of cultivars are being recorded over several years, to provide information on the influence of cultivar and growing season on the amount of seed returned to the soil under normal husbandry conditions.

Seeds from intact berries of black currant, strawberry and raspberry were planted in pots outdoors in early August at 2·5 cm depth. They produced no seedlings that autumn, but large numbers emerged in the following April, black currant being slightly earlier and raspberry slightly later than strawberry. Emergence in May and early June was substantial, but relatively few seedlings appeared thereafter. Periodic soil disturbance did not stimulate further emergence.

When freshly harvested seeds of field bean, barley and oilseed rape were sown outdoors in pots at 2·5 cm depth in late September, virtually all seeds produced seedlings before the end of November; at 7·5 cm depth, all the beans, just over half the barley, but only a quarter of the oilseed rape seeds produced plants; at 15 cm depth all the beans, but only a few barley and no oilseed rape seedlings emerged. Autumn sown one-year-old Italian ryegrass seeds showed almost complete emergence from 2·5 cm, less than 20% from

7·5 cm and only an occasional seedling from 15 cm depth of sowing. By contrast just over one-third of wild white clover seeds produced plants at 2·5 cm, while virtually none emerged from greater depths by the end of the growing season.

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

01030 *Control of growth, yield and quality of vegetable crops by cultural methods and choice of genotype*

Calabrese maturity

Studies on the influence of sowing date on harvest date have been continued to provide better guidance on crop production for specific harvest periods.

Weekly sowings of cv. Corvet started on 2 March and, were continued until 5 July. Time from sowing to 50% harvest of main spears declined almost linearly from 150 days when sown on 2 March to about 86 days when sown in mid-May. The crop produced from the sowing on 27 June was the latest to be completely harvested without frost damage, and required 97 days to reach 50% maturity.

So far it has not proved possible to relate maturity in calabrese to a day degree integral.

(R. Thompson, H. Taylor)

Potatoes — seed preparation

Seed tubers of cv. Pentland Crown were stored at 2, 5, 9 and 16°C. At the highest temperature growth of the apical sprout was rapid and the tubers had to be desprouted in February.

Tubers from the four treatments were planted on 2 May and harvested on 15 October. Total yields were 58, 63, 60 and 30 t/ha respectively from main stem populations of 35, 31, 24 and 13 per m^2.

The relationship between yield and stem density was similar to that recorded in experiments elsewhere, except for the desprouted treatment in which yield was lower than would be expected on the basis of density alone.

Some of the biochemical changes in the seed tubers during storage were monitored at Bath University and will be reported elsewhere.

(R. Thompson, P. P. Rutherford)[1]

[1] Bath University.

01050 *Cultural techniques for control of growth, yield and quality of protein and other seed crops used for food manufacture*

Field beans — competition and pod set

The spacing between pots, each containing two plants was changed periodically to give densities of 5 and 100 plants per m^2 and hence two levels of competition for light. Changes were made at several stages of development to determine the effects of competition on compensation in the components of yield. Spacings were changed from close to wide or vice versa on 21 June, 6 July, 31 July and 22 August, spanning the period of flowering and much of pod growth. When changed from one spacing to the other, plants remained at the new spacing either until the next of the above dates, or until the end of the season. There were two control treatments with plants grown at the wide or close spacing for the whole season.

As would be expected, the dry weight of beans per plant were greater from continuous wide spacing (24.7 g/plant) than from continuous close spacing (6·5 g/plant). Wide spacing for any of the three periods between 21 June and 22 August, following initial close spacing, gave about double the yield of the continuously close spaced plants. For example, when wide spaced for 15 days at the end of June, yields equivalent to 15 t/ha (15% m.c.) were obtained, compared with 7·6 t/ha when close spaced for the whole season. Prolonging any of these three periods at wide spacing until the end of the season did not markedly affect yields.

When close spaced for any of these three periods following wide spacing, yields were markedly reduced. The period of growth when plants appeared to be most susceptible to competition stress occurred between 6 July and 31 July; during this time pods were developed between the fourth and the eighth pod-bearing nodes.

Differences in yield between the wide-spaced and narrow-spaced controls arose from differences in numbers of pod-bearing nodes per plant and pods per pod-bearing node, not from number of beans per pod or from average bean weight. However, average seed size was halved without affecting numbers of pods by introducing competition about 22 August. Competition during the mid-phase of pod development (6 July-31 July) did not affect average seed size, but produced a large increase in numbers of pods which failed to develop to maturity. Conversely a temporary shift to wide spacing during this period doubled the number of pods per plant compared with that from continuous close spacing. Thus an increased pod load can be supported by a canopy that would normally have produced many fewer pods. Average bean size was maximised by an initial period at high density, which limited pod numbers, followed by low density which probably increased assimilate available for pod filling.

(R. Thompson, H. Taylor)

Field bean — measured maximum (MM) yield*

Three contrasting genotypes, Maris Bead (a conventional cultivar), TI (terminal inflorescence) and CH421 (dwarf) were compared under MM and normal growing conditions. Growth was monitored by classical growth analysis, and detailed examination was made of canopy development and growth in relation to pod growth and development. Analysis of the detailed measurements is not yet complete, but it is clear that the relative performance under the two sets of conditions differed from that of the previous year. Total dry matter production was similar in the two plots, at 12 and 13 t/ha for Maris Bead from the control and MM plots respectively, 6·9 and 7·3 t/ha for TI and 2·7 and 2·9 t/ha for CH421. However, dry weights of beans produced for the MM plots were appreciably less than from the controls, in contrast to the results in 1978; in the two years the MM plots of Maris Bead yielded at the rate of 4·2 and 3·8 t/ha, while the controls produced 3·0 and 5·8 t/ha.

(R. Thompson, H. Taylor)

Field beans — EEC joint cultivar trial

The performance of twelve contrasting cultivars was examined as part of an EEC organised experiment covering eight European countries. The highest yield was given by the large seeded (106 mg) Wierboon, 7·4 t/ha, but the next highest yield was obtained from small seeded (33 mg) Kristall, 6·7 t/ha. The cultivars Russian and Felix were again early, but low yielding with 3·1 and 4·5 t/ha respectively in mid-September, which was about one month earlier than the commonly grown Maris Bead. Chocolate spot infection of Felix and Russian contributed to their early senescence. The level of chocolate spot infection was positively correlated ($r=0·796$) with earliness of flowering.

(R. Thompson, H. Taylor)

Field beans — desiccation

Desiccant sprays are largely intercepted by the foliage of the bean and, though the leaves may be rapidly killed, the pods and stem often remain green for a considerable time afterwards. The effectiveness of several chemicals has been examined for promoting early ripening of the seed as well as for desiccation of the foliage. These include metoxuron, glyphosate, ethephon, diquat and MCPA. Each chemical was applied to cv. Maris Bead when the uppermost pods were full (235 days after sowing) or when the lower pods were beginning to turn black (253 days after sowing).

At the 235 day stage, diquat and metoxuron produced rapid drying of

* Annual Report 1977, p.29.

the seeds, but reduced yields significantly, while at the later stage the rate of seed drying was only marginally better than the control.

No chemical gave the required rapid kill of stem tissue without yield reduction.

(R. Thompson, H. Taylor)

Field beans — pod profile development

The development of the profiles of seed yield in cv. Maris Bead was studied throughout the various phases of bud, flower and pod growth with plants grown at two levels of competition, 11 and 44 plants per m^2. A total of 52 and 74 buds per plant were produced from high and low densities respectively. Corresponding values for the number of buds developing into open flowers were 46 and 70, of which 28 and 55 respectively developed into pods at least 1 cm long. Many such pods, however, aborted leaving final mature pod numbers of 14 and 33 per plant for the high and low densities respectively. Thus, of the original buds produced, about 27% developed into pods contributing to yield at high density and about 45% at low density; the greatest losses occurred between the stage when pods were about 1 cm long and maturity.

Loss of buds and young pods ocurred predominantly at the higher nodes in contrast to loss of flowers which was greatest at the lower nodes. Final yields were 358 g/m^2 and 940 g/m^2 for the low and high densities respectively.

(Shabaan Khalil, R. Thompson)

Field beans — chocolate spot

Leaves were selected from plants of six cultivars in the EEC trial (see above) for assessment of susceptibility to chocolate spot (*Botrytis fabae*) by a modification of the method devised by J. G. Harrison[1]. The leaves were placed on wet absorbent paper in polythene covered dishes after inoculation with a suspension of *B. fabae* spores. The size of lesion produced correlated well with scores for chocolate spot on field grown plants, those which were most susceptible being readily identified. Position of the leaf on the stem affected response in the laboratory detached-leaf test; for example, lesions on leaves from node 5 were 50% larger than those on leaves from node 6. It is possible that this method may provide a simple screening method for susceptibility to chocolate spot in breeding material.

(Shaaban Khalil, J. G. Harrison[1], R. Thompson)

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[1] Mycology Section.

01018 *Control of growth, yield and quality of raspberries by cultural methods and choice of genotype*

National Fruit Trial 1975

In this, the final year of the trial, the EMRS cultivar 2476/123 (Joy) once again produced the heaviest yield, 27 t/ha. Yields from all the cultivars in the trial were high with even Malling Jewel cropping at 15 t/ha. The other standard cultivars, Glen Clova, Malling Admiral and Leo yielded about 19 t/ha. In the three full cropping years of this trial, the average annual yield of Joy was 25.7 t/ha. This was some 35% more than Glen Clova and some 95% more than Malling Jewel in spite of the numbers of bearing canes per stool in these cultivars being greater (6·7 and 4·9 respectively, compared to 4·5 in Joy). More nodes on the canes of Glen Clova and Malling Jewel produced laterals than did those on canes of Joy, so the yield superiority of Joy can be attributed entirely to fruit size and numbers of fruit per node. The average fruit size of Glen Clova and Jewel were very similar (3·56 g and 3·58 g), but about 25% less than that of Joy (4·50 g). This accounts for some of the difference in yield per node, which averaged 60·9 g in Joy, 24·0 g in Glen Clova and 23·3 g in Malling Jewel, but most of the difference must have arisen from numbers of fruit per node. By calculation these were 13·5 in Joy, 6·7 in Glen Clova and 6·5 in Malling Jewel.

(M. R. Cormack)

Control of cane vigour

1979 yield in the NFT again showed no clear overall response to removal of the first flush of young canes with dinoseb-in-oil. Experience of the technique at SHRI over a wide range of cultivars and selections since 1973 suggests that the three most important characteristics required to ensure a positive response to this form of vigour control are (a) large numbers of canes produced per stool, (b) early emergence and growth of the first flush of young canes, (c) rapid emergence of a second flush after the removal of the first one. Glen Clova is the only relatively recent British cultivar to show all these attributes consistently. Of the older cultivars, Malling Promise and Norfolk Giant come nearest to the desired specification. Many of the new selections and cultivars which produce relatively few, but very tall and high-yielding canes per stool have not responded positively to the removal of the first flush of young canes. Excessive cane height is therefore not a reliable indicator of the potential of a raspberry plant to respond to this form of vigour control.

In an experiement on Glen Clova, rate of nitrogen application again had no effect on yield of fruit on biennially cropped plots or on annually cropped plots given cane vigour control treatment.

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

Biennial cropping

In the final year of this experiment on six cultivars, the biennial fruiting plots outyielded the annual plots by a mean of 85%. Malling Admiral has performed consistently well when cropped biennially, while Malling Jewel has responded poorly.

In both cultivars the target of doubling the primocane numbers in the biennial plots was attained, but in Malling Jewel the yield per cane was much reduced in the subsequent cropping year, while in Malling Admiral it was maintained at the same level as in the annual plots.

This experiment has now been adapted to accommodate a mechanical harvester to compare machine picking efficiencies in the two systems of growing.

(M. R. Cormack, P. D. Waister)

FRUIT

01014 *Physiological and cultural factors affecting the mechanical harvesting of soft fruits*

A new Littau mechanical harvester was imported from the USA just before the start of the harvest season. It is a self-propelled, straddle machine which shakes the row in a side-to-side fashion by means of horizontal bars, instead of vibrating laterals in a fore and aft direction as does the Agricultural Sciences machine. After only limited experience of the possible settings of the Littau, the two machines were operated in the same plantation of cv. Glen Isla, at 2 day and 7 day intervals, using a standard setting for each. Fruit recovery by the two machines was similar, neither of them harvesting more than 50% of that picked by hand. Yields from the 2 day harvests were only slightly better than for the 7 day.

It seems unlikely that settings of the Littau were at the optimum. The low recovery relative to hand-harvesting was shown in a second experiment to be at least in part a feature of this cultivar. Plots of six cultivars were harvested by the Littau machine at 3 and 10 day intervals, the latter being chosen as an extreme treatment to measure the 'holding ability' of the fruit. The standard cultivar Malling Jewel gave the best results, with a total of 71% recovery at the 3 day intervals. Glen Isla was much the worst, with only 37% recovery. Yields from all cultivars were lower at the 10 day picking frequency, even in those types considered to have good holding characteristics.

Some of the reasons for differences in picking efficiency in different cultivars are known but have not yet been adequately quantified. By using the extremes of the range, Glen Isla and Malling Jewel, it is hoped to define desirable and undesirable cultivar characteristics with some certainty in 1980.

(M. R. Cormack, P. D. Waister)

Fruit retention strength

As in 1978, ripe berries of cv. Malling Jewel were removed twice weekly throughout the cropping period for measurement of fruit retention strength (FRS) and titratable acidity (TA). The results were similar to the previous year in that at each of the first four harvests the spread of figures for FRS was greater than in the later harvests and was not well-related to TA. However, at the early harvests the mean values for FRS were much lower than in 1978, for equivalent values of TA. While titratable acidity continues to be a useful objective measure of relative ripeness on individual harvest occasions, there is some modifying factor which reduces the usefulness of the relationship for season-long assessment of changes in ease of fruit removal.

(D. T. Mason)

01019 *Control of growth, yield and quality of strawberries by cultural methods and choice of genotype*

Cultivars from the Pacific Northwest

Strawberry cultivars in the Pacific Northwest of the USA have been selected for suitability for processing by freezing, and are red-fleshed. They are potentially useful for the freezing market in Britain, but their yield performance has not been good in this country. Five of these cultivars have been planted, together with five European lines, for comparison of growth and development, with the object of identifying the nature of the yield constraint under local conditions.

(M. R. Cormack, P. D. Waister)

Calculated and recorded yields

Potential yields calculated from flower numbers and weighted mean berry sizes are usually much in excess of harvested yields. A study was made of yield components in plots of cv. Saladin where all sources of loss during the season were quantified. It had been thought that picker errors, such as trampling, truss breakage and green fruit removel, might account for a large part of the discrepancy, but preliminary analysis shows that even when these losses were largely prevented only 40% of the flowers developed into harvested fruit. Of the total flowers recorded, 10% did not set fruit, 13% set fruit but failed to develop further, 11% of fruit was destroyed by birds or other predators, 13% was lost through mould, 8% was damaged, and 5% was still green at the end of the normal picking season.

(J. M. Brown, M. R. Cormack)

Runner production

The comparison of runner production of cv. Cambridge Favourite at SHRI with that at WSAC (Auchincruive) (see Ann. Rept, 1978, p. 49) was repeated, except that in 1978 the spacing of the mother plants was doubled to give 0·84 m^2 of bed per plant.

The total number of runner plants produced was approximately the same at both sites, 105 and 106 per mother plant at SHRI and WSAC respectively, but when the plants were lifted in spring 1979 nearly twice as many runners were too small for planting or were dead at SHRI and WSAC. Seventy plantable runner plants (minimum fresh weight 3·1 g and with a minimum of 8 roots) per mother plant were harvested at SHRI compared with 88 at WSAC; 46% of those at SHRI and 55% of those at WSAC were classified as large (minimum fresh weight 6·7 g).

Runners lifted from the previous experiment were planted at SHRI in April, 1978, and allowed to runner freely and form matted rows, which were cropped in 1979. Although large runner plants originating from WSAC had produced significantly more crowns than small runners from SHRI this difference was compensated for by a significantly larger number of berries/crown in the rows derived from the small SHRI runners. Consequently, the effect of size or source of the planting material on the subsequent yield was not significant.

(D. T. Mason, P. J. Dudney[1])

01012 *Ecology of new crops for Scotland*

Rubus species

The blackberry Ashton Cross again outyielded all others in observation plots, but a thornless clone of cv. Bedford Giant came a close second. In previous years this clone has given poor yields because of very erratic set of drupelets. The indigenous species *R. distractiformis*, was productive but small-fruited. For the second year in succession virtually all boysenberry canes were killed during the winter.

The experiment on biennial cropping of Ashton Cross was terminated. Yields of this cultivar in the fruiting year have not been adequate to compensate for the lack of crop in alternate years.

Vaccinium species

The highbush blueberry cultivar Bluecrop continued to crop satisfactorily, as did the collection of American cranberries (*V. macrocarpon*). No further experimental work is planned for these fruits, but the plantations will be maintained for records of stability of cropping.

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[1]West of Scotland Agricultural College, Auchincruive, Ayr.

Windbreaks

In past reports a hybrid poplar has been noted as showing rapid growth. It was planted as *P. trichocarpa x tacamahaca* but suspicions about its naming were confirmed by the Forestry Commission, Alice Holt, who suggest it is probably *P. x generosa*, a product of the first artificial poplar cross. Though rapid-growing and of good habit it is canker-susceptible.

An authenticated form of *P. trichocarpa x tacamahaca* (TT32) has been planted with 14 other poplar species and cultivars in a new windbreak, for observation of growth rate and plant form.

(M. R. Cormack)

01044 *Statistics*

Statistics (service)

There has been a move away from the use of arc-sine transformations for percentage data, especially for small or unequal plot sizes, towards the use of the GLIM package. This has created a heavier demand for explanations of the inferences and assumptions involved until the user community becomes accustomed to the technique.

Following a visit by P. Digby[1], users in the Plant Breeding Section have employed resolvable incomplete block designs for their large trials of cultivars. J. McNicol[2] has provided helpful comments on the use of programs to design and analyse these trials.

Work continues with J. M. Duncan[3] on fitting models to describe the variation of concentrations of 'infective particles' of *P. fragariae* in soil. The techniques essentially derive from dilution assay. One unexpected result was brought out by analysis: the large residual deviance suggested fitting the soil dilution levels as a treatment factor and it appears that an antagonistic effect is present in the soil. This is subject to further investigation.

(J. B. Cowan, J. M. Duncan)

Assessment of various measures of diversity in weed populations has focused on two aspects, their statistical amenability, and the different aspects of weed behaviour which they reveal. Analysis of variance has shown that diversity indices differ in their response to treatments such as crop density.

(P. B. Topham, H. M. Lawson)

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[1]ARCUS.

[2]SPBS.

[3]Mycology Section.

01045 *Computing (service)*

The PDP11/10 mini computer which has supported our Remote Job Entry access to ERCC computers is to be upgraded to become a Terminal Control Processor (TCP): an eight channel muliplexer for interactive terminals has been added. In order to house the TCP software, a 24K bytes memory expansion was purchased so that the machine now has its maximum addressable capacity of 56K bytes. High speed paper tape input/output was also added, in the form of a Trend UDR 350 cps reader with an interface which allowed the connection of an existing Data Dynamics 1132 tape punch.

(R. J. Clark, J. B. Cowan)

Computer jobs put through the batch terminal:

	1978		1979	
	Jobs	%	Jobs	%
Crops Research	589	52·5	666	61·9
Plant Breeding	244	21·7	200	18·6
Mycology	161	14·3	87	8·1
Zoology	125	11·1	115	10·7
Virology	4	0·4	8	0·7
	1123		1076	

The number of jobs declined slightly, partly due to increased usage of the GLIM package which is generally used interactively. The number of variates analysed (8838) rose by 10%; the time to a successful run dropped to under half a day, although the mean number of submissions before this occurred remained almost constant at 2·4, indicating the effective service given by NUMAC.

The increase in equipment and facilities detailed below does not show any sign of reducing usage of the Edinburgh mainframes. The two systems fill different but complementary niches, and each tends to have a distinct user-community. The digitising system in particular has permitted data to be acquired systematically and in volume so that there has then been a need to analyse it using mainframe facilities.

(R. J. Clark, J. B. Cowan)

Since its installation on 7 June a Tektronix Graphic Information System digitiser has been used extensively. Software support was bought to allow immediate use of the unfamiliar facilities; programs were written for RNA particle lengths and traces, potato lesion areas, soil crust impedance, cornicle analysis, nematode measurement and analysis, and potato root lengths. The system consists of a Summagraphics 20 x 20 inch digitising tablet linked to a Tektronix 4051 Graphics terminal which has a communications backpack. The Tektronix has 16k memory, a resident extended Basic interpreter and a magnetic tape cartridge unit. It is also used as a graphics terminal to the Edinburgh Multiaccess System.

(R. J. Clark)

The System One M6800 Microcomputer has been used extensively for text editing, especially to allow redrafting of papers, and two of the Institute's typists have been trained to use the machine as a word processor.

A Statistics Package was written by P. Smith[1] at the request of the data processing group. Analyses available include factorial and hierarchical ANOVA and multiple and polynominal regression. Missing values can be accommodated. Data is entered onto disk files and corrected using the same EDIT program as is used for text processing. A supplementary program provides for general transformations and the calculation of derived variables.

The contents of disk files can be transmitted to the ERCC computers using a program written by A. J. Breame[2] and the disk operating system commands on the System One have been amended so that their syntax resembles the corresponding ERCC EMAS commands as far as possible.

Users have taken advantage of the BASIC interpreter to develop and run their own programs. Their applications have included entering and manipulating tabular data with accompanying text, sorting of lists, displaying genetic frequencies in a cross-classification, soil-water content calculations, calculating simple sample statistics, and accumulating statistics from meteorological data.

(J. B. Cowan)

Computer mapping

Development was continued, using the GIMMS package, of a computerised base map for the European Plant Parasitic Nematode Survey in collaboration with W. Berry[3].

The CAMGRID package was used for individual countries. The Institute's capability in mapping has led to enquiries and at the present this

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[1]Plant Breeding Section.

[2]AVRI.

[3]University Department of Dundee.

package is being used to illustrate nematode sampling data from sugar beet growing areas in the UK, and by a Belgian worker for his distribution studies.

(P. B. Topham, T. J. W. Alphey)

Data capture

Three Gravitron electronic balances were purchased, each with parallel BCD output. A. J. Breame[1] designed and constructed serialiser interfaces so that the balances can be connected to ASR33 teletypes which produce paper tape to be read in via the PDP11. The principal users of this facility have taken charge of 'cleaning up' their data tapes using the EMAS EDIT program. Despite its limitations the system has been satisfactory and robust.

Any development of the system—which might incorporate intelligent error checking, length as well as weight measurement, and the use of a random access storage medium—will be able to make use of the serialisers since we are standardising on the V24 interface specification.

Mark Sense computer cards are now being used for data capture. Over 4000 cards were read in on the card reader, which has a special 'MARKS' mode, into an EMAS file for checking. Such was the success of the Card Reader software that spurious marks or duplicates were instantly detected and reading stopped to allow corrections to be made. Thanks are due to S. Currie[2], who writes the PDP11 software.

(P. B. Topham, J. B. Cowan, R. J. Clark)

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[1]AVRI.

[2]Edinburgh Regional Computer Centre.

PLANT BREEDING

D. L. JENNINGS

Many plant breeding projects were influenced by either the severe winter conditions of 1978-79 or the cold weather of late spring. Excessive flower drop occurred in certain cultivars of black currant, apparently caused by the abnormally cold weather of late May. It was severe in some of the genotypes selected for frost tolerance, emphasising that spring frost tolerance is not always sufficient to guarantee yield stability: this seems to require independently inherited tolerances to a sequence of adverse spring conditions. Winter cane injury affected the yields of raspberry selections, but some yielded well in spite of a high incidence of cane death and others escaped damage.

Discussion with Long Ashton Research Station on strawberry breeding led to agreement on increased collaboration and reciprocation in testing each other's selections. Our contribution will be particularly concerned with assessing suitability for machine harvesting and resistance to red core disease.

Among the vegetables, the severe weather provided information on the hardiness of some of our Brassicae material, notably the savoy and white cabbage lines. In Brussels sprouts, the second generation of the cyclic single cross programme showed encouraging improvement over the first generation, and in calabrese three different populations were set up for further selection.

03001 *Strawberry: breeding and associated genetic studies*

Collaboration with Long Ashton Research Station (LARS)

Discussions were held at LARS on methods of achieving greater collaboration between our two breeding programmes and on the dispersal of breeding lines resulting from the phasing out of strawberry breeding at John Innes Institute. It was agreed to initiate reciprocal screening especially for autumn and double cropping at Long Ashton and field resistance to red core at Auchincruive. Arrangements were also made for the Food and Beverages Division at LARS to assess the processing quality and flavour of fruit samples harvested at LARS from SHRI genotypes sent at an early stage of selection.

Screening for disease resistance

Mildew, caused by *Sphaerotheca macularis,* is not a major disease of strawberries in the UK, but resistance is an important asset in a new cultivar; screening of immature seedlings for resistance would be valuable if the results correlated well with resistance in mature field-grown plants. To test this 1400 individually identified three-month-old seedlings were scored under glasshouse conditions and again as 16 and 28-month-old field plants. Of 25 crosses from which seedlings were derived, field scores from only two families in the first year, and a different three in the second year were significantly correlated with those obtained in the glasshouse. There was no significant correlation between the mean resistances of the families in the two environments, but there was a highly significant correlation between the mean field scores in different years. Although the inheritance of mildew resistance in both environments was largely governed by genes with additive effects, the non-additive component was also significant. The best parents proved to be cv. Cambridge Favourite, MdUS 2650 (a common parent of the four new SHRI cultivars) and a derivative of cv. Siletz × cv. Talisman.

From 1969-71 many crosses were made with the object of producing a series of selections with similar characteristics to those of established commercial cultivars, but with improved field resistance to red core disease. The resistance source in most cases was 53Q13, a first generation derivative of *Fragaria virginiana I* which is small and soft fruited, but easily decapped. Because resistance from this source is dominant, it was easy to select highly field resistant F_1s, but low vigour resulted when these F_1s were back-crossed to improve fruit quality. However, outcrossing to other established cultivars gave a range of valuable selections which are now at an advanced stage of screening. In this year's red core screening trial a Gorella derivative, 69DB54, gave the highest score for resistance. At Invergowrie and Auchincruive it gave a high yield of large fruit with good flavour, but unfortunately skin strength may be inadequate. Selections derived from Tioga were firm with tough skins, but were difficult to decap by hand or machine because of their deeply inserted calyces. Selections derived from Senga Sengana were red fleshed and easily decapped, but tended to lack uniformity of size. Selections with the desired combination of characters and field resistance to red core disease appear easier to obtain for the fresh market or PYO than for processing.

Mechanical harvesting

A prototype strawberry harvester developed by NIAE and Smallford Engineering has been purchased to evaluate the suitability of selections for mowing and for elevation of their leaves and trusses. Studies of machine/

selection interaction early in the breeding programme is desirable since many problems have arisen due to the poor pick-up operation at the cutter bar. Engineering assistance has been provided by the WSAC to incorporate some of the improvements present in the 1980 model.

In the past several selections were bred with very stiff peduncles so that the fruits were held up to facilitate machine pick-up. Unfortunately these selections had short pedicels which resulted in a grape-like bunching of the fruit. These clusters tended to be transported over the top of the roller decapping bed, or gripped by the rollers and presented to the band knife at angles which resulted in deep and/or oblique slicing of the fruit. Selection is now for intermediate length peduncles with longer pedicels. Tests on the current model of decapper have shown that pedicels must exceed 25mm. Measurements of pedicel length from replicated plots show that the main UK cultivars, Cambridge Favourite, Redgauntlet and Gorella, have short pedicels with means of approximately 26-28mm. Litessa pedicels are 36-37mm and the means of Troubadour, Silver Jubilee and Saladin range from 42-50mm. These last three, plus Tantallon, 65G67 and 65L111 have a common parent (MdUs 2650) and all have long pedicels, indicating that it is a highly heritable character. Variation over years was small for most cultivars except Cambridge Vigour. Most within clone variation occurred between pedicel ranks, but within ranks variation was greatest with primary pedicels. The removal of the primary fruits, which are usually the largest, by hand for fresh sale prior to machine harvesting, should therefore improve the uniformity of the product presented to the singulator and decapper.

(H. J. Gooding, R. J. McNicol)

03003 *Strawberry: breeding systems*

Recurrent selection programme

Thirty families including sibs and selfs have been planted for evaluation, and 18 first generation inbred selections were selfed, sibbed or backcrossed. The performance of 33 single-plant unit selections grown as four plant units under walk-in polythene tunnels was encouraging. One selection from a topcross showed promise for freezing and gave an indication of the potential of this programme. Among the inbreds, four were selected from each source population for further varying levels of close breeding. The most productive parents of good first generation inbred selections included Silver Jubilee (65G95) and 69DZ67. Since September 1978, the work under this project has been curtailed because of the loss of a scientific post.

(R. J. McNicol, H. J. Gooding)

A notable feature in 1979 was the high incidence of cane death in many raspberry cultivars. Our leading selections gave a variable performance: for example, M30 gave variable yields in regional trials, 6820/54 and 7210/204 showed appreciable cane death, but gave good yields in spite of it, but 6820/64 had a high incidence of cane death and cropped poorly.

A new trial of 25 raspberries, selected mostly because of their promise of high yield potential, cropped for the first time in 1979. Several of them yielded remarkably well, including some with excellent fruit quality and a good growth habit. Seven new selections, some from this trial, were submitted to the National Fruit Trials; they include selections having a range of cropping seasons, and several which have characters thought to suit them for machine harvesting.

High yield potential was again emphasised when making new selections in 1979 and several selections notable for the high expression of one or more yield components were obtained. Detailed analyses of their yield components suggested that progress had been made in achieving high fruit number per lateral combined with high lateral number per cane. Some of them were chosen for further crossing with other parents selected for earliness, good growth habit or fruit quality.

In recent years, plants with an erect compact growth habit have been favoured in selection. To obtain a better understanding of variation in plant habit, the growth of contrasting types was studied by monthly records of growth. These studies showed that the compact habit was achieved by slower cane growth and earlier growth cessation, and that it resulted in high numbers of nodes in the cropping region. In some genotypes the growth of newly-established plants was inadequate, but application of twice the normal rate of nitrogen fertiliser gave a notable response, particularly in the time of growth cessation. The effect of this on cropping will be tested in 1980.

(D. L. Jennings, A. Dale, Barbara M. M. Tulloch, Eleanor Carmichael)

Disease and pest resistance

Previous reports have described resistance to *Leptosphaeria coniothyrium* derived from cv. Latham and its derivatives. A further survey was made in 1979 to locate new sources of resistance among 15 cultivars and unnamed raspberry genotypes, and evidence of resistance was found in three unnamed Canadian selections from the cross cv. Chief × cv. Indian Summer. As Chief is related to Latham this result accords with previous findings of the resistance of the latter cultivar. The value of the new resistance sources for breeding is being assessed.

It is known that raspberries with glabrous canes (gene *H*) are less prone to diseases caused by *Botrytis cinerea* and *Didymella applanata* than raspberries with sub-glabrous cane (gene *h*). It was previously thought that cane hairiness favoured disease escape, but an experiment in which wounds of 140 glabrous and 140 sub-glabrous canes were inoculated with mycelial inocula gave mean lesion lengths of 97·5 and 149·9 mm respectively for *B. cinerea* and 41·47 and 48.69 mm respectively for *D. applanta.* It is therefore concluded that the differences between the two kinds of cane are due to factors operating after infection.

In another field experiment the resistance to *B. cinerea* of a black raspberry selection was shown to be considerably higher than that of Malling 1473/35, the resistance source previously used in breeding; the mean lesion lengths obtained from mycelial inoculations being 62·9, 126·0 and 226·4 mm respectively for the black raspberry derivative, Malling 1473/35 and a susceptible control. In this experiment inoculations made on 17 July or 14 August gave greater discrimination between genotypes than inoculations made on 18 June. In an experiment to compare eight families for resistance, the smallest lesion sizes for both *B. cinerea* and *D. applanata* were obtained in families related to the black raspberry, *R. crataegifolius, R. pileatus* or *R. coreanus.* The coefficients of correlation between lesions of the two pathogens were 0·8881 (d.f.=7) for family differences, but only 0·1759 (d.f.=116) for differences between plants within families. This indicates that the families differed similarly in their resistances to the two diseases, but that there was little or no association between the two resistances in segregating families.

Samples of 30 fruits from plants selected from families derived from crossing red raspberry with black raspberry, *R. pileatus* or *R. coreanus* were tested for resistance to *B. cinerea* and other fruit rot pathogens. The fruit was held for 5 days at 20°C and the sampling was repeated on three dates where there was sufficient fruit. Most derivatives of *R. pileatus* showed a very low incidence of fruit rot, but promising plants from each resistance source were selected for breeding. These selections were not notable for good fruit texture and so the low incidence of fruit rot is possibly due to the presence of a form of plant resistance. Breeding to combine this with improved fruit texture is being attempted to test the hypothesis that this combination will produce higher levels of resistance.

(D. L. Jennings, B. W. Eliot, Eleanor Carmichael)

In a previous report reference was made to the difficulty of interpreting the reactions to bushy dwarf virus of some of the plants obtained by crossing susceptible and immune cultivars. This difficulty arose from inconsistent results in sap transmission tests in 1978. However, when sap transmission and ELISA tests were made in 1979, the year after grafting, it was found that a selfed progeny of cv. Lloyd George bred true for susceptibility, a

selfed progeny of the immune cv. Glen Clova segregated 3 : 1 for immune : susceptible, and a progeny of the cross Lloyd George × Glen Clova segregated 1 : 1. These results accord fully with the hypothesis that immunity is conferred by a single dominant gene, which is designated *Bu*.

Previous results indicated that immunity from raspberry vein chlorosis virus is conferred by a single recessive gene. Further information on this hypothesis is being sought from graft tests on plants from two families related to the immune cv. Cuthbert. Segregation of symptoms will be studied in 1980.

(A. T. Jones, D. L. Jennings)

Tissue Culture

Attempts were made to propagate plants of Tayberry, blackberry (cv. Ashton Cross) and raspberry by tissue culture of excised axillary buds. Good success was obtained with Tayberry and Ashton Cross and plants of the former were obtained to re-establish a nuclear stock for propogation. No success was obtained with raspberry.

(Eleanor Carmichael)

03008 *Breeding early erect blackberries and other* Rubus *berries*

Six selections of blackberries and two selections of hybrid berries were submitted to the National Fruit Trials. The six blackberries are all spine-free and have shown earliness and erectness in trials at SHRI; one of the hybrid berries is similar to the Tayberry, but possibly more hardy, and the other is an erect compact form.

A dominant factor for spinelessness would be particularly useful for blackberry breeding and is essential for our objective of breeding spine-free raspberry-blackberry hybrids of the Tayberry type. For the latter purpose it should preferably be carried in the tetraploid raspberry parent and must be sufficiently dominant to express itself in the hexaploid hybrid. Several sources of thornlessness are therefore being investigated and progress is as follows:

(1) the tetraploid hybrid 74118B5 has been derived from the old octoploid thornfree American cv. Austin Thornless and fertile thornfree selections have been obtained from crossing it with tetraploid blackberries.

(2) the septaploid thornfree USDA hybrid 1362 has been used in crosses with hexaploid Tayberry-like hybrids to give fertile thornfree hybrids of high ploidy.

(3) the diploid ornamental raspberry *R. parviflorus* has been crossed with the raspberry and tetraploid hybrids from the cross were used in 1979 in a first backcross to tetraploid raspberries.

(D. L. Jennings, Eleanor Carmichael)

Three selections outstanding for fruit quality — M48/2, 243/7 and 71EA/7/65 — were sent for trial at the National Fruit Trials and 71EA/7/65, two hybrids of M48/2 and six of cv. Ben More were included in a trial at Luddington EHS. The NFT selections were also propagated for spring frost tests.

Twenty-one selections were sent to seven locations in the east or west of Scotland for assessment by the Scottish Agricultural Colleges.

Stoolbeds of 20 selections already in NFT trials were established, so that nuclear stocks can be produced in 1981/82 and propagation can go ahead rapidly if a decision is taken to proceed with any of them after their second or third cropping season. To provide material for commercial juice processing tests, M48/2 was propagated at the West of Scotland Agricultural College and six 243/7 hybrids were propagated at SHRI.

Yield, plant habit and disease resistance

Yields of 50 selected hybrids in three-plant units were recorded in their second cropping year. Yields ranged from the equivalent of 18·6 t/ha for a cv. Ben Nevis × *Ribes dikuscha* hybrid to zero for two cv. Goliath × cv. Öjebyn hybrids severely affected by bud necrosis. Comparable yields for the cultivars Ben Nevis, Ben Lomond and Ben More were 8·8, 6·7 and 3·3 t/ha respectively. The most common failings of these hybrids were thin weak branches with insufficient strength to support the weight of the crop, and poor quality fruit. One early-maturing Ben Lomond hybrid, however, was selected for Regional Trials.

Selection was continued for the third or fourth successive year in progenies of the cultivars Westra, Ben Lomond, Ben More, 238/36/12 and 243/7. Yields of the Westra hybrids were appreciably better than previously, but it is uncertain whether this was a season or an age effect. Selections in progenies of Ben Lomond and 238/36/12 maintained their record of consistent cropping. A progeny of 39 plants of 238/36/12 × Ben Lomond was propagated for further observation.

Two thousand two-year-old plants from progenies in the nursery were screened for mildew resistance and then selected for superior habit or branch characteristics before being planted for fruiting. They included hybrids of Ben Nevis and Ben Lomond, Ben More, Westra, Edina, 243/7, 238/36/12, M48/2, *Ribes hudsonianum* and the three Calobotrya species *R. sanguineum*, *R. glutinosum* and *R. laxiflorum*. The same procedure was applied to 4000 two-year-old plants raised in 1978.

Some hybrids of 243/7 × *R. glutinosum* inherited an improved branch strength and superior form of mildew resistance from *R. glutinosum*, and a selfed progeny of P11/8/74, a backcross of *R. sanguineum*, segregated 3:1 for mildew resistance. Hybrids of P10/8/2 (Westra × 243/7) crossed with

R. laxiflorum ranged in growth habit from the horizontal form of *R. laxiflorum* to a moderately erect one resembling their *R. nigrum* parent; they also segregated for resistances to both mildew and leaf spot (*Pseudopeziza ribis*) inherited from *R. laxiflorum*. However, none of 48 *R. americanum* hybrids showed the outstanding form of leaf spot resistance of their parent species. Notable features of hybrids derived from *R. hudsonianum* were their massive fibrous root systems and resistance to leaf spot; but unfortunately many of them were severely affected by either bud necrosis or winter killing.

Three-plant units of 568 selections, selected cultivars and inter-species hybrids were planted for further observation.

New progenies

Six thousand seedlings of the cultivars Ben More, Edina, Merveille de la Gironde, Matkakoski, 243/7 and P11/8/74 were planted in the nursery for selection in 1980.

The *R. sanguineum* hybrid P11/8/74, Westra × (cv. Baldwin × *R. sanguineum*), was used as seed parent in a cross to the partially sterile F1 hybrid in an attempt to combine its self-fertility and upright growth habit with the desired timber qualities of the latter, and also in crosses with a wide range of other hybrids. With the exception of the cross to the F1, seed production was adequate, but variable in quality. Crosses were also made with 243/7 and 71EA/7/65 to combine high quality fruit with good habit or improved branch strength, and with Ben More, cv. Sopernik, 238/36/12 and P9/13/2 (a late-flowering Ben More × *R. bracteosum* derivative) to combine late flowering with spring frost tolerance.

(M. M. Anderson, Judith Thomson)

Juice Quality

Juices from 314 genotypes sampled in 1978 were assessed for colour and ascorbic acid content: 246 of them excelled Baldwin for colour and 15 for ascorbic acid, while the colour intensity of eight, including 71EA/7/65, 243/7 and two of its hybrids was twice that of Baldwin. Altogether 1055 samples have been assessed since 1976, and none has exceeded 243/7 for its combination of intense colour, high ascorbic acid content and superior flavour.

Six samples were assessed for colour and flavour by Beecham Products (Research and Development). Juice of M48/2 had a better colour intensity than that of Baldwin and 14 other genotypes not including 243/7, and a bottled sample stored for six months at 30°C showed a colour advantage over Baldwin equivalent to three-and-a-half months of extra shelf-life. Juices of Ben Nevis, Ben More and Ben Lomond showed similar advantages equivalent to 3, 2 and 1½ months respectively. Only the samples with the best colour were acceptable for flavour.

Samples of 325 selections from progenies of Westra, Ben Lomond, Ben More and 243/7 were collected for study in 1979 and 39 of them have so far been assessed for colour quality on a Pye Unicam spectrophotometer using wavelengths of 520 nm and 430 nm. Absorbance values for the parents Ben Lomond and 243/7 were extremely high, those for Baldwin were intermediate and those for Ben More extremely low. Ben More was also poor for ascorbic acid content.

The fading of monomeric pigments in 11 pasteurised juice samples was evident in Ben Lomond samples, but less so in samples of 243/7 and its hybrids. Parallel tests by Beecham Products rated 243/7 superior to all others for overall quality, including flavour, but gave a poor rating for Ben Nevis and Ben More.

Multiple regression and principle component analyses of the quality components assessed for 1978 samples showed similar associations to those reported for the 1977 samples. There appear to be two important relationships: (i) an effect of dilution, whereby a high juice yield and high pH were associated with a low content of ascorbic acid adjusted to standard specific gravity and a low sugar/acid ratio; (ii) an effect of acidity, whereby a low pH was associated with a high lovibond reading for red colour, a high sugar/acid ratio and a low content of ascorbic acid adjusted to standard specific gravity.

(Judith Thomson, M. M. Anderson)

Consistency of cropping

During the year both experimental work and field observations identified three major causes of yield loss: bud necrosis (see p. 30), low temperatures above 0°C during flowering and spring frosts. In particular, the breeding values of Ben More and its sister seedling 238/36/12 were diminished by their susceptibility to yield-reducing factors unconnected with spring frosts.

At SHRI, bud necrosis (see Crops Research Section, p. 30) killed virtually all the flower buds on plants of 238/36/12 and depleted the numbers on plants of Ben More, Ben Lomond, Ben Nevis and several of their hybrids. Adjacent but unrelated genotypes were either unaffected or showed only minor injury. Of 300 hybrids examined under identical growing conditions only one, a *Ribes dikuscha* × 238/36 derivative, was as seriously affected as 238/36/12.

Bud necrosis also contributed to the poor performance of Ben More at Luddington EHS, but nearby heavily-yielding plants of its sister hybrids 238/36/12 and 238/36/19 were unaffected at this site. Bud necrosis was not a problem at the National Fruit Trials. This scanty evidence suggests that these genotypes may be peculiarly sensitive to bud necrosis, whatever its cause, and until the cause is understood further breeding with genotypes prone to it is a problem of some concern.

At the National Fruit Trials nearly all of the open flowers of Ben More dropped after abnormally cold weather during early May; the lowest daily minimum temperature, −1·2°C, was recorded 5 days after the commencement of flowering. Serious, but less extensive losses occurred in other genotypes, including Baldwin. Yields reflected these differences and exposed a hitherto unknown defect of Ben More. However, large differences in yield between Ben More and the late-flowering cultivars Black Reward and Sopernik suggested that excessive flower drop was not closely associated with the lateness of their flowering.

It was impossible to separate low temperature effects from those of bud necrosis at Luddington, where the yields of 238/36/19, 238/36/12, Ben Lomond, Ben Nevis, Baldwin, Black Reward, Ben More and Jet were 21·0, 15·5, 14·9, 12·8, 12·4, 11·3, 4·6 and 1·4 t/ha respectively. This poor performance of Ben More was particularly disappointing because its mean yield from 1976 to 1978 was 13·8 t/ha. Similarly, at the National Fruit Trials, the flower drop of Ben More demonstrated that its known spring frost tolerance was insufficient to guarantee consistency of yield, which requires independently inherited tolerances to a sequence of adverse spring conditions

(M. M. Anderson)

Tolerance to spring frosts

An experiment was designed with two aims: to develop a method to identify black currants whose flowers are tolerant to spring frosts, and to assess the tolerance of the flowers of a range of SHRI cultivars and selections.

Pot plants were raised from single bud cuttings in 1978, restricted to single stems and overwintered outside. In early March, 1979, they were transferred to a well-ventilated cold glasshouse to avoid any severe frosts during flowering. Each cultivar was frosted at the grape, first flower and full flower stages. At each stage, five plants of each cultivar were frosted at −3°, −4° or −5°C for 4 h and five kept as unfrosted controls.

The cultivars tested were in three groups: Ben Lomond, Ben Nevis and some of their ancestors; Ben More, some of its sister selections and their ancestors; and several control cultivars one of which was Baldwin.

The flowers of all the cultivars were most tolerant of frost at the grape stage and least tolerant at full flower, as judged by their appearance a week after treatment. Ben More and its allies were the most tolerant, Ben Lomond and its allies and most of the control cultivars were partially tolerant, while Baldwin was the least tolerant.

When the plants were re-examined three weeks after full flower, several cultivars were found to have lost many of their fruits. To assess these losses, the capacity of surviving flowers to develop was measured. This was denoted as the number of green fruits present expressed as a percentage

of the flowers which had survived for a week after they were frosted. It was similar for frosted and unfrosted plants, but the early-flowering cultivars had least fruit drop whilst the late-flowering cultivars had most. However, it was clear that fruit development was independent of frost tolerance because of the two most tolerant cultivars, 238/36/12 retained most of its fruit whilst Ben More lost almost half.

(A. Dale, Barbara M. M. Tulloch)

03010 *Brassicas: genetics of S-allele incompatibility systems in* Brassica oleracea

Partial self-incompatibility in Brassica oleracea

In some inbreds a pollen mixture interaction has been found, mixtures containing 25 per cent cross pollen giving more sibs than self pollen alone (Ann. Rept 1978). Self and cross pollen are both deposited on stigmas in the production of hybrid seed and this interaction may explain the high sib levels sometimes found in hybrid seed lots.

During 1979 a cyclone spore separator was used to obtain increased quantities of pollen for use in mixtures ranging from 10 to 40 per cent by weight of cross pollen. Good mixing of self and cross pollen in the required concentrations was obtained. To collect sufficient quantities it was necessary to store the pollen in a deep-freeze during the collection and mixing process, and no detectable loss of viability, as measured by pollen-tube growth, occurred during the first two weeks following collection. However, when mixtures involving pollen stored for seven to 10 days were used for seed production, extremely low seed sets were obtained. The reasons for this are not understood and further experiments are planned for 1980.

(T. Hodgkin)

03011 *Brussels sprouts: breeding hybrid cultivars*

Yield components

Ten cultivars of Brussels sprouts were intercrossed in a half diallel and the progenies grown in 1976 and 1978 (Ann. Rept 1977, 1978). The results from both years have now been analysed. General combining ability (GCA) accounted for the between-progeny variation in number of sprouts over 12 mm, and there was no year × progeny interaction. The inheritance of mean sprout weight and uniformity of sprout size was more complex than that of sprout number, and both GCA and specific combining ability were highly significant. The cultivars Perfect Line and Peer Gynt contributed to high sprout weights in the half diallel progenies, and the cultivars Achilles and Jade E to uniformity of sprout size. As with sprout number there was no evidence of a significant progeny × year interaction.

To compare different selection methods, nine outbred plants were intercrossed in a half-diallel, selfed and test-crossed to two F1 cultivars with good general combining ability. The progenies were grown in a replicated trial in 1979 and sprout yield and quality components measured at harvests in October, November and December. The information obtained from the three groups of progeny will be evaluated and the selection methods compared.

During the November harvest a high incidence of internal browning (IB) was found. Analyses of the November and December harvest data showed highly significant differences in the incidence between the selfed progenies (range 0% to 60%), and indicated that IB expression in the half diallel and test-cross progenies was consistent with inheritance by additive genes, together with a degree of dominance for the absence of IB. This information will enable progenies with extremes of IB expression to be bred and used to develop reliable testing procedures for the disorder.

(T. Hodgkin)

Improvement of glossy inbred lines

Sixty-seven hybrid progenies produced for the second generation of the cyclic single cross selection programme were sown in cold frames and transplanted in an alpha incomplete block design with three replications.

In a good growing season and with closer spacing, 60 × 60 cm compared with 60 × 90 cm in the 1975 trial, the plants were tall, erect and free from mildew, but they suffered considerable slug damage which affected button quality.

Plots were sampled three times from October to December. An index similar to that described for the first cycle of this programme (Ann. Rept. 1976, p.49) was designed to rank progenies for further selection.

Analysis is incomplete but morphological differences between progenies were noticeable and there was greater uniformity within many of them than in material of the first cycle.

(A. J. Redfern)

03012 *Cabbage: breeding hybrid cultivars*

Three replicated trials of hybrid material at varying stages of selection were grown. In one, advanced autumn-maturing savoy material was compared and five selections were made for entry into NIAB Breeders' Trials in 1980. In another, 45 mid to late maturing savoy and in the third, 14 Celtic type winter hardy lines were grown for maturity period, yield and quality assessments; these two groups both having been selected from the partial half diallel (Ann. Rept 1977, p. 60).

Winter survival and flowering characteristics were recorded in the 'S' inbred line and in 161 savoy and white cabbage inbreds selected for good combining ability with the 'S' and 'DK' inbred lines. The material was sown on 4 June and grown in a replicated trial. One replicate was badly damaged by flooding and compacted snow.

Harsh winter conditions killed some lines completely, but 52% of all plants survived until June, by which time 78% of them had flowered. Ninety-five per cent of the 'S' line survivors but only 75% of the survivors of the newer material flowered. The latter group tended to be later maturing, smaller and without solid heads.

The non-flowering plants had probably been vernalised, but extensive damage by pigeons and from other causes resulted in the development of vegetative shoots only. A similar response has been observed in previous years.

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

03013 *Brassicas: isoenzyme analysis in* Brassica oleracea

The search for more systems to supplement acid phosphatase isoenzyme analysis for sib determination was continued by staining for the enzyme glutamate oxaloacetate transaminase (GOT) following electrophoresis on polyacrylamide gel using procedures similar to those for acid phosphatase. GOT was shown to be polymorphic in seed and cotyledon extracts with a number of bands being detected in preliminary experiments. Work on this enzyme was discontinued when it gave insufficient variability between those cultivars not amenable to sib recognition by acid phosphatase analysis.

Co-operative work with commercial seed houses continued with the identification of technical problems resulting from initial use of the sib recognition techniques, and practical instruction in the technique was given to technical staff of a Dutch seed company.

Material from a collection of putative wild *B. oleracea* growing near Dover was analysed for acid phosphatase isoenzymes of seed zone 2 (acp-1) and cotyledon zone 1 (acp-3) to search for rare or previously unknown alleles. Only alleles common in the species were identified, but differences in allele frequencies between the populations of two sites were noted. The frequency differences may have resulted from the collection procedures, rather than reflecting real population differences.

Studies to investigate whether analogous variation to that of *B. oleracea* is present in related species and genera were extended to *Raphanus sativus*. A number of bands were recognised in seed zone 2 and cotyledon zone 1, with those of the latter zone having greater mobility than in *B. oleracea*. Half-seed procedures (Ann. Rept 1978) were used to analyse 16 families of *B. oleracea, B. campestris, B. napus* and *R. sativus* for seed zone 2 and

cotyledon zone 1. The independent inheritance of these zones already reported for *B. oleracea* (Ann. Rept 1978) was confirmed, and shown to be independent in all except *R. sativus* which was not adequately analysed.

Extracts of stigmas, made before and after compatible pollinations, were stained for acid phosphatase and esterase after polyacrylamide gel electrophoresis. No differences in enzyme activities were found to result from pollination.

(Eveline M. Wiseman, A. B. Wills)

03015 *Brassicas: genetics and cytology of* Brassica oleracea

Studies of seedling genes were continued by growing 65 progenies that segregated 46 different combinations which tested possible linkages among 22 marker genes. Two of the characters, fused cotyledon and anthocyanin pigmentation, have not given consistent results in previous years and it has not always been possible to assign an exact genotype to parent plants. Segregations consistent with determination of fused cotyledon by two duplicate genes were found in progenies grown in 1979, but in some selfed families control at a single locus with differential viability could not be rejected as a possibility. There was no convincing evidence of linkage between fused cotyledon and eight genes, including acp-3. Differences in the anthocyanin pigmentation of seedling hypocotyls are recorded as routine, but the scores may be highly subjective and the intensity sometimes varies with seedling age and environmental factors. The scores considered the most reliable are those where strong pigmentation can be contrasted either with slight pigmentation, the recessive condition, or with total absence due to the presence of a different gene. In a family showing a clear backcross segregation of strong versus slight pigmentation there was linkage between this gene (A) and glossy foliage (Go-1) with $31{\cdot}13 \pm 4{\cdot}50\%$ recombination. Two unrelated families showed linkage between A and fern leaf (Fn) and recombination was estimated as $32{\cdot}89 \pm 0{\cdot}76\%$ and $32{\cdot}41 \pm 0{\cdot}73\%$ respectively. However, there was no linkage between Go-1 and Fn where these two genes segregated together.

A hairy leaf condition provisionally designated Hr^{sp}, with an extreme manifestation of hairs on leaves, hypocotyl and cotyledons showed linkage in a backcross with pale-green foliage, similar to the phenotype of pg-2. Linkage between Hr-1, Hr-2 and pg-2 is already known, but these hairy-leaf genes do not produce the extreme phenotype shown by Hr^{sp}.

Acid phosphatase (acp-3) was not linked with any of six genes against which it was tested and no previously unrecorded linkages were found.

Severe winter conditions again caused high losses among families being overwintered to flower in 1979. No new relationships occurred among families that survived.

(A. B. Wills, P. Smith)

03019 *Calabrese Breeding*

Data on yield, quality and period of maturity from the trial grown in 1978 (Ann. Rept 1978, p. 70) was subjected to principal components analysis to identify lines with combinations of desirable characters.

Selections were made which showed quality combined with low spear leaf weight, yield combined with quality and lateness, and yield combined with quality. These were used to produce three differing populations to be established by mass pollination of the parent lines.

Parent material for each population was flowered in pots and any showing defects such as blindness or pale green foliage were discarded. The inbred lines varied so greatly in flowering period that the earliest had ceased to flower by the time the latest had begun. The late sowing and cool season favoured fungal diseases and both seed development and ripening were poor.

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

MYCOLOGY

R. A. FOX

Studies on the levels of infection of raspberry canes wounded by mechanical harvesting showed that the simple modification of covering the fingers of the Agricultural Science's harvester with rubber sleeves nearly eliminated the problem of infection at finger wounds. The use of an experimental spraying rig and fluorescent tracers to study the effects of alternative pressures, boom layouts, and the position, orientation and type of nozzle showed that variations of conventional hydraulic spraying methods are unlikely to give better cover than the unsatisfactory levels achievable with current commercial sprayers. The improved cover obtained by using a high velocity air-blast sprayer suggests that adequate performance might be obtained by air-assisted hydraulic methods. Continued studies on raspberry flower and fruit infection by *Botrytis cinerea*, showed that cryptic infection of the plug, surprisingly, may decrease as fruit matures, presumably as a result of the hosts' defence mechanisms, and that the main source of infection is from the spent stamens and their associated basal tissue.

Continued studies on cultural control of potato gangrene suggest that, in general, the lower levels of inoculum and warmer temperatures that usually accompany early harvesting and storage, are more important in preventing the disease developing than very low storage temperatures are in enhancing its incidence. Observations on the development of lesions on seed tubers post-planting show, as expected, seasonal effects, but lend weight to the need to plant truly clean seed.

The important results reported herein on the role and mode of action of phytoalexins arising from work on quiescent infection in Erwinia/potato, of pectic enzymes in Erwinia spp in relation to potato tuber rots and blackleg, and of toxins produced by *Botrytis fabae* in the etiology of chocolate spot of beans, together stress the need for strengthening work on basic studies of host/pathogen interactions.

SOIL MICROBIOLOGY AND ROOT DISEASES

02017 *Biology of potato gangrene*

Lesion development in planted tubers

Previous results suggest that there may be marked seasonal influences on the rate of spread of gangrene lesions in seed tubers after planting (Ann.

Rept 1978, p. 71-72). Inoculated tubers, cv Pentland Crown, were planted in the field or in the glasshouse in pots of Universal Compost kept in temperature controlled boxes at 10 or 15°C or at glasshouse ambient temperature (12-22°C). Tuber samples were taken weekly from the end of April to mid-July to record changes in lesion size. Lesion areas on field grown tubers increased steadily for 6 weeks until, by mid-June, they were almost three times as large as when planted. Further spread appeared to be inhibited by the development of a corky zone delimiting the rot from the healthy storage parenchyma which became hard in texture — a phase coincident with rapid shoot development. The rots in later samples became progressively dark and hollow and were invaded by saprophytes and an increasing proportion were also affected by soft rots.

In the glasshouse the rate of lesion spread tended to be lower with increases in temperature, but treatment differences were not significant. The lesion areas on tubers in pots kept at ambient temperature were similar to those of tubers planted in the field throughout the sampling period despite the temperature of the field soil being consistently lower. The 10 and 15°C treatments had induced slightly larger lesions at all sampling dates. The progress of lesions in field planted tubers was similar to that in 1978 despite temperatures being much lower than in that season.

In another glasshouse experiment, carried out over the same period, inoculated tubers were planted into insulated bins of soil; one bin was maintained at near saturation by frequent watering and the other allowed progressively to dry. Insulating the surface of the wet soil with polystyrene chips reduced evaporative cooling and kept the temperature of the bins within 1°C of each other. The rate of lesion spread was initially lower in the dry than in the wet treatment, but it then rapidly increased and lesion sizes became more extensive in the dry than in any of the other treatments. The onset of this rapid expansion coincided with shoot extension, suggesting that tuber resistance was lowered by the considerable water stress then placed upon it. This result was similar to that found in pot experiments in 1978 in which lesion development was found to progress fastest in dry conditions. The results suggest that in the field a combination of low soil temperatures and low rainfall, especially during early rapid shoot growth, favour the rapid expansion of gangrene lesions which may lead to high inoculum levels in the soil later in the growing season.

Infection of potato leaves

Neither *Phoma exigua* var. *foveata* nor *Phoma exigua* var. *exigua* has been isolated from potato leaves. To assess the possibility of direct penetration of leaves, twelve isolates of the var. *foveata* and two of the var. *exigua* were used to inoculate leaves of the cultivars Pentland Crown, Golden Wonder, King Edward and Pentland Ivory. Spores alone, comminuted mycelium and both — all labelled by fluorescent dyes — were variously used as

inocula applied to intact, needle wounded, or carborundum-abraded upper and lower surfaces of attached leaves. Although germinated pycnospores and fine ramifying hyphae which developed small pycnidia could be detected on leaf surfaces, no evidence of penetration was found when tissue sections were examined by fluorescent microscopy. Nevertheless, the fungus was occasionally recovered after rigorous surface sterilisation, there being no difference between damaged and undamaged leaves. When detached leaves from field and glasshouse grown plants were similarly inoculated and then kept with their petioles in water both intra- and intercellular spread rapidly occurred, the leaves becoming extensively colonised within 17-20 days. Both varieties of the fungus parasitised the senescent tissue with equal ease.

Following observations in the Republic of Ireland, samples of healthy leaves were removed from field grown plants during July and during September and after rigorous surface sterilisation segments were plated on tap water agar containing chloramphenicol, fentin hydroxide and either paraquat or glyphosate. Although initial examination had shown no evidence of lesions, nevertheless, both the var. *exigua* and the var. *foveata* were isolated from pycnidia which developed on the leaf segments, *ca.* 30% of which were positive at the second sampling date although only 5% at the earlier date. Whereas these results clearly indicate that both var. *foveata* and var, *exigua* may invade leaves without symptom expressions, how they do so and why they have not been detected previously using conventional isolation methods must be the subject of further investigations.

(R. A. Fox, E. Patricia Dashwood, H. M. Wilson)

02024 *Autecology of the strawberry red core fungus* (Phytophthora fragariae)

Survival of oospores in soil

An experiment to examine the effects of soil moisture content and temperature on the viability and subsequent germination of oospores buried on monofilament nylon cloth in soil was continued (Ann. Rept 1978, p. 75). Samples were examined after 6 months storage in soil kept under controlled conditions and in soil held in containers buried in the field.

No viable oospores were recovered from samples which had been stored at −20°C. Most oospores stored at −1°C and between 23 and 83% moisture holding capacity (MHC) were viable, but more than 50% held at 17% MHC were dead and at 100% MHC 90% of the oogonial envelopes contained no oospores.

Some empty oogonial envelopes were found in samples held at 5°C the number increasing with increasing moisture content, e.g. at 17% MHC only 3% were empty compared to 61% at 100% MHC. At all moisture levels

some oospores were in the activated thin-walled state. The results at 15°C were similar to those at 5°C except that at the lowest moisture level (17% MHC) 83% of the oospores were dead.

At room temperature (20-22°C) the numbers of empty oogonia were low, the highest percentage (34%) being at 100% MHC. At intermediate moisture levels, 80-90% of oospores were viable, but at 17% MHC most were dead.

There were fewer viable oospores in the 30°C samples and these were found only in those held moist (>67% MHC).

Samples recovered from the field after burial at 50 and 150 mm gave results similar to those of controlled storage at 5 and 15°C.

Samples from the controlled temperature/moisture regimes were further examined by baiting them with plants of cv. Baron Solemacher using 40 bait plants per sample. In general, the proportion of infected bait plants corresponded inversely with the figures for empty oogonia and/or dead oospores. Thus at 15°C and 17% MHC, where all the oospores appeared dead, 0·5 ml of soil gave no infection in 40 tests; at 50% MHC, where 70% of the oogonia were empty and 26% contained viable oospores, 0·5 ml of soil resulted in eight infected bait plants, but no infection was recorded with wet soil (100% MHC) where only 5% of the oogonia contained oospores.

When oospores recovered from the nylon cloth for germination studies were repeatedly washed in distilled water, omitting a dilute $HgCl_2$ wash, it was found that some were contaminated with other microorganisms. Bacteria, actinomycetes, yeasts and filamentous fungi were all observed, but an association between them and the status of the oospore, e.g. dead, viable, activated, was not apparent.

(J. M. Duncan)

02013 *Biology of root diseases in field peas and beans*

Biology of Botrytis fabae *in bean*

Chocolate spot lesions on field bean leaves previously inoculated with an aqueous suspension of *B. fabae* conidia were measured before and after exposure to different relative humidities and temperatures. The leaves were in a sealed system immersed in water in a temperature controlled bath and the humidity depended on the saturated salt solution through which the air within the system was continuously bubbled. Lesions increased in size only slowly when the relative humidity of the air was below 66%. Following a lag phase immediately after infection the rate of increase was linear and proportional to humidity between *ca.* 70 and 100% r.h. Humidity did not interact with temperature between 10 and 20°C.

A heat stable phytotoxic fraction obtained from bean leaves infected with *B. fabae* was soluble in water and 90% ethanol, but was insoluble in

100% ethanol, diethyl ether and acetone. The toxic activity was not lost when ammonium sulphate was added to saturation in order to precipitate polysaccharides. It was not lost through a dialysis membrane immersed in water and was rapidly eluted from Sephadex G25 or G75. These results indicate that the toxic component is a non-protein compound of high molecular weight. It was equally active when dissolved in buffer solutions of pH 4·0, 7·0 or 9·2. Ultra-violet absorption peaks were detected at *ca.* 191, 259 and 320 nm in phytotoxic fractions eluted from Sephadex, but these may have been caused by non-toxic impurities.

Aggressive lesions developed at 100% r.h. after inoculating bean leaves with a mixture of conidia of *B. cinerea* and pollen grains. A phytotoxin with similar properties to that from *B. fabae* lesions was extracted from the infected leaves.

Observations on the movement of red dye in leaves introduced by abrading eosin powder into the lamina, suggested that in dry air (<70% r.h.) toxins from a chocolate spot lesion become concentrated in the transpiration stream and may kill surrounding uninfected tissues. These may become dessicated and prevent further fungal growth, accounting for the dry tissue frequently seen surrounding lesions in dry air and from which it is possible to isolate the pathogen. Eosin movement in leaves in saturated air, however, suggested that the toxin may diffuse throughout the lamina and become too dilute to kill leaf tissues. Indeed, when *ca.* 0·05 ml of a toxic extract from chocolate spot lesions was injected into laminae, lesions developed on leaflets exposed to low humidities while they were absent from those kept at 100% r.h.

Lesion diameter 4 days after inoculating leaves of 12 cultivars of field bean with *B. fabae* conidia and keeping them in a saturated atmosphere at room temperature did not correlate significantly with estimates of chocolate spot severity in field plots at Invergowrie. This result confirms that obtained in 1978 and indicates that this type of laboratory assessment is of little use in predicting disease severity in the field.

Chocolate spot lesions develop faster on leaves higher up the stem than on those lower down, which senesce first. Field observations suggested that leaves of cultivars most susceptible to the disease may senesce earlier than those of less susceptible cultivars. In order to investigate the relation between senescence and susceptibility the chlorophyll content (as an indicator of senescence) of the second pair of leaflets of twelve bean cultivars grown in a glasshouse, was determined at fortnightly intervals. Absorption of light by 80% acetone leaf extracts was measured at 645 and 663 nm and chlorophyll content was calculated using Arnon's formula. Differences in chlorophyll content between cultivars were not significant. Leaves remained green, eventually withering and turning brown, in contrast to those of plants in the field which become yellow or cream coloured before falling off.

To determine whether infection by *B. fabae* accelerates yellowing of leaves, 10 leaves of each of 12 cultivars were each inoculated with a drop of spore suspension and kept at 100% r.h. at room temperature. Mean chlorophyll content of uninfected tissue surrounding lesions 4 days later was not significantly different from that of uninoculated control leaves and there was no interaction with cultivar.

An attempt was made to induce *B. fabae* to produce apothecia. Autoclaved bean stems were inoculated with a conidial suspension, sealed in a plastic bag and kept in the dark at room temperature (*ca.* 20-22°C). After 3 weeks the stems were removed and allowed to dry at room temperature. Lengths of 10 mm of stem bearing sclerotia were placed on autoclaved moist silver sand in 20 Petri dishes and kept at 3°C in darkness for 9 weeks or 17 weeks. The stem pieces in three dishes removed on each occasion were painted with a suspension in water of microconidia from a different isolate of *B. fabae*, those in another three dishes were painted with microconidia in aqueous soil extract solution while the remaining four dishes were left intact. The plates were kept in darkness at 10°C for 2 weeks, then exposed to daylight in a glasshouse at *ca.* 15°C. The stem pieces were examined at weekly intervals for 12 weeks. Apothecia were absent, but conidia were abundant on sclerotia of all treatments.

(J. G. Harrison)

02010 *Seed quality-soil interactions and the effects on seedling emergence, growth and yield*

Barley seed production and seedling emergence

In 1978, seeds of barley, cv. Golden Promise, were harvested on 7 September, 14 September, 12 October and 8 November from a farm crop at Invergowrie end, in contrast to previous results (Ann. Rept 1978, p. 78), no reduction in germination or seedling vigour due to delayed harvest was noted, nor were the emergence abilities of the seeds impaired when they were sown in the following spring. In 1979, seeds were harvested again from a farm crop, both by hand and by small-plot combine harvester on 29 August, 24 September and 22 October. They were dried immediately after harvesting at 35°C in a forced draught oven to reduce their moisture content to 10%. All the seed lots were later adjusted to 20% m.c., stored at 32°C in polyethylene bags and samples removed 11, 15, 18, 22, 25 and 29 days after the start of storage. The germination and vigour of the seeds as harvested were not affected by method or date of harvest, but the rate of deterioration as shown by decline in viability or rate of seedling growth was greater in the later harvested seeds and in the seeds harvested by combine.

(D. A. Perry)

Causes of barley seed mortality in wet soil

Barley seeds which had been deteriorated at 20% m.c. and 30°C died when they were sown in wet soil (Ann. Rept 1978, p. 79) and although mortality was increased by the presence of soil microorganisms, it still occurred in sterilised media under anaerobic conditions. More deteriorated seeds than non-deteriorated seeds were killed when placed in anaerobic conditions and ethanol concentrations (analysed by gas liquid chromotography following aqueous extraction) after 4 days at 20°C on filter paper were 300-400 μg/g seed d.m. for both seed types. The ethanol concentration of non-deteriorated seeds in wet field soil at 32% m.c. and 20°C initially rose after 1 day to 32 μg/g d.m., but then fell to negligible levels after 2 days, while in deteriorated seeds it rose at a similar rate and continued to do so up to 80 μg/g d.m. after 4 days. Negligible concentrations were found in all seeds in soil at 16% m.c. Similar results were obtained from a field experiment in which seeds were sown in normal and excessively wet seed bed conditions. Dry seeds were exposed to ethanol concentrations ranging between 0·1-10% in a sterile medium containing 15% v/w of the solutions and more deteriorated than non-deteriorated seeds were killed at intermediate concentrations. Oxygen consumption of deteriorated and non-deteriorated seeds 24 hours after the start of imbibition were 70 and 105 μl/g/h respectively in optimum water levels for germination and the seed coat and a water film were effective barriers to gaseous diffusion. Non-deteriorated seeds were observed to germinate faster than deteriorated seeds.

It is postulated that anaerobic conditions develop within seeds in wet conditions and toxic metabolites such as ethanol accumulate. The rapid emergence of radicles in non-deteriorated seeds allows oxygen to diffuse in and releases toxic metabolites, while in deteriorated seeds, the products of anaerobiosis, to which they are intrinsically more sensitive than non-deteriorated seeds, continue to increase to lethal levels.

(D. R. Ellerton)

Carrot seedling emergence

Twelve seed lots of several cultivars showing a range of viability from 81-91% and a range of seed size from 0·58-1·97 g/1000 seeds were sown on 9 May, 10, 20, 40 mm deep with a loose soil covering, 20 mm deep in soil kept dry under translucent covers, and 20 mm deep and compacted by rolling after sowing. Mean emergences from seeds sown at 10, 20, 40 mm were 79·5, 54·2 and 8·2% respectively and from those in dry and compact soil were 41·4 and 56·7% (SED ±4·93) respectively. Germination correlated best with emergence ($r = +0.69$) when seeds were sown 10 mm deep and not when they were sown deeply or in dry and compact soil. In contrast, seed weight was significantly correlated with emergence when seeds were sown at 40 mm and in compact soil ($r = +0.78$ and $+0.68$ respectively), but not when sown shallowly.

(D. A. Perry)

Cavity spot of carrot

The number of pectolytic anaerobes in the rhizosphere was estimated by scraping or shaking excess soil from roots and lightly brushing adhering soil into sterile saline. Ten-fold dilutions were plated on P_1 pectate agar and the number of pits in the pectate layer counted. Soil samples taken at least 20 mm distance from roots were diluted and similarly plated. Sub-culturing a sample of isolates on pectate plates in air showed that the majority of pits were caused by obligate anaerobes. The numbers found in the rhizosphere and surrounding soils in the irrigated field experiment average 14×10^3 and 62×10^3 propagules/g dry soil and they were similar in the irrigated and non-irrigated plots. Rhizosphere soils of carrots from 11 local farm crops contained between 15 and 60×10^3 propagules/g dry soil (average 30×10^3) while surrounding soil contained between 6 and 14×10^3/g (average 8×10^3/g) providing evidence that anaerobes had multiplied in the rhizospheres during the growing season. However, the size of the populations was not correlated with the incidence of cavity spot in the crops. Populations of pectolytic anaerobes within miscellaneous crops examined on the farm at Invergowrie increased in the rhizospheres of beetroot, leek and raspberry, but not in strawberry or calabrese. Populations increased with depth from the surface down to 150 mm.

(D. A. Perry)

PLANT AND PATHOGEN PHYSIOLOGY

02026 *The nature and implication of quiescent fungal and bacterial infections*

The close association of pathogen inhibition, cell necrosis, and phytoalexin accumulation in plants suggested that necrosis of some cells may be caused by phytoalexins reaching toxic concentrations. The phytotoxic nature of the phytoalexin rishitin, previously demonstrated with isolated tobacco protoplasts, was confirmed using potato leaf epidermal strips incubated with 300 μg rishitin/ml in 1% Evans blue which rapidly stained the cytoplasm showing that damage to the plasmalemma had occurred. In addition, the nuclei stained particularly strongly and frequently increased in diameter and many chloroplasts lysed, suggesting rapid effects on several cell membranes. As with earlier work on plant protoplasts, these results did not preclude the possibility that the primary site of action of rishitin was within the cell and the membranes were affected as a consequence of some other cellular disruption. This latter possibility was shown to be less likely when rishitin also caused lysis of isolated potato chloroplasts suspended in 0·15 M phosphate buffer pH 6·5, thus showing a primary site of action of rishitin to be either membranes or to be within the chloroplast.

Rishitin only slightly affected the rate of respiration of isolated tobacco protoplasts suggesting it was not acting directly on the respiratory enzymes but that this effect was secondary and a consequence of rishitin acting elsewhere. This compared dramatically with phaseollin which rapidly inhibited respiration possibly by acting as an uncoupler though, like rishitin, it also disrupted plant cell membranes making them permeable to Evans blue within 5 min.

In an attempt to demonstrate that rishitin could affect membrane permeability directly, the effect of rishitin on liposomes (phospholipid vesicles) was studied. Liposomes were prepared from lecithin/cholesterol/phosphatidic acid or lecithin/cholesterol/stearylamine mixtures and the effect of rishitin on their permeability to a range of small molecular weight non-electrolytes was measured. It was shown that rishitin increased the permeability of liposomes to all the low molecular weight non-electrolytes particularly when mixed with the lecithin prior to liposome formation, and that rishitin affected both negatively and positively charged liposomes. Liposome permeability was affected more by rishitin than by phytuberin thereby correlating with rishitin's higher toxicity to plants, fungi and bacteria. In addition, rishitin affected the transition temperature of liposomes prepared from dimyristoyl-L-3-lecithin.

These results suggest that rishitin acts by increasing the permeability of membranes to electrolytes and small molecular weight compounds (possibly by increasing membrane fluidity) causing rapid leakage and decompartmentalisation resulting in cell death. Attempts to produce rishitin-resistant mutants of plant pathogens would therefore be unlikely to succeed as resistance could be linked with decreased nutrient uptake and hence low vigour.

(G. D. Lyon)

02015 *Disorders of vegetables*

Cavity spot of carrots

A field experiment was sown on 1 May with seeds of cv. Red Cored Chantenay and a population of 500 plants/m² was established in four beds 20 m long and 1·5 m wide. Fertilisers (50, 180, 150 kg/ha N, P, K respectively), chlorfenvinphos (22·5 kg/ha) and trifluralin (2·34 l/ha) were incorporated into the soil before sowing and the beds were rolled after sowing. On 2 August a 4 m long section of each bed was trickle irrigated continuously for 14 days and a further section was irrigated continuously from 20 August for a similar period, treatments being randonmised within beds. Samples of roots occupying 0·25 m² were collected after each irrigation period, examined for lesions and plated on Lund's P_1 pectate plates incubated anaerobically and on Stewart's pectate plates incubated in air. Although some typical soft rot lesions were observed, neither

Clostridium spp nor Erwinia spp were consistently isolated from them. Lesion incidence in samples from 0·5 m^2 harvested on 22 October were 23·8 and 22·2% on the irrigated plots and 13·6% ($P<5\%$) on the non-irrigated plots.

(D. A. Perry)

02018 *Diseases of potato tubers*

Pathogenicity of Erwinia carotovora

The susceptibility of potato tubers to decay and the pathogenicity of isolates of *E. carotovora* var. *atroseptica,* when assessed by the ED50 of bacterial numbers required for induction of visible decay in infected tubers held in an atmosphere of 10% O_2 and 90% N_2 at 22°C, were positively correlated to the water status of the tuber tissue. A difference of 1 bar in the water potential resulted in more than a 100 fold difference in the ED50 values. Pathogenicity of var. *carotovora* was *ca.* 500 times greater than that of var, *atroseptica* at 30°C, but at 15°C pathogenicity was variable and was apparently related to the ability of the different isolates to produce polygalacturonic acid transeliminase *in vitro* at that temperature. Susceptibility of tubers to infection by var. *atroseptica* tended to fall during winter storage and cv. Pentland Crown and cv. King Edward were the most susceptible while cv. Bintje and cv. Majestic were the most resistant—the reverse of their relative blackleg susceptibility.

(M. C. M. Pérombelon, R. Lowe)

Wound periderm formation in gangrene affected tubers

It is stated in many papers that gangrene lesions may be cut off by a wound periderm. However, a survey of published illustrations suggest that whilst a 'barrier' may be formed it does not arise from a true wound periderm. Infected lesions and uninfected wounds in tubers of cv. Pentland Crown of different physiological ages were examined after subjecting them to a wide range of temperatures and relative humidities and in the medullary zones no evidence was found of wound periderm formation. Macroscopically, a barrier may readily be seen around gangrene lesions; microscopically, it is revealed as a layer of partially collapsed and compressed dead cells in which the pathogen has destroyed the cell contents, and the middle lamellae have mostly been broken down. It appears that although under certain circumstances it may be an effective barrier to lesion extension this build up of dead cell walls has mistakenly been thought to arise from wound periderm activity. However, transmission and scanning electron microscopy show that fine hyphae may often be found penetrating a layer of two to four live cells beyond the barrier.

In the skin periderm area, a true wound periderm may be initiated, but evidence to date suggests that it is not able to form sufficiently rapidly to stop advance of the pathogen at the low temperatures at which lesion expansion usually occurs. Further work is required to ascertain if the phenomena briefly described here from Pentland Crown is common among other cultivars.

Potato periderm as a site for infection by Phoma exigua *var.* foveata

When tubers age in the field and in store their surface characteristics alter as the periderm changes from a thin, smooth, easily scuffed structure in immature tubers to a well-set, firm, slightly roughened and scuff resistant layer in mature tubers. The concomitant physical and physiological changes could effect the suitability and susceptibility of the periderm as a site for colonisation and infection. In field experiments over the past 6 years periderm populations of the pathogen have been assessed for successive harvests preceded or not by haulm destruction. Samples from late harvests always had the highest scores, the inoculum level in the soil then being also high, but some samples from very early harvests also had high populations despite much lower levels of soil inoculum suggesting that the periderm may more readily be invaded and colonised while immature. Where the onset of 'skin set' was advanced by killing haulm early in the season and comparing the tubers with those harvested from plants still growing, differences in the periderm populations were not associated with the degree of periderm maturity; the more mature periderm frequently had the highest populations. Although these results could be explained by increased levels of inoculum provided by dead and senescent haulm, root and stolen systems, they might also be affected by induced changes in periderm structure about which little was known. Periderm sections of cv. Pentland Crown were prepared from tubers harvested from 10 successive samples taken from the beginning of August to the end of October. The thickness of the periderm and the number of cell layers in it increased up to the beginning of September from a mean of $11{\cdot}9 \times 10^2\mu$ to $16{\cdot}0 \times 10^2\mu$ and 8 cells to 10 cells deep respectively and thereafter remained unchanged. Over the same period the number of cell layers with suberized walls increased from an average of six to eight and the frequency of sections with a gap immediately below the suberized layer decreased to nil. The gap is an artefact which occurs during section preparation, but it provides an indication of the tendency of the skin to slough off when exposed to damage. From September to October the main changes in the periderm were those associated with growth stresses and soil abrasion the regular columna arrangement of cells gradually changed to a more irregular pattern when cracks and peeling in the outer layers induced secondary areas of cell division, the new cells in turn becoming suberized and forming new columns. In undamaged zones lateral stress induced by tuber expansion appeared to

promote the development of radial cross-section walls. The initially smooth surface of the periderm became rough and eventually consisted of islets of thick periderm surrounded and/or separated by younger thinner-walled cells. The proportion of periderm cells containing nuclei was variable but averaged *ca.* 26% over the first five harvests, decreased to 18% for the next three harvests and finally increased to 22% by the last harvest date. These proportions represent trends since some nuclei were lost from cells during section preparations; at later harvests most of the nuclei counted were those in newly formed cells associated with damaged areas.

Periderm samples from tubers of growing plants (N) were compared with those from tubers harvested on two dates after haulm destruction early (K_1) and late (K_2) in the growing season. Except for the final K_2 harvest the periderm of the K tubers was thinner than that of the corresponding N tubers, the number of cell layers was similar, but the individual cells were somewhat flattened. From the two harvests following K_1 in August, 22 and 20% of the cells were nucleate compared to 28 and 27% of cells in periderms of the equivalent N tubers. Following K_2 in September the proportion was only 16% in both subsequent harvests in contrast to 20 and 22% in the equivalent N tubers. The lowest numbers of nuclei in the K periderm samples, probably associated with decreased meristematic activity as tuber growth ceased, might be related to differences in resistance to infection. Particularly noticeable were the differences in nucleate cells comparing only the two outermost cells layers of periderm; the proportion enucleate was far higher in the samples of tubers taken following haulm destruction.

(R. A. Fox, E. Patricia Dashwood, H. M. Wilson)

02027 *Studies of plant pathogens*

Pectic enzyme production by Erwinia carotovora

The levels of polygalacturonic acid transeliminase (PATE) and of polygalacturonase (PG) produced by three strains of *E. carotovora* var. *carotovora* and one strain of *E. carotovora* var. *atroseptica* in nutrient and pectate broths at 15 and 30°C were determined spectrophotometrically and by viscometry respectively at different growth phases. Although both enzymes were induced in large quantities in pectate broth only trace levels of PATE and low levels of PG were produced constitutively. Enzyme levels expressed in terms of bacterial numbers were higher in the early exponential growth phase than later probably because of catabolic repression. Differential effect of temperature on PATE production by two varieties of *E. carotovora* as reported previously (Ann. Rept 1978, p. 81) was confirmed especially the low levels produced by var. *atroseptica* at 30°C. A similar relationship was found in the case of PG. Enzyme production by var.

carotovora strains was greater and more rapid at 30°C than that by the var. *atroseptica* strains, but the opposite was true at 15°C.

(M. C. M. Pérombelon, R. Lowe)

Genetics of E. carotovora

The conjugational transfer and expression of the R factors RP_4 and R68·45 in *E. carotovora* have been studied. Higher transfer frequencies were obtained when mating was done on filter membranes than in broth and at the optimal growth temperature of the recipient strains. Although both R factors could be transferred from *E. coli* or *Pseudomonas aeruginosa* as donors to most strains of *E. carotovora* var. *carotovora* and var. *atroseptica* transfer frequency was high in only a few strains. It was $>10^{-4}$ per donor cell in 4 out of 18 strains of var. *carotovora* for both R factors and $>10^{-6}$ per donor cell in 2 and 4 out of 10 strains of var. *atroseptica* for RP_4 and R68·45 respectively. High transfer frequencies for both factors were not always present in the same strain. Transfer frequency in the reciprocal crosses was *ca.* 10^{-1} per donor cell, while it was intermediate in homologous crosses between R^+ and R^- strains of *E. carotovora.*

E. carotovora R^+ transconjugants retained the biochemical and pathogenic properties of the parental wild type strains. Presence of the R factors was ascertained by the demonstration of multiple antibiotic resistance which, however, tended to be less than that of the donor strains. Sensitivity to the male specific phages PRD1 and PRR1 was not present to the same degree in all R^+ transconjugants from a single cross. Moreover, sensitivity was greater and more frequent in transconjugants which had acquired RP_4 rather than R68·45 plasmids. Both ethidium bromide and sodium dodecyl sulphate had no significant curing effect.

Both R factors were able to mediate gene transfer when *E. carotovora* var. *carotovora* strain $193R^+$ was crossed with strains 193 str^R nal^R his arg and 193 str^R nal^R his leu, but the frequency was low, *ca.* 10^{-7} to 10^{-8} per donor cell while the transfer frequency of the R factors was *ca.* 10^{-2} to 10^{-3} per donor cell.

(M. C. M. Pérombelon)

EPIDEMIOLOGY AND ETIOLOGY

02003 *Shoot disorders of cane and bush fruits*

Cane diseases of raspberry

Cane blight

Young canes of cv. Malling Jewel inoculated in the field with mycelium or pycnospores of *Leptosphaeria coniothyrium* at 2 week intervals from 22 July to 16 September, 1977, were sampled on 26-28 June, 1978, to

determine lesion size and assess their potential yield (numbers of fruits plus flowers) before harvest (Ann. Rept 1978, p. 84). In mid-July canes were very susceptible to infection, but became increasingly resistant throughout summer. Consequently too few canes inoculated on 22 July survived to be included in the analysis because the aggresive infections structurally weakened them and most snapped. Inoculations made with mycelium were more aggressive than those with pycnospores, the latter causing yield loss only when inoculated on or before 5 August whereas the former caused some loss even in mid-September. Uninoculated wounded controls developed no lesions.

Yield analysis of all canes in the experiment, grouped and ranked by lesion length, showed that lateral shoot and fruit number were reduced by lesions in the size range 10-20 cm or greater. Analysis of 134 canes ranked by score for girdling of the vascular cylinder (score 1, 2, 3 or 4 for 25, 50, 75 and 100% girdled, respectively) showed a discontinuous distribution with no canes scored in class 2 and only three in class 3, indicating that there may be factors controlling lesion spread. Significant loss in yield occurred only if lesions girdled the canes. There was substantial statistical agreement between the two assessment methods for lesion severity, but the girdle score taken at the widest point of the lesion is the simplest method for evaluating cane blight lesions in field trials.

(B. Williamson, A. J. Hargreaves)

The incidence and severity of cane blight in plots of cv. Glen Isla harvested mechanically either by the Agricultural Sciences harvester (using vibrating-fingers to dislodge berries) of by the Littau harvester (using beater-bars) was compared at different harvest intervals (2 and 7 days) and forward speeds (*ca.* 0·8 and 1·6 k.p.h.).

The highest percentage of canes infected at harvester wounds was in the plots harvested at 2 day intervals with Agricultural Sciences harvester (47%), but this was not significantly higher than in any other treatment plots which ranged from 30 to 40%. The incidence of catching-plate wounds was not significantly less on canes in treatments harvested by the Littau harvester (50-58%) than in plots harvested by Agricultural Sciences machine at 2 day (71%) or 7 day harvest intervals (56%).

In the worst treatment (canes harvested by Agricultural Sciences machine at 2 day intervals) only 11% of canes were infected at finger wounds in a season when evidently the inoculum levels and environmental conditions were conducive to infection because 43% of canes were infected at plate wounds. This represents a substantial reduction in the number of potential infection sites and it was achieved simply by covering the vibrating-fingers with rubber sleeves.

In 1975, prior to the introduction of rubber-sleeved fingers on the

Agricultural Sciences harvester, 81% of canes in plots of cv. Glen Isla were wounded by fingers and 44% of these were infected. In 1979, at a 7 day harvest interval only 2·6 and 0·2% of canes became infected in the cropping region at finger or beater-bar wounds caused by the Agricultural Sciences and Littau machines, respectively.

(B. Williamson)

Cane Spot

No method has been available for producing conidia of *Elsinoe veneta* in pure culture in sufficient quantities for screening plants for resistance. Spore production was substantially enhanced within 20 hours of flooding with water 4 day-old point-inoculated cultures on agar containing 0·1% Pfeffer's mineral salt solution supplemented with 0·5% yeast extract.

(C. J. Whitehart)

Spur blight and cane botrytis

Didymella applanata and *Botrytis cinerea* affect the growth of some buds at infected nodes in the cropping region of canes (Ann. Rept 1978, p. 85), but neither fungus penetrates the periderm which protects the vascular tissues of canes. The effect of these diseases on yield, assuming the extreme case that total lateral shoot failure occurs at each affected node, was simulated by removing all buds on fruiting canes of the cultivars Glen Clova, Glen Isla, Malling Jewel and Malling Orion from the base to 45, 67, 90 and 112 cm in February, 1979. There was no significant difference in the number of lateral shoots or fruit yield between plots disbudded up to 67 cm above the base and those untreated. However, there was significant loss in yield in plots disbudded to 90 and 112 cm. There was evidence that the crop compensated for laterals lost at the base of canes by increases in the number of fertile laterals at the top and in mean berry weight. Most spur blight and botrytis lesions occur at nodes below 67 cm, the majority in the non-cropping region at the base (Ann. Rept 1976, p. 69) and cultivars differ in tolerance to these diseases at nodes in the cropping region of canes (Ann. Rept 1978, p. 85). Therefore, assessments of spur blight and botrytis should take account of cultivar tolerance, plant compensation phenomena and the frequency and position of lesions on canes. Extreme disbudding treatments (i.e. 90 and 112 cm) may affect the competitive relationships between fruiting and young canes. Assessment of cane production in the year of disbudding showed that only in plots disbudded to 112 cm was there an increase in the mean number of canes per stool as compared with untreated plots.

(B. Williamson, H. M. Lawson)

Bacterial galls of raspberry

Modification of New and Kerr's selective medium has facilitated the isolation of Agrobacterium spp. from galls and the soil. Only 3 of 204 presumptive agrobacteria isolates obtained from a field with a past history of galling in raspberry plantations were virulent when tested on *Datura stramonium*. None inhibited *in vitro* the growth of virulent strains previously isolated from raspberry galls. In an attempt to achieve biological control, the search is proceeding for a substitute for strain K84 which will be active against local virulent strains from *Rubus* spp.

When streptomycin resistant virulent and avirulent strains of Agrobacterium were inoculated in Datura stems, population numbers of the virulent strains tended to fall after 7 days when galling became visible. The numbers of the avirulent strain were not affected even after 7 weeks. There was little movement of the bacteria up the stem from the inoculation point (3 cm) and only slight movement downwards.

(M. C. M. Pérombelon, R. Lowe)

02022 *Harvest disorders of soft fruit*

Superficial and cryptic infection of raspberry buds, flowers, and young fruit by *Botrytis cinerea* was examined for the third successive season using isolation techniques similar to those used in 1977 and 1978. Again, infection remained low until the onset of fruit ripening in mid-July when the incidence rose to 7% in buds and 39% in flowers and thereafter increased to 20 and 60% respectively by the end of the month. When green and newly ripened fruit were surface-sterilised and cut into transverse or longitudinal sections, arranged serially on agar plates, mycelium of *B. cinerea* was observed to develop earlier and occur more frequently in the basal or central sections. Similar results were obtained with very young green fruit in which the incidence was nearly as high as that in ripe fruit. Fruit plugs were then examined separately and the basal sections were found to be uniformily infected whereas the tip sections revealed negligible infection. Surprisingly, the overall incidence in plugs from ripe fruit was less than that in plugs from green fruit suggesting a loss of fungal viability as the plugs matured. Further examination was made of the base (top) of the plug area by separately plating the petals and stamens and the respective plugs bases. The levels of infection detected in plug base, sepals and stamens was 40, 47 and 85% for red fruit plugs and 35, 57 and 89% for green fruit plugs indicating that the stamens probably play a major role in fruit infection. Fungal mycelium was easily detected microscopically in stamens although, of course, it was not necessarily that of *B. cinerea*, nevertheless, earlier experiments involving complete dissection of floral parts showed that only stamens appear to be infected in young flowers or just opened buds and *B. cinerea* was usually the only fungus present.

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

Red core of Strawberry

The differences in fruit yield from healthy and diseased plants of two susceptible and three resistant cultivars were compared in a glasshouse experiment. There were significant decreases (96-100%) in yield when the susceptible cultivars were diseased and all components (number of trusses, number of flowers/truss, number of fruit/truss and berry weight) were adversely affected. A significant decrease (43%) in yield was recorded for only one of the resistant cultivars and all components except truss number were adversely affected.

Several methods of screening seedlings for resistance to a composite of races were evaluated using progeny derived from selfing one of the most resistant cultivars. The proportion of resistant progeny determined by rapid subjective assessment of the roots varied from 4-50% with zoospores and comminuted mycelium as inocula and was 75% in one method where oospores were the inocula. Water stress accompanied by temperatures above 20°C in the later stages of a 3-week test could eliminate differences in disease severity between susceptible and resistant progeny. The standard used in measuring the efficiency of these methods was that all seedling progeny which were as resistant as the parent should be identified easily after as short as possible a period of testing. The highest efficiency rating for any method was 98%, i.e. two out of every 100 seedlings classified as resistant were more susceptible than the parent after recovery, vegetative propogation and re-testing as young runner plants. However, it has yet to be confirmed that some resistant seedlings were not classified as susceptible by this method.

(I. G. Montgomerie, D. M. Kennedy)

Eight cultivars were evaluated for root susceptibility to a composite of races in experiments which included cv. Cambridge Favourite (susceptible) and 53Q13 (slightly susceptible) as standards. Differences in susceptibility between the cultivars Bounty, Harvester, Hatton Main's Seedling, Northwest, Rainier, Shuksan and Cambridge Favourite were not significant. Cv. Olympus was less susceptible than Cambridge Favourite, but more susceptible than 53Q13 and the difference between cv. Linn and 53Q13 was not significant.

(D. M. Kennedy)

Stamen blight of raspberry

Although spore dispersal by humidifiers (which also maintained a water film around axillary buds) achieved even distribution of *Hapalosphaeria deformans*, when evaluated by collecting samples on glass slides, germina-

tion was decreased from 80 to 15%. A growth cabinet regime of 20°C day/10°C night temperatures, and 18 hour day-length with maximum light intensity of 17216 lux for 48 hours during and after inoculation by this method, failed to induce disease in the 25 cultivars tested. When the same spore suspension was introduced to axillary buds by hypodermic injection 21 cultivars were diseased. These included Glen Esk, Heritage, Malling Leo, Malling Orion, September and Vetan. Hypodermic injection was used in another experiment to examine tissue susceptibility in four genotypes containing different combinations of characters for hairy and spiny stems. Those with hairy stems had a smaller proportion of diseased flowers/inflorescence than genotypes with non-hairy stems whereas the proportion of diseased flowers on plants with spiny and non-spiny stems was similar.

(I. G. Montgomerie, D. M. Kennedy)

Verticillium wilt of strawberry

Three breeder's selections were tested for susceptibility to Verticillium wilt (*V. dahliae* and *V. albo-atrum*) in glasshouse experiments each of which contained the standard cultivars Cambridge Vigour, Redgauntlet and Talisman. 65 L111 and 69 FT118 were as susceptible as Cambridge Vigour and 69 ET30 was as tolerant as Redgauntlet or Talisman.

(D. M. Kennedy)

02007 *Biology of diseases of ornamental bulbs*

Smoulder of narcissus

Isolates of *Botrytis narcissicola* and *Botrytis cinerea* cannot be distinguished by conidiophore or conidial morphology, but they may be separated by the size and distribution of sclerotia produced *in vitro* in petri dishes. Most isolates collected from field-grown daffodils showing a wide range of symptoms were *B. narcissicola*, but *B. cinerea* was often found in senescent foliage and outer bulb scales and, occasionally, in leaf-tip lesions. Isolates could readily be differentiated by their pathogenicity to narcissus bulb scales and leaves, those of *B. nacissicola*, unlike those of *B. cinerea*, consistently produce spreading lesions. The differences between the two species both in their pathogenicity and frequency of association with symptoms in the field demonstrate that *B. narcissicola* is the major cause of smoulder and that *B. cinerea* occurs on narcissus possibly as a weak parasite or saprophyte.

The presence of botrytis sclerotia in outer bulb scales is of little value in predicting which plants would emerge with smoulder, a finding of importance to the Scottish Certification Scheme; moreover, some sclerotia could be those of *B. cinerea*. Nevertheless, infected bulbs were identified as the major source of smoulder outbreaks and secondary spread by conidia may

be enhanced by damaging leaves and via open stem ends left after flower picking. Both Botrytis spp. were sensitive to six phytoalexins they elicited in tissue undergoing resistant reactions. No phytoalexins were detected, or extensive lignification seen, in or at the edge of spreading lesions, suggesting that pathogenesis by *B. narcissicola* depends on an ability to suppress the host's resistance mechanisms.

(T. M. O'Neill)

02019 *Gangrene, blackleg and soft rot and contamination of VTSC seed potato stocks*

Blackleg etiology: field studies

The susceptibility of four cultivars to blackleg was examined by inoculating seed tubers with suspensions containing different concentrations of *Erwinia carotovora* var. *atroseptica* as in previous years (Ann. Rept 1977, p. 85, 1978, p. 86). Blackleg incidence was related to the level of seed contamination provided contamination was not high (inoculum dose of $<10^7$ cells/ml). High levels of contamination resulted in a high incidence of blanking caused by seed decay before or sprout death soon after emergence so that the resultant low blackleg levels were associated with reduced plant populations. Blanking incidence was greatest with cv. Golden Wonder (21%) and least with cv. Bintje (7%), the cultivars Up-to-Date and Pentland Crown being intermediate. As found previously (Ann. Rept 1978, p. 86), the most and least resistant cultivars to blackleg were Pentland Crown and Bintje respectively with 4 and 41% of the disease when examined in September. Blackleg levels in Up-to-Date and Golden Wonder plots were 14 and 5% respectively. The disease incidence increased slowly until the end of August in all except Up-to-Date, but in September it rose sharply in all cultivars following a prolonged wet period. Yield at harvest was inversely related to the numerical levels of blackleg, but was reduced in plots where there had been extensive blanking.

Seed tubers of Bintje were inoculated by vacuum infiltration soon after harvest with *E. carotovora* var. *atroseptica*. Half the number were wounded in a cement mixer and half left untreated. Seed from both treatments were either stored at 5°C in trays or buried in moist peat until planting time when their water status was determined psychrometrically. Wounding had little effect on tuber water status which, however, was high (*ca.* – 8 bars) and low (*ca.* – 11 bars) in peat and tray stored tubers respectively. The incidence of blanking was greater with wounded seed (*ca.* 18%) than with peat and tray stored seed which were equally affected (*ca.* 7%). In contrast blackleg levels in August and September were equally high with wounded and not wounded seed stored in peat (August 15%, September 26%) and equally low with seed stored in trays (August 8%, September 15%).

(M. C. M. Pérombelon, R. Lowe)

Growth of E. carotovora *in mother tubers, stems and daughter tubers*

When seed tubers of cv. Majestic were vacuum inoculated at planting time with *E. carotovora* var. *carotovora* and var. *atroseptica* in ratios of 1 : 1000 and 1000 : 1, var. *atroseptica* tended to predominate in June in rotting mother tubers irrespective of the initial proportions, but the opposite was true in August. The var. *carotovora* was also three to six times more frequently detected in healthy stem bases and in progeny tubers when they were examined in August and September, again irrespective of the initial proportions of the two varieties used to inoculate the seed.

(M. C. M. Pérombelon, R. Lowe)

Contamination of foliage by E. carotovora

Studies on the survival of *E. carotovora* on leaves of field grown plants confirmed and extended previous results (Ann. Rept 1978, p. 87). Leaves were inoculated with streptomycin resistant strains of var. *carotovora* and var. *atroseptica* in July and September. Bacteria in the July inoculated plots could not be enumerated after 2 days of dry and sunny weather, whereas they persisted in quantifiable numbers in the September inoculated plots for 3 weeks during which time the leaves were frequently wetted by rain and dew. Both could still be detected after more than 8 weeks in the July inoculated plots, but enrichment techniques were necessary except on 21st and 35th day after preceding wet periods when they could be enumerated directly. They were also recovered in Octobr from *ca.* 10% of the progeny of inoculated plants and from the leaves of some neighbouring non-inoculated plants less than 5 m away from the inoculated ones.

Leaves and progeny tubers of plants grown from VTSC grade seed known to be erwinia-free and sited in plots of 60 plants within a commercial potato crop were found to be contaminated by five times more var. *carotovora* than var. *atroseptica.* The bacteria tended to react similarly to bacteriocin typing as those present on the foliage of neighbouring plants of the commercial crop.

(M. C. M. Pérombelon, R. Lowe)

Contamination of VTSC stocks by E. carotovora

Surveys done since 1973 of VTSC stocks in the process of multiplication on four farms for contamination by *E. carotovora* showed that (a) contamination could occur even within 1-2 years, but usually was at a low level (b) contamination tended to be greater after the third year when clones are bulked and thereafter grown by conventional methods used for lower grade seed stocks (c) more var. *carotovora* than var. *atroseptica* was present in

most stocks, but occasional sudden reversal in the proportion of the two bacteria could occur from one generation to the next (d) the general contamination level varied from farm to farm: one farm produced consistently stocks with a low level of contamination even after 4-5 years of multiplication and on another the stocks were extensively contaminated at all times. Contamination on the remaining two farms was variable.

(M. C. M. Pérombelon, R. Lowe)

PLANT PROTECTION

02001 *Chemical and cultural control and economic importance of diseases of cane and bush fruits*

One pre-harvest and two post-harvest sprays of imazalil, benomyl, WL 47675 or triforine were applied to machine-harvested plots of raspberry cv. Malling Jewel for control of cane blight in 1978. The incidence of vascular lesions at harvester wounds was assessed in February, 1979. Infections were rare in unsprayed plots, only 9·1% and 3·8% of canes developed lesions at catching-plate and vibrating-finger wounds, respectively. Only benomyl reduced significantly the number of canes affected by lesions at plate wounds. Fresh weight yields were not recorded in 1979 because of (1) a low incidence of cane blight in control plots (2) injury to fruiting canes by late winter frosts (3) particularly severe infestations by clay-coloured weevils (*Otiorrhynchus singularis*) that adversely affected emergence and yield of laterals.

The spray programme was repeated on the same plots in summer, 1979, but triadimefon was substituted for WL 47675, which had been withdrawn commercially, and the plots were harvested by the Agricultural Sciences and Littau harvesters. Benomyl, triforine and triadimefon significantly reduced the incidence of cane blight at plate wounds from 43 in unsprayed plots to 13, 19 and 24, respectively. Less than 1% of canes were affected by lesions in the cropping region at wounds caused by vibrating-fingers of the Agricultural Sciences harvester or beater-bars of the Littau harvester in a season when plate wounds in unsprayed plots were heavily infected. This result contrasts markedly with studies in 1975 using the Agricultural Sciences harvester in Malling Jewel where 81% of canes were wounded by fingers and 40% of these became infected. Low infection levels at finger wounds in the 1979 trial probably results from the use of rubber sleeves on the fingers of the Agricultural Sciences harvester and the milder action of the beater bars of the Littau harvester.

(B. Williamson)

Raspberry flowers at mid-lateral nodes and abaxial leaf surfaces have received only traces of spray deposit with conventional high volume hydraulic spraying methods (Ann. Rept 1978, p. 91). An experimental hydraulic sprayer was constructed to test alternative pressures, boom designs and nozzle orientations which may enhance cover of difficult target areas within the crop. Qualitative assessment of cover of targets by fluorescent tracer dye applied to unreplicated observation plots showed that increased pressure, straddle booms and inclined nozzles did not appreciably improve the cover of targets by spray droplets. In contrast, a high velocity air blast sprayer (Kinkelder Pony) used in August at the water rate of 450 l/ha gave better cover of abaxial leaf surfaces and young canes than a conventional hydrualic sprayer applying 1000 l/ha at equivalent concentrations of dye. These results suggest that air-assisted hydraulic spraying methods may have advantages for raspberries where improved cover can be achieved with lower volumes, but high velocity fans have caused injury to foliage in some conditions, e.g. temporarily reduced tractor speed.

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

02004 *Chemical and cultural control and economic importance of strawberry red core*

Chemical control

In a trial started in 1977 there was a significant increase in yield from all plants which had received annual applications of fungicides. Plants sprayed each autumn with LS 74783 following a pre-plant root soak were the highest yielding, but the difference between this treatment and an annual soil drench with dichlofluanid was non-significant. The yield from plants which had received the pre-plant root soak alone in the establishment year and an autumn and spring foliar spray in the second year was similar to that from plants receiving annual soil drenches of SN 66752. In adjacent disease assessment plots which had been re-planted in April, 1978, and examined 12 months later, there was a significant decrease in disease severity in all treated plants. The treatment giving the best disease control was the pre-plant root soak followed by an annual foliar spray with LS 74783.

The efficacy of soil drenches of metalaxyl was compared with that of foliar sprays of LS 74783 applied at different times in the autumn following spring-planting. One year later the disease severity recorded in roots of all treated plants was significantly less than in untreated ones. When fungicides were appplied in September, October or November or September and March the metalaxyl soil drench was more effective than LS 74783 applied

[1] Zoology Section.

as a foliar spray. There was no significant difference between fungicides when applications were made in December. Single soil drenches of metalaxyl were equally effective when appplication was made in September, October or November and no disease was recorded following a two drench treatment in September and March. Single foliar sprays of LS 74783 were equally effective when applied in September, October, November or December, but a two spray treatment in September and March was more effective than the single spray applied in December.

In the third fruiting year of a trial planted in spring, 1976, all treated plants yielded more than untreated ones. These differences were significant at the 5% level except when etridiazole had been applied as a soil drench at 0·2% in the first 2 years and 0·12% in the third. Yields from plants drenched annually with either LS 731038 or LS 74783 were significantly higher than any others.

There was no significant difference in yield from plants receiving an annual foliar spray of LS 731038 or an annual soil drench of captafol. Adjacent disease assessment plots replanted with healthy runners in spring 1978 were evaluated 1 year later. The only treatments which resulted in significant decreases in disease severity were a soil drench with captafol or one with LS 74783, captafol giving significantly better control than LS 74783.

In a pot experiment, the effectiveness of a drench of captafol (0·3g/plant) or dichlofluanid (0·9 g/plant) in preventing or decreasing disease was evaluated when the compost (JI) was drip irrigated for 7 hours daily. Plants were inoculated with zoospores at intervals of 1, 15, 29, 43, 64, 85 and 106 days after fungicide application and disease recorded 14 days later. No infections occurred 15 days after captafol and 43 days after dichlofluanid treatments and both were equally effective in decreasing disease severity 106 days after application. In another experiment the number of diseased roots was similar (96-100%) when untreated plants were inoculated with zoospores and incubated for 14 days in compost receiving 0·05, 0·2 or 4 l water daily. Plants in compost drenched with captafol (0·3 g/plant) or LS 74783 (0·45 g a.i./plant) 3 days before inoculation had 0-4% diseased roots irrespective of the level of watering. Plants in compost drenched with metalaxyl (0·045 g/plant) showed no disease at the lower levels of watering and although 82% of roots were infected at the highest level, only 18% of the total root length was diseased compared to 100% in untreated plants. When the experiment was repeated, zoospores were added 3 and 17 days after fungicide drenches and incubation increased to 35 days. Whereas at the lowest level of watering 0-0·2% of the total root length was diseased in all treated plants, at the highest level of watering differences in diease severity were significant between all tratments and varied from 2% (LS 74783) and 42% (captafol) to 76% (metalaxyl). The efficacy of pre-plant root soaks for 4 hours in LS 74783 (0·3% a.i.) and in

metalaxyl (0·03%) were compared when plants, inoculated 3 and 17 days after treatment, were watered at a rate of 0·3 l/day for 35 days. There was no significant difference between treated plants which had 2% and 3% respectively of their total root length diseased compared to 81% in untreated ones.

Experiments on the effect of four systemic fungicides on zoospores *in vitro* showed that germination was most sensitive to water containing metalaxyl, 100 ppm preventing any germination and 10 ppm decreasing germination from 80 to 2%. In water containing LS 74783, 100 ppm a.i. decreased germination to 2% and 10 ppm a.i. to 29%. Neither compound had any effect at 1 ppm a.i. and LS 731038 and SN 66752 had no effect at any of the concentrations tested.

Diseased plants lifted in January, dipped in 0·16% thiram to control storage rotting and stored at −1°C for 5·5 months transmitted the disease to healthy plants as effectively as diseased plants lifted from the field in June.

(I. G. Montgomerie, D. M. Kennedy)

Biological control

Seventeen actinomycete isolates were added separately to peat/sand mixtures containing young plants of *Fragaria vesca*. Measurements of the rate of spread of disease incited by zoospores of *P. fragariae* indicated that none of the antagonists had a suppressive effect.

(I. G. Montgomerie, D. M. Kennedy)

Physical control

To determine whether *P. fragariae* could be eradicated from soil by heat treatment, soil naturally infested or infested with oospores or comminuted mycelium was heat-treated for 10 min with steam/air mixtures adjusted to give different temperatures; its infectivity was then assessed by bait tests. In addition, oospores were placed within sandwiches of monofilament nylon cloth which were also buried in the soil and similarly treated; after recovery the oospores were surface sterilised in dilute $HgCl_2$ washed and tested for germinability (Ann. Rept 1978, p. 75). In one experiment, treatment at 54°C for 10 min sufficed to eliminate the infectivity of all soil samples, but in a duplicate experiment it did not indicating technical difficulties either in uniform distribution of the steam/air mixtures or in monitoring their temperatures.

When temperature regimes were closely controlled using small volumes of soil in culture tubes held in a water bath for 10 min, oospore viability was unaffected at temperatures at or below 42°C, but it was reduced to 77 and 60% of the control at 42 and 45°C respectively; at 48°C all oospores

were killed. Compared to the controls, significantly fewer of the oospores germinated than had appeared viable and germinable after treatment at 45°C.

(J. M. Duncan)

Crop rotation and soil inoculum levels

In the spring of 1978 an area of Midloan field naturally infested with *P. fragariae* was divided into 32 plots each $2{\cdot}4 \times 3{\cdot}14$ m which were then planted with alpine strawberries (cv. Baron Solemacher) or sown with barley or peas, or left fallow. Soil samples were taken before planting and also after harvesting in November, 1978, and assessed for infectivity using bait plants. The fungus was detected on most occasions in most plots. Although infectivity fluctuated from one sampling date to the next, the levels were generally higher in those plots where strawberries had been grown and there were little differences among the other treatments. The plots were replanted with the same crops in 1979 for further observations.

(J. M. Duncan)

Detection of red core in planting stocks

In an attempt to measure the sensitivity of the root-tip bait test for detecting red core in planting stocks (Ann. Rept 1978, p. 93), tests were carried out with uninfected strawberry root-tips to which known numbers of infected root-tips had been added. The test proved to be highly effective in detecting infection. In one trial the disease was detected in samples prepared from 99 uninfected and 1 infected root system on 10 occasions out of 10 trials. The test was still positive in 5 out of 8 trials when older infected material was used.

(J. M. Duncan)

02016 *Chemical and cultural control of potato gangrene*

The effect of harvest date

The effects of harvest dates on the incidence of gangrene in potatoes stored over winter at 3°C was similar to that in 1975 and 1977 confirming the established patterns of high levels in prematurely harvested tubers then a decrease in incidence in early harvested tubers followed by a sharp rise after late harvests. The incidence in 1978 for all harvests was higher than that of 1975 and 1977 and the final increase occurred earlier, but was more gradual. As all handling and storage conditions were standard, the higher incidence reflects a seasonal influence on latent infection at harvest. In 1978 the dry soil conditions in May and June promoted lesion spread on and in the mother tubers and the below average soil temperatures throughout the growing season favoured survival of the pathogen in soil.

Effect of haulm desiccation

Tubers were harvested on three successive dates at 10 day intervals following haulm kill by desiccant herbicide in mid-August and at the end of September, and gangrene incidence was assessed after over-winter storage. The trends were similar to that in tubers from untreated plots harvested on the same dates except that the incidence was somewhat lower, particularly in the first harvest following haulm destruction. The earlier skin set induced by haulm desiccation may so reduce wound damage during harvest and grading as to more than offset the effects of any increase in inoculum released by the dying haulm and root system. In the three seasons 1975-77 gangrene incidence was similarly reduced in the harvests following early haulm destruction; harvests from later dates of haulm destruction had the same or slightly higher levels of gangrene incidence compared to those from untreated plot. Differences in skin set following later dates of haulm destruction may be small, but the inoculum from the haulm may be more important. Environmental conditions may not only affect inoculum viability directly, but may also influence the amount derived from the dying parts because of secondary effects on the efficiency of the action of the desiccant. In 1978, results from periderm tests showed that surface populations of the pathogen in harvests following haulm destruction were in some cases lower than those in the corresponding controls although the induced gangrene score was similar.

Effect of storage temperature

The influence of storage conditions on gangrene incidence was again very pronounced. Whereas the incidence in tubers stored at ambient temperatures in a straw bale store did not exceed 1%, except for the two last harvests when they were ca 6%, the incidence under controlled storage conditions at 3°C ranged from 10-16% at early harvests rising to 23-30% in the late harvests. The differences in results cannot be attributed to differences in temperature over most of the storage period and there must have been major effects of early higher temperatures in the bale store. The winter temperatures of 1978-79 were well below average and recording showed that air temperature in the bale store remained similar to or below that of the constant temperature store from the end of November to March; for an 8 week period in the early part of 1979 the ambient temperature in store never exceeded 1°C, i.e. on average 2°C lower than that of the controlled store. Although the differences in incidence between the two stores may be attributed to the higher earlier ambient temperatures in the bale store promoting the healing of harvest wounds, the results suggest that further experiments should be done to determine the effects of near freezing temperature on lesion extension.

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

02020 *Development of histological and histochemical methods*

Specimens embedded in glycol methacrylate can be stained by a wide range of histochemical reagents for high resolution light microscopy. One disadvantage has been that methacrylic acid, which contaminates the resins from most suppliers, binds some basic dyes preferentially and restricts their use for staining biological specimens. The methacrylic acid contaminant is now extracted by Amberlyst A-21 ion-exchange resin and the purified resin stored at −18°C before use. Further refinements have been introduced to improve sectioning, e.g. sections are cut on tungsten-coated glass knives and collected on 10% ethanol for mounting on slides. These techniques also reduce electrostatic charges, a major disadvantage of dry-sectioning methods which often results in loss of sections.

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

[1] Zoology Section.

VIROLOGY

B. D. HARRISON

In contrast to many recent years, 1979 did not see the adoption of any major new technique in our research on plant viruses. Instead it was a year in which recently introduced techniques were used to provide information of new kinds. For example, experiments with DNA complementary in nucleotide sequence to virus RNA provided the first evidence that the larger piece of the genome of a nepovirus can replicate without the aid of the smaller piece; immunosorbent electron microscopy gave evidence that potato leafroll virus is serologically related to several luteoviruses; and enzyme-linked immunosorbent assay was used to check virus-tested narcissus stocks for freedom from narcissus mosaic and narcissus tip necrosis viruses, and was applied to the detection of potato leafroll virus in potato foliage and tubers. The research involving enzyme-linked immunosorbent assay was aided by an equipment grant from the Potato Marketing Board for the purchase of a recording colorimeter.

Work on potato viruses was intensified somewhat during the year, work on viruses of other crop plants studied extensively in previous years was maintained, and many new findings are recorded in subsequent sections of this report. Particularly worth noting are the studies on the inheritance of reaction of raspberry to viruses (see Plant Breeding Section report), the purification and use in serological tests of the geographically widely disseminated carrot redleaf virus, the detection of virus particles by immunosorbent electron microscopy in extracts of single virus-carrying nematodes, and the planting in the field of the first ½-tonne of virus-tested narcissus bulbs.

TOBRAVIRUSES

04002 *Viruses with nematode vectors and/or multipartite genomes*

Genomes of strains of tobacco rattle virus (TRV)

Results reported last year of hybridization analysis using complementary DNA copies of the RNA species of TRV strain ORE-Y suggested that the culture contains two kinds of RNA-2 molecule of similar size, in addition to RNA-1. The two RNA-2 species were resolved by electrophoresis at

60°C in 2·1% polyacrylamide gels in the presence of 8 M urea, and estimated to have mol. wt. of $1 \cdot 10 \times 10^6$ and $1 \cdot 15 \times 10^6$. The origin of these two species is still uncertain, but they have both been in our stocks of strain ORE-Y at least since 1972.

No homology was detected between the RNA-1 molecules of strain ORE-Y and the distantly related strain CAM. Therefore if there are any conserved sequences common to RNA-1 of all strains of TRV, they must be short, and certainly less than 200 bases in total.

(D. J. Robinson)

The spinach yellow mottle (SYM) strain of TRV produces particles of four modal lengths containing RNA species with mol. wt. ($\times 10^{-6}$) of 2·4, 1·4, 0·7 and 0·6, respectively. Complementary DNA copies were prepared from each of the two largest RNA species and from a mixture of the two smallest ones. The $1 \cdot 4 \times 10^6$ dalton species of this strain is twice as large as the RNA-2 of strain CAM, and hybridization experiments showed that it has twice the sequence complexity. Thus the wide variation in size of RNA-2 molecules among TRV strains is not necessarily the result of varying degrees of internal repitition.

As with strain ORE-Y, no homology was detected between RNA-1 and RNA-2 of strain SYM, in contrast to the common sequence of about 500 bases previously reported in strain CAM. Such common sequences are not therefore an essential feature of TRV strains. The mixture of the two smallest RNA species of strain SYM apparently consists largely of specific sequences from both RNA-1 and RNA-2. The origin and function of these species is the subject of continuing work.

(D. J. Robinson, A. T. Jones)

Strain SYM has the distinctive property, among TRV strains, of consistently invading *Chenopodium amaranticolor* plants systemically. However, this did not happen with infections initiated either by RNA-1-containing particles only, or by pseudo-recombinant isolates containing RNA-1 of strain SYM and RNA-2 of strain PRN. In contrast, pseudo-recombinants containing RNA-1 of strain PRN and RNA-2 of strain SYM became systemic in *C. amaranticolor*, indicating that the determinant for this property is in RNA-2.

(B. D. Harrison, A. T. Jones, A. Kurppa)

04002 *Viruses with nematode vectors and/or multipartite genomes*

Protein linked to nepovirus RNA

The discovery of a small protein needed for infectivity and covalently attached to tobacco ringspot virus (TRSV) RNA was described in last year's report. In further work, evidence was obtained for a similar protein attached to the RNA of raspberry ringspot (RRV), tomato black ring (TBRV) and strawberry latent ringspot viruses.

Chemical characterisation of these proteins was made difficult by the heterogeneity of preparations obtained by digesting nepovirus RNA with ribonuclease. For example, thin layer chromatography of ^{125}I-labelled protein usually resulted in three to five radioactive spots, and this heterogeneity was still observed when the concentrations of the labelling reagents were decreased or when Iodogen (see p. 108) was used in place of chloramine T. Despite this heterogeneity, evidence was obtained that the genome-linked proteins of RRV, TRSV and TBRV are virus specific. They could be distinguished by electrophoresis in 20% polyacrylamide gels and they yielded different radioactive peptides when treated either with trypsin or with V8 protease from *Staphylococcus aureus*. In contrast, no difference was found between the genome-linked proteins of TRSV grown in either *Nicotiana clevelandii* or cucumber, in those of different strains of RRV or of TBRV, or in those attached to RNA-1, RNA-2 or satellite RNA of TBRV. The genome-linked proteins of nepoviruses probably are virus-coded.

In experiments to ascertain whether this novel structural feature occurs in a range of plant virus groups, no evidence was obtained for a protein linked to RNA of tobacco mosaic, tobacco rattle or tomato bushy stunt viruses. A protein was found attached to RNA of Echtes Ackerbohnen-mosaik-Virus and turnip rosette virus. A genome-linked protein therefore seems to be characteristic, but not diagnostic, of nepoviruses.

(M. A. Mayo, H. Barker)

Replication of nepovirus RNA-1 without the aid of RNA-2

Complementary DNA (cDNA) copies of the two separated parts of the RNA genome of tomato black ring virus (TBRV, A strain) have been prepared. In hybridization experiments between these copies and the genome RNA species, no sequences common to the two parts of the genome were detected.

The cDNA copies were used to detect and measure virus RNA sequences in extracts from isolated *Nicotiana tabacum* or *N. benthamiana* mesophyll protoplasts. Less than 1% of the protoplasts contained virus

particle antigen, detected by staining with fluorescent antibody, 48 h after inoculation with either middle or bottom component nucleoprotein particles alone, whereas 80% or more of the protoplasts contained antigen following inoculation with a mixture of the two nucleoprotein components. Analysis of RNA extracts using cDNA showed that RNA-1 sequences had been replicated in protoplasts inoculated with bottom component particles only. Assuming that 80% of the protoplasts were infected by bottom component particles, each infected protoplast at 24 h after inoculation contained an average of about 7×10^4 copies of RNA-1. This compares with about 6×10^4 copies of RNA-1 and 11×10^4 copies of RNA-2 per infected protoplast inoculated with both TBRV nucleoprotein components. By 48 h after inoculation however, protoplasts inoculated with both components contained an average of more than 2×10^5 copies of RNA-1, whereas no further increase had taken place in protoplasts inoculated with bottom component only. Tests on protoplasts inoculated only with middle component particles gave no evidence for independent replication of RNA-2.

In parallel experiments, inoculated protoplasts were incubated in media containing ^{3}H-uridine, and labelled RNA was extracted and analyzed by electrophoresis in polyacrylamide gels. After incubation, protoplasts inoculated only with bottom component particles contained labelled RNA corresponding in size to RNA-1, those inoculated only with middle component contained neither RNA-1 nor RNA-2, and those inoculated with both components contained both RNA-1 and RNA-2. When the labelling period was from 1 to 19 h after inoculation, the RNA-1 zone from protoplasts inoculated only with bottom component was as heavily labelled as that from protoplasts inoculated with both components, but when labelling was from 19 to 44 h after inoculation, the zone from protoplasts inoculated only with bottom component was weakly labelled relative to that from protoplasts inoculated with both components.

The results of local-lesion infectivity assays in *Chenopodium amaranticolor* indicated that RNA extracted from protoplasts inoculated 24 h earlier with both middle and bottom component particles was very infective, but RNA from protoplasts inoculated with either middle or bottom component particles alone did not induce lesions. However, RNA from protoplasts inoculated with bottom component alone became able to produce lesions when middle component particles were added to it. Adding bottom component particles had no effect, and nor did adding either middle or bottom component particles to RNA extracted from protoplasts inoculated with middle component alone. The amount of biologically active RNA-1, detected in this way in extracts of protoplasts inoculated with bottom component alone, decreased slightly between 24 and 48 h after inoculation. In contrast, the amount of TBRV RNA capable of inducing local lesions increased about four-fold between 24 and 48 h after inoculation of protoplasts with a mixture of middle and bottom components.

Taken together these results show unequivocally that TBRV RNA-1 can replicate without the aid of RNA-2, and suggest that RNA-1 may code for a virus replicase or replicase sub-unit. Also, because the genome-linked protein of TBRV is needed for lesion production and is apparently virus-coded, RNA-1 must contain the nucleotide sequence coding for this protein. Further work is needed to determine whether the genome-linked protein itself is the hypothetical virus replicase or replicase sub-unit.

(D. J. Robinson, H. Barker, B. D. Harrison, M. A. Mayo)

Temperature-sensitive mutants of tomato black ring virus

Seven nitrous-acid mutants with temperature-sensitive behaviour determined by RNA-1 were studied. At 28°C, they produced no symptoms in *Chenopodium amaranticolor* plants, and no infective virus nucleoprotein or RNA was detected in extracts prepared from leaves 7-10 days after they were inoculated. In contrast, the wild-type isolate multiplied readily at 28°C, and produced symptoms in inoculated leaves.

The seven mutants could be distinguished from each other, and from a previously reported temperature-sensitive RNA-1 mutant, by a combination of several properties: type of local lesions produced in *C. amaranticolor*, ratio of bottom to middle component in purified preparations of virus particles, frequency and type of revertants arising in cultures, and ratio of amount of virus produced in tobacco mesophyll protoplasts at 26°C to that produced at 20°C. However, as compared with the wild-type isolate, the mutants tended to produce lesions of a more chlorotic type, had a decreased relative amount of bottom component particles, and they replicated less efficiently or not at all in protoplasts at 26°C. With some of the mutants, and with the wild-type isolate, the ratio of amount of bottom to middle component was not greatly affected by the temperature at which source plants were kept, but with other mutants this ratio was more abnormal at 20-24°C than at 15-17°C.

Purified preparations of the particles of some mutants contained small amounts of previously unidentified RNA species in addition to RNA-1 and RNA-2. The new species were obtained from particles sedimenting in sucrose density gradients less rapidly than middle component. Up to four ultraviolet-absorbing bands were detected by electrophoresis in polyacrylamide gel; they stained with toluidine blue, and were not evident in preparations previously treated with ribonuclease A in 0·015 M sodium chloride + 0·0015 M sodium citrate, suggesting that they represent single-stranded RNA. These electrophoretic components had the mobilities expected of single-stranded RNA molecules of about 150,000, 250,000, 400,000 and 900,000 daltons.

A nitrous-acid mutant (M17) with temperature-sensitive behaviour determined by RNA-2 was also studied. At 20°C it produced symptoms

in plants indistinguishable from those of the wild-type isolate, and yields of infective virus particles were similar; in contrast, at 26°C in leaves of tobacco it produced less than 0·2% of the infective nucleoprotein particles produced by the wild-type isolate. The infectivity of extracts of leaves kept at 20°C was inactivated at a lower temperature than that needed for inactivation of the wild-type isolate or the mutant RNA-1 isolates, and purified preparations of M17 particles contained an abnormally small proportion of middle component and of RNA-2. These observations suggest that isolate M17 has an altered coat protein and/or an altered RNA-2 replication or packaging mechanism; however, isolate M17 was serologically indistinguishable from the wild-type isolate in gel-diffusion tests with purified virus particles.

A further difference between isolate M17 and the mutant RNA-1 isolates was found in temperature-shift experiments in which tobacco mesophyll protoplasts were kept at 20°C for the first 15 h after inoculation and thereafter at 26°C. In these conditions only a trace of infective virus nucleoprotein was produced in protoplasts inoculated with isolate M17. In protoplasts inoculated with mutant RNA-1 isolates, a small amount of infective virus was produced in 15 h at 20°C and, after the protoplasts were transferred to 26°C, the virus continued to accumulate to a small extent and some of the protoplasts became stainable by fluorescent antibody to TBRV particles. Thus functions of the RNA-2 of mutant RNA-1 isolates were expressed at the non-permissive temperature once virus replication had been initiated at the permissive temperature.

(R. L. S. Forster, B. D. Harrison)

Apparent complementation between isolates of tomato black ring virus with mutant RNA-1

Pseudo-recombinant isolates were produced by mixing the middle or bottom component of each mutant RNA-1 isolate with the bottom or middle component of the wild-type isolate. The behaviour of these pseudo-recombinants indicated that all the temperature-sensitive defects were coded by RNA-1. This conclusion was also supported by supplementation tests in which middle or bottom component particles of the wild-type isolate were added to inocula of each mutant.

Complementation tests were made by inoculating *C. amaranticolor* plants with pairs of RNA-1 mutants, and keeping the plants at 26°C for 5 days and thereafter at 20°C. In these conditions some of the pairs of mutants produced lesions, but none of the mutants did so on their own. For example, lesions were produced in some, but not all tests in which isolate 1107 was inoculated together with isolate 1040 or isolate 1078.

Further evidence was obtained in experiments with tobacco protoplasts kept at 20 or 26°C for 2 days after inoculation. For example, in one

test mutants 1078 and 1107 on their own produced no infective nucleoprotein in protoplasts at 26°C and none of the protoplasts stained with fluorescent antibody to TBRV particles, whereas a mixture of the two produced about a fifth of the virus yielded by protoplasts inoculated with the wild-type isolate, and 22% of the mixedly inoculated protoplasts stained with the fluorescent antibody. The virus produced in these mixedly infected protoplasts retained the temperature-sensitive behaviour of the mutants. Although these results indicate that genetic complementation occurs, the phenomenon was not observed in all experiments and some condition critical for its expression has yet to be identified.

(R. L. S. Forster, B. D. Harrison)

Cross-protection between strains of raspberry ringspot virus

Two kinds of experiment were made to study the behaviour of strains of raspberry ringspot virus inoculated to *Nicotiana benthamiana* cells already infected with another isolate of the same virus. In the first kind of test, 'recovered' systemically infected leaves were used as sources of protoplasts, which were inoculated *in vitro* with the challenge isolate, incubated, and stained with fluorescent antibody specific for the challenge virus. In the second kind of experiment, intact recovered leaves were inoculated with the challenge virus, and protoplasts were prepared and stained at intervals afterwards. No additional symptoms developed in the leaves in this type of test.

In both kinds of test, many cells or protoplasts that initially were infected with strain S were able to support the synthesis of strain E particle antigen, but far fewer of the cells or protoplasts intially infected with strain E supported the synthesis of strain S antigen. Little difference was found in the amount of ^{125}I-labelled virus bound by protoplasts from healthy, strain E-infected or strain S-infected plants when they were inoculated with either strain of the virus. Thus the difference in protection conferred by the two virus strains seems not to be related to the amount of inoculum bound to inoculated protoplasts.

In further tests, pseudo-recombinant isolates prepared from strains E and S proved able to multiply in cells already infected with the heterologous pseudo-recombinant. Thus the challenge virus multiplied when both parts of its genome differed from those of the protecting virus.

(H. Barker, B. D. Harrison)

Properties of cherry leaf roll virus

To ascertain which genetic determinants for biological properties can be assigned to the two parts of the genome, pseudo-recombinant isolates were produced by exchanging the middle (M) and bottom (B) nucleoprotein components of virus strains from elderberry and rhubarb. The infectivity

of the pseudo-recombinants in *Nicotiana clevelandii* sap was lost on storage at 18°C sooner than that of the parent isolates. Component B (containing RNA-1) was found to determine lesion type and severity of systemic symptoms in Chenopodium and Nicotiana spp. However, virulence also depended on the interaction of components M and B, in such a way that neither pseudo-recombinant caused such severe symptoms as the parent providing component B. The results of tests in tobacco indicated that the plant-protection phenomenon involves determinants carried in both nucleoprotein components of either the protecting or the challenge isolate.

(A. T. Jones)

Serological tests in which mixtures of virus particles with antiserum were examined in the electron microscope showed that the elderberry and dogwood strains of cherry leaf roll virus were unrelated to any of four other viruses with similar properties: Australian lucerne latent, grapevine Bulgarian latent, peach rosette mosaic and tomato ringspot viruses.

(A. T. Jones, G. H. Duncan)

Tomato black ring virus satellite RNA

Satellite RNA was found in two out of nine isolates of the Scottish serotype of TBRV and in four out of five isolates of the German serotype. However, it is not clear to what extent the presence of satellite RNA depended on the species from which the virus was originally obtained or on the herbaceous hosts in which it was later maintained in the glasshouse. Cultures of TBRV-S, the stock culture of the Scottish (beet ringspot) serotype and TBRV-G, the type culture of the German (potato bouquet) serotype, each with and without satellite RNA, were inoculated to a broad range of standard herbaceous test plants. No host was found which would reliably indicate the presence or absence of satellite RNA, although isolates of both serotypes lacking satellite RNA tended to induce bright yellow lesions in inoculated leaves of *Petunia hybrida*, whereas isolates containing satellite RNA usually did not.

Satellite RNA associated with both serotypes occurred in equal or greater concentration in inoculated leaves than in systemically infected leaves of *Chenopodium quinoa, Nicotiana clevelandii* and *Petunia hybrida.* In both kinds of leaf of *N. clevelandii* and *P. hybrida* the amount of RNA-1 or B component exceeded that of RNA-2 or M component, but the reverse was true in *C. quinoa.* In none of the three species was the ratio of RNA-1/RNA-2 or that of B/M component affected by the presence of satellite RNA. In *Chenopodium amaranticolor* and *C. quinoa* the amount of satellite RNA was small in inoculated leaves and very small in systemically infected leaves. Satellite RNA was sometimes eliminated from a culture by passage through systemically infected leaves of *C. amaranticolor,*

but was still present in a culture of TBRV-G after 13 passages through systemically infected leaves of *C. quinoa*.

TBRV-S did not support multiplication of satellite RNA from TBRV-G nor did TBRV-G support multiplication of satellite RNA from TBRV-S although both isolates supported multiplication of their homologous satellite RNA. This result complements the previous finding that each satellite RNA specifies a different *in vitro* translation product and therefore presumably has a different nucleotide sequence.

(R. I. Hamilton, A. F. Murant)

Particles of satellite-free isolates of TBRV-S form three sedimenting components with sedimentation coefficients and buoyant densities in CsCl as follows: (T) 55 *S*, $\rho = 1{\cdot}285$ g/cm^3; (M) 97 *S*, $\rho = 1{\cdot}44$ g/cm^3; (B) 121 *S*, $\rho = 1{\cdot}50$ g/cm^3. Particles of satellite-containing isolates of TBRV-S form several additional sedimenting components whose sedimentation coefficients and buoyant densities are: (T′) *ca.* 67 *S*, $\rho = 1{\cdot}34$ g/cm^3; (T″) *ca.* 80 *S*, $\rho = 1{\cdot}385$ g/cm^3; (T‴) sedimentation coefficient not determined, but probably *ca.* 93 *S*, $\rho = 1{\cdot}43$ g/cm^3; and (M′) *ca.* 110 *S*, $\rho = 1{\cdot}47$ g/cm^3. These additional components form a series increasing in buoyant density by increments of about 0·045 g/cm^3. Preparations of separated T′, T″, M, M′ and B components of the satellite-containing isolate were made by centrifugation in sucrose density gradients followed by equilibrium banding in CsCl. Preparations of M component contained only RNA-2, but those of B component contained all three RNA species. Preparations of T′, T″ and M′ components contained satellite RNA and those of M′ also contained RNA-2. The properties of T′, T″, T‴ and M′ components suggest that they contain respectively one, two, three and four molecules of satellite RNA. It is not clear whether the presence of RNA-2 in preparations of M′ component results from contamination with M component, and that of both RNA-2 and satellite RNA in preparations of B component results from contamination with M and M′ components, or from the presence of particles containing one molecule of RNA-2 and respectively either one or two molecules of satellite RNA.

(A. F. Murant, J. H. Raschké)

Detection of nepovirus particles in nematode extracts by electron microscope serology

Particles of six nepoviruses were detected in extracts of their respective nematode vectors by immunosorbent electron microscopy (ISEM), which was at least one thousand times more sensitive than conventional electron microscopy. Nematodes were extracted from soil after *ca.* 4 wk access to virus-infected source plants, then were transferred to plastic microanalysis tubes and comminuted using the "micro-mortar" extraction

technique (see p. 109). Single nematodes were extracted in 15 μl medium and groups of five or more nematodes were extracted in 5 μl medium/nematode; 5-10 μl of these extracts was then used for ISEM.

ISEM detected virus particles in >90% of the extracts of Longidorus nematodes and in 70% of those of Xiphinema nematodes. The slash test, by comparison, detected virus in only 50% of the extracts of Longidorus nematodes, and in none of those of Xiphinema nematodes. With each virus/vector combination there were considerable differences in the numbers of virus particles detected in extracts of replicate single nematodes or groups of five. The greatest number of virus particles recorded was from a single *Longidorus macrosoma* carrying raspberry ringspot virus (27 particles/μm^2 grid area), and the fewest from a single *Xiphinema diversicaudatum* carrying arabis mosaic virus (4/1,000 μm^2).

The ISEM technique is more sensitive, more reliable and quicker than other methods of detecting virus particles in nematode extracts. It was also used to estimate the amounts of virus in the roots of virus source and bait plants, and offers many advantages for a range of virus-vector studies.

(I. M. Roberts, D. J. F. Brown[1])

VIRUSES OF FLOWER BULBS

04010 *Viruses infecting bulbous ornamentals*

Tulip virus X (TVX)

In the year following manual inoculation with TVX, tulip plants of cultivars Paul Richter, Crimson Rambler and Merry Widow developed chlorotic flecks and eliptical markings on leaves resembling those in naturally infected plants. Petal symptoms were most obvious in Paul Richter and consisted of streaks of intensified pigmentation, resembling somewhat those caused by lily symptomless virus.

Analytical centrifugation of infective sap and of purified preparations of particles of each of two single-lesion isolates of the virus revealed two components of about 100 *S* and 118 *S*. Although this raises the possibility that cultures may contain a mixture of two viruses, only one peak (modal length 487 nm) was apparent in particle-length distributions of virus particles, and only one polypeptide species and one nucleic acid species detectable by polyacrylamide gel electrophoresis were obtained from purified virus particles.

(W. P. Mowat)

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[1] Zoology Section.

Virus spread in narcissus

In a continuation of the series of trials to study the spread of narcissus yellow stripe virus in the field during a 1-year period, plots were planted in 1978 at Portmahomack, at Kirton EHS and at SHRI. The incidence of yellow stripe at planting was 7% and the incidences after 1 year at the three sites were 9%, 8% and 20% respectively. The larger increase recorded at SHRI may reflect virus spread occurring late in the season because plants in these plots were allowed to senesce naturally *in situ* and not lifted in July as is the normal practice. Further work is in progress to test this possibility.

In a field trial on the spread of narcissus mosaic and narcissus tip necrosis viruses, narcissus infector plants were grown in a plot of virus-tested plants of cv. Sempre Avanti, but no virus spread was detected after two growing seasons. These two viruses therefore seem unlikely to cause difficulties in maintaining the health of virus-tested stocks in the field.

(W. P. Mowat)

Control of the field spread of non-persistent aphid-borne viruses in lilies

An experiment in 1976 showed that polyethylene windbreak screens (Rokolene) at 30 cm spacing were as effective as barriers of barley plants in preventing virus spread. In 1979 the effect of Rokolene barriers at 76 cm spacing was compared with that of a weekly spray of 1% emulsion of Albolineum oil, the treatments being tested separately and combined. Of the 40 bait plants in each treatment, none became infected in plots sprayed with oil emulsion alone, none in sprayed plots with Rokolene barries, five in plots with barriers alone and six in untreated plots. Thus at this wider spacing Rokolene barriers did not prevent virus spread and, because 76 cm is about the smallest spacing that could be used by growers, this method is not a practical alternative to spraying with oil emulsions even when the amount of spread is as small as that in the experiment.

(W. P. Mowat, J. A. T. Woodford[1])

04011 *Production of virus-tested bulb stocks*

Propagation of virus-tested narcissus

The fourth annual batch of virus-tested clones multiplied at SHRI from mother bulbs by one cycle of twin-scaling, and weighing 25 kg, was released in August to ESCA and NSCA for further multiplication. This issue consisted of two clones of cv. Carlton, one of cv. Sempre Avanti, three of cv. Barrett Browning and six of cv. Verger.

(W. P. Mowat, J. Chambers)

[1] Zoology Section.

The main problem in propogating bulbs by the twin-scale method results from dormancy in the first year. Not only is the increase in bulb weight lessened, but also many of the dormant bulbils are so small that they are not recovered for transplanting at the end of the year. However, in tests with Carlton it was found that survival of twin-scales and bulbil formation were not adversely affected by incubation for 16 wk at 23°C, and 80% of the bulbils emerged later, compared with 52% of those formed after incubation for the standard period of 12 wk at 23°C. If these results are confirmed, the way would seem clear for the twin-scaling method to be taken up for routine use by nuclear stock organizations.

(J. Chambers, W. P. Mowat)

Virus-indexing of virus-tested clones

About 22,000 plants of clones of the cultivars Carlton and Sempre Avanti multiplied by ESCA and NSCA were released to the Scottish Nuclear Stocks Association (Flower Bulbs) Ltd. for field propagation. Because the mode of spread of narcissus mosaic and narcissus tip necrosis viruses is unknown and infected plants may not show obvious symptoms, leaf samples from about 8% of the plants were tested for these viruses by enzyme-linked immunosorbent assay in groups of 26-30. No infection was found.

(W. P. Mowat)

Selection of sites for narcissus propagation

In co-operation with NSCA and DAFS Scientific Services, several possible sites were tested for freedom from nematode-transmitted viruses and their vectors, and a site was selected for the field propagation of virus-tested clones in 1979. As an insurance, soil at the selected site was treated with the nematicide Telone II and the effect on the nematode population was assessed.

A site infested both with longidorid nematodes, and with trichodorid nematodes carrying tobacco rattle virus, was also fumigated with Telone II. Half the area was fallowed after treatment and the other half was cropped with barley to test the effect of these practices on re-infestation by nematode vectors and soil infectivity (see Zoology Section report).

(W. P. Mowat, T. Alphey[1])

[1] Zoology Section.

04003 *Viruses infecting raspberry*

Effects of four aphid-borne viruses latent in raspberry

Further results from this field experiment involving the *Amphorophora idaei*-resistant genotypes cv. Malling Leo, cv. Malling Orion and selection 20/54 infected with four aphid-borne viruses, confirmed and extended last year's findings. Thus, there was no great difference in the total length of cane produced by infected and healthy plants, but mean cane length was less in virus-infected than healthy plants, particularly in Malling Leo. However, the potential fruiting advantage of the longer healthy canes was lost by tipping all cane at 1·5 m. Consequently, no significant effect of virus infection on total fruit yield was detected in any of the genotypes. However, in Malling Leo the mean weight of berries was decreased by infection and berry number was increased, largely because the number of fruiting canes was increased. Also, fruit on virus-infected Malling Leo plants ripened 3 to 4 days earlier than that on control plants.

(A. T. Jones)

Records of sap-transmissible viruses in Rubus plants

A single plant of *A. idaei*-resistant raspberry selection 20/54 showing ringspot symptoms was found to be free of nepoviruses, but to contain cucumber mosaic virus. Plants of cv. Malling Leo grafted with scions from this plant also developed ringspot symptoms. The virus isolate was indistinguishable serologically from a cucumber mosaic virus isolate obtained from black currant plants imported from Holland. This is only the second report of this virus in raspberry.

In graft-inoculation tests of the susceptibility of Rubus genotypes to nepoviruses, raspberry ringspot virus infected Tayberry and tomato black ring virus infected Malling Leo. Natural infection with arabis mosaic virus was recorded in cv. Malling Jewel from Wales. Strawberry latent ringspot virus was obtained from cv. Glen Isla raspberry and from cv. Himalaya Giant blackberry naturally infected in England.

(A. T. Jones)

04004 *Production of virus-tested raspberry stocks*

During the year the system for virus indexing and propagation of Rubus was reviewed and where necessary reorganized to clarify and rationalize the procedures. Fifteen imported Rubus species and selections, six breeders' selections from EMRS and thirty-seven breeders' selections from SHRI were indexed for virus. Heat-labile latent viruses were eliminated from the red raspberry cv. Malling Joy by heat treatment, and a virus-tested stock was thus provided for propagation.

(A. T. Jones, J. G. Lindsay)

04007 *Viruses affecting umbelliferous crop plants*

Carrot red leaf virus

In host range tests, the virus infected carrot (*Daucus carota*), chervil (*Anthriscus cerefolium*), coriander (*Coriandrum sativum*), dill (*Anethum graviolens*), slender celery (*Apium leptophyllum*) and shepherd's needle (*Scandix pecten-veneris*), but did not infect six other umbelliferous or thirteen non-umbelliferous species. Partially purified preparations of virus particles were obtained by incubating extracts of infected chervil tissue overnight with Driselase, treating the digest with 1% Triton X-100, centrifuging it at low speed and recovering the virus from the supernatant fluid by sedimentation through 20% sucrose. After further differential centrifugation, yields of about 1 mg virus/kg infected leaf were obtained. The 30 nm diameter isometric virus particles have a sedimentation coefficient ($s_{20,w}$) of about 100 *S* and a buoyant density in CsCl of 1·40 g/cm³.

A rabbit, injected intradermally with *ca.* 50 μg virus on each of two occasions, yielded antiserum with a titre of 1/512 measured by double diffusion in agarose gels and of 1/4000 by electron microscopy or density gradient centrifugation of virus/antiserum mixtures. The virus was detected in sap from infected chervil leaves and in extracts from groups of five to ten virus-carrying aphids (*Cavariella aegopodii*) by enzyme-linked immunosorbent assay and by immunosorbent electron microscopy (ISEM). Analysis of virus/antiserum mixtures by density gradient centrifugation showed that carrot red leaf virus is distantly related to the following luteoviruses: barley yellow dwarf (RPV and MAV strains), beet western yellows, potato leafroll, soybean dwarf and tobacco necrotic dwarf. Relationships were also found by ISEM, but only the less distant ones were detected by electron microscopy of virus/antiserum mixtures. The density gradient technique was preferred to the other tests for determining the degree of relationship.

(P. M. Waterhouse, A. F. Murant)

Viruses from Heracleum sphondylium

Wild hogweed plants (*H. sphondylium*) commonly contain, in addition to parsnip yellow fleck and heracleum latent (HLV) viruses, several poorly characterized viruses, of which four, code-named HV3, HV4, HV5 and HV6, were reported previously. Of these, HV6 is of interest because it has very flexuous particles about 1500 nm long, similar to those of closteroviruses. Although transmitted by Cavariella spp. it was not transmitted by *Myzus persicae* and did not infect sugar beet or *Chenopodium capitatum*. It therefore differs from beet yellows virus in vector specificity and host

range and it did not react with antiserum to beet yellows virus in immunosorbent electron microscopy.

Aphids (Cavariella spp.) transmitted HLV from naturally infected hogweed plants, but not from those inoculated manually nor from carrot, celery, chervil, coriander, dill, parsley or *Cryptotaenia japonica* plants inoculated by means of aphids. These data suggest that aphid transmission of HLV may depend on a helper virus that infects hogweed, but not the other umbelliferous species tested. Attempts to separate and identify such a helper virus have so far been unsuccessful.

(A. F. Murant)

POTATO VIRUSES

04001 *Potato viruses, especially soil-borne viruses*

Detection of potato viruses by immunosorbent electron microscopy (ISEM)

The application of ISEM to the detection of potato leafroll virus (PLRV) was described in last year's report. In further work the technique was used to compare the virus content of aphid extracts prepared in phosphate buffer using ' micro-mortars " (see p. 109). Ten to thirty times more PLRV particles were found in extracts of virus-carrying *Myzus persicae* than in those of *Macrosiphum euphorbiae* when either groups of 10-20 aphids or single aphids were sampled. However, there were substantial differences between the numbers of PLRV particles obtained from different individuals of the same species.

ISEM was also used to detect potato mop-top virus in extracts of inoculated tobacco leaves, and of naturally infected potato tubers (cv. Arran Pilot) with symptoms of primary infection. The technique was at least a thousand times more sensitive than conventional electron microscopy. The particles that attached to the grids were of two predominant lengths, about 125 nm or about 290 nm, and the peaks in length-distribution diagrams were more clearly defined than those obtained by conventional electron microscopy of particles in purified preparations. ISEM therefore has special advantages in work with viruses, such as potato mop-top virus, which occur in low concentration and have fragile particles.

(I. M. Roberts, B. D. Harrison)

Detection of potato leafroll virus (PLRV) by enzyme-linked immunosorbent assay (ELISA)

Workers elsewhere have shown that ELISA can be used to detect PLRV in potato leaf and tuber tissue. The purpose of the research described here was to study the factors affecting the success of the method and to explore its applicability to the detection of PLRV in the foliage and tubers of field-grown plants with either primary or secondary infection.

Purified preparations of PLRV particles were obtained by the Driselase method of Takanami & Kubo (1979) from the foliage of both glasshouse-grown and field-grown potato plants; the yield was 0·6-1·0 mg virus/kg leaf tissue. Using this material as the immunogen, antisera with titres of 1/1000-1/2000 in gel-diffusion precipitin tests were readily obtained. One antiserum failed to react with virus-free potato leaf sap in gel-diffusion tests, and another reacted to an antiserum titre of 1/8. Using globulins from the first antiserum, PLRV at 10 ng/ml was detected consistently by ELISA. The reaction was slightly impaired when potato leaf extracts diluted less than 1/10 were added to the samples, but was unaffected by greater dilutions of leaf extract. Globulins from the second antiserum could be used satisfactorily for coating micro-titre plates, but were unsuitable for conjugating with enzyme.

The detection end-point of PLRV in leaf sap of potato cv. Cara plants grown from infected tubers in the glasshouse was about 1/100, and the virus was reliably detected in extracts of composite samples of one infected and fifteen virus-free leaves. It was detected in infected leaves of all twenty-seven cultivars tested. PLRV concentration was much less in extracts of roots or stolons than in leaf extracts.

PLRV was readily detectable 2 weeks before symptoms developed in field-grown plants of the cultivars Cara and Maris Piper with secondary infection and remained so for at least 5 weeks. Its concentration was slightly greater in old than in young leaves and was similar to that in glasshouse-grown plants. In field-grown plants of Maris Piper with primary infection, PLRV was detected in tip leaves 21-42 days after lower leaves were inoculated by aphids; in some shoots it later reached a concentration in tip leaves similar to that in leaves with secondary infection. Although symptoms of primary infection developed in the young leaves of some infected shoots, they were inconspicuous and were not observed until at least a week after PLRV was detected by ELISA.

In tests to detect PLRV in tubers of field-grown plants, the reaction of virus-free tuber extracts was minimized by pre-incubating the extracts at room temperature and by careful choice of the dilution of enzyme-conjugated globulin. Proceeding thus, PLRV was reliably detected in tubers produced by secondarily infected plants of all six cultivars tested. PLRV concentration was greater in heel-end than in rose-end vascular tissue of recently harvested tubers, but increased in rose-end tissue when tubers previously stored at 4°C for at least 5 months were placed at 15-24°C for 2 wk.

PLRV occurred at greater concentration in tubers from plants of Maris Piper with natural or experimentally-induced primary infection than in tubers from secondarily infected plants; again PLRV concentration was greater in heel-end than in rose-end vascular tissue. Plants whose shoots were infected earliest in the growing season were invaded systemically

and produced the greatest proportion of infected tubers; plants infected late in the season also produced infected tubers although PLRV was not detected in the tops of their shoots. PLRV concentration in tubers from the earliest-infected plants was less than in tubers from later-infected plants. The virus was detected reliably by ELISA in tubers from progenies that were totally infected, but was not detected in all infected tubers from partially infected progenies.

These results indicate that ELISA is suitable as a routine method of indexing potato foliage and tubers for PLRV, although the virus will not be detected in all infected tubers produced by plants to which it is transmitted late in the growing season.

(T. Tamada, B. D. Harrison)

Serological relationship of potato leafroll virus (PLRV) to luteoviruses

The affinities of PLRV have been the subject of some controversy because of early, but now discredited, claims that its particles contain DNA. Evidence was therefore sought from electron microscope serological tests. In immunosorbent electron microscopy tests, many particles of a Scottish isolate of PLRV in tissue extracts became attached to grids coated with antisera prepared to Canadian, Japanese or Swiss isolates of PLRV. Moderate numbers of particles became attached using antiserum to tobacco necrotic dwarf virus or to bean leafroll virus, smaller numbers using antiserum to soybean dwarf virus or to barley yellow dwarf virus (RPV strain), and a few particles became attached using antiserum to barley yellow dwarf virus (MAV strain) or to beet western yellows virus. A similar pattern of antigenic relationships was deduced from tests in which the binding of antibody molecules to purified PLRV particles exposed to different concentrations of the antisera was assessed by electron microscopy. It was concluded that these viruses should all be included in the luteovirus group and that their apparent degree of relationship to PLRV is: tobacco necrotic dwarf virus > bean leafroll virus > soybean dwarf virus > barley yellow dwarf virus (RPV strain) > barley yellow dwarf virus (MAV strain).

(I. M. Roberts, T. Tamada, B. D. Harrison)

OTHER VIRUSES

04014 *Identification of viruses in relation to diseases of other crop plants*

Viruses in swede

In collaboration with the Scottish Plant Breeding Station an exploratory survey was made for turnip crinkle virus in six cultivars of swede grown at each of five sites in Scotland and northern England in 1978. The virus was not detected by enzyme-linked immunosorbent assay or by inoculation of *Chenopodium amaranticolor* in any of 116 batches each of 25 plants. No

infection with turnip mosaic virus was detected in the infectivity test, but tomato black ring virus occurred in six batches of plants from Aberdeen.

The rate of spread of turnip crinkle virus was studied in a field trial at SHRI in 1979. In plots of four cultivars of swede, each plot containing one plant inoculated with turnip crinkle virus, only one new infection was detected by the end of the growing season, although flea-beetles were found in the plots and the leaves of infector and healthy plants were in contact.

These results, if representative of other years, suggest that turnip crinkle virus does not occur commonly in swedes in northern Britain and that it is not spread readily by flea-beetles or by plant contact.

(W. P. Mowat)

Susceptibility of strawberry genotypes to nepoviruses

Tests of the ability of nepoviruses to infect strawberry cultivars bred at SHRI have been hampered by the lack of a reliable method of infection. Graft inoculation, and growing plants in a glasshouse in pots of field soil containing virus-carrying nematodes, succeeded in infecting only a small proportion of plants of susceptible genotypes. Attempts were therefore made to devise a more effective method. Using plantlets of strawberry cv. Cambridge Favourite propagated by tissue culture, and exposing them to arabis mosaic virus-carrying *Xiphinema diversicaudatum* by the methods routinely practised in Zoology Section, the virus was transmitted to the roots of 80-90% of the plants. However, the shoots of fewer than 10% of these plants contained the virus 6 wk after inoculation and ways are being sought of increasing the frequency of systemic invasion.

(A. T. Jones, D. J. F. Brown[1])

Seed-borne viruses in legumes

Tests in 1979 on samples of fifteen seed stocks of field bean and broad bean failed to detect broad bean stain virus or Echtes Ackerbohnenmosaik-Virus. However, bean yellow mosaic virus was detected in one of these fifteen stocks and isometric particles, believed to be those of vicia cryptic virus, were found in six of ten stocks examined. The particles presumed to be those of vicia cryptic virus occurred in very low concentration in bean sap, even in preparations concentrated by ultracentrifugation. However, the number of particles seen in the electron microscope increased when carbon-filmed grids were allowed to float on sap extracts for 1-2 h. Pre-coating grids with diluted antiserum to bean yellow mosaic, broad bean stain or Echtes Ackerbohnenmosaik viruses, or to poly I/C, before floating them on drops of concentrated tissue extracts also increased the number of putative

[1] Zoology Section.

vicia cryptic virus particles seen. However, whereas in the first method particles tended to clump together, in the second they were more evenly dispersed on the grid.

(A. T. Jones, G. H. Duncan, J. G. Lindsay)

Sap from guar (*Cyamopsis tetragonoloba*) seedlings showing chlorosis and narrow twisted leaves were found to contain flexuous filamentous particles *ca.* 700-750 nm long not present in apparently healthy plants. The particles occurred in 15-20% of the seedlings, but the virus was not transmitted mechanically to several herbaceous species tested.

(A. T. Jones)

TECHNIQUES

04017 *Characterization of plant virus proteins and nucleic acids*

Iodination of particles of raspberry ringspot virus

The routine method of protein iodination that involves treatment with chloramine T and potassium iodide, and then with sodium metabisulphite, inactivated the infectivity of particles of raspberry ringspot virus. In contrast, particles iodinated using the sparingly soluble 1, 3, 4, 6-tetrachloro-3α, 6α-diphenylglycoluril (Iodogen) in place of chloramine T, and without the treatment with sodium metabisulphite, were as infective as untreated virus. When radioactive iodide was used at 30 m Ci/μmole, and at a concentration equimolar to that of virus coat protein molecules (mol. wt. 54,000), about 5% of the iodide became bound to the virus particles. Specific radioactivities of 34,000 cpm/μg and 18,000 cpm/μg were obtained for particles of the E and S strains of raspberry ringspot virus, respectively.

(M. A. Mayo)

04021 *Techniques for electron microscopy*

Preparation of extracts from small amounts of source material

Two techniques were devized for preparing extracts for electron microscopy from small amounts of virus-containing material. The 'mini-mortar' technique uses a US-BPI watch glass as the mortar, and the pestle is a mated, soft (soda) glass rod, *ca.* 5 mm diameter. The source material (100-300 mg) is first ground to a smooth paste with 20-100 mg of washed, 600-mesh Carborundum powder, and a small amount of an extraction medium, *e.g.* distilled water, buffer, or fixative. More medium is then added to give the required extract volume (0·3-2·0 ml) and the resultant slurry is clarified by centrifugation at low speed, after which the virus-containing supernatant fluid is used.

The effectiveness of this method was improved further by transferring the virus extracts into plastic micro-analysis tubes (0·75 or 1·5 ml), for centrifugation. The tubes are used with brass collars which were specially made to fit the rotor of a standard bench micro angle centrifuge. These tubes have several advantages over conventional glass or plastic centrifuge tubes. They are disposable, conical in shape with a tight-fitting lid which makes them safe to use with fixatives, and are hydrophobic, allowing complete removal of supernatant fluids from small discrete sediments.

The convenience of these tubes led to the development of the " micro-mortar " extraction method, in which the tube itself becomes the mortar, and the pestle is a finely tapered glass rod, the end of which is ground with emery paper to match the shape of the tube. The technique is essentially similar to the " mini-mortar " method, but on a much smaller scale: 0·5-10·0 mg of tissue can be ground with *ca.* 5 mg Carborundum to give extract volumes of 5-10 μl. The " micro-mortar " method has the advantage that there is no loss of material caused by transfer between containers, and the Carborundum used to grind the sample becomes embedded in the sides of the tube during grinding so as to produce a very abrasive surface.

These two techniques have proved to be much more efficient in releasing virus particles from tissues than other extraction methods used for electron microscopy. For example, they greatly facilitated the detection of anthriscus yellows and hogweed latent viruses in phloem tissue and they enabled viruses which occur in low concentrations in sap, *e.g.* potato leafroll and potato mop-top viruses in potato tubers, to be detected reliably by immunosorbent electron microscopy. The " micro-mortar " technique has also proved indispensable for detection of virus particles in extracts of individual vector aphids and nematodes.

(I. M. Roberts, G. H. Duncan)

Method of obtaining comparative counts of particles

The method involves the determination of the area of the field of view in the binoculars of the electron microscope, relative to a standard area (SA), which was taken as 1000 μm^2. The magnification of the image seen in the binoculars was determined using negatively stained catalase crystals, and the area of the specimen observed was calculated. This was done for several magnification settings, and a table prepared giving a relative area factor (RAF) for each magnification. In practice the number of particles/SA is estimated by counting the numbers of particles per field of view in a minimum of five randomly chosen areas in each of three different and well separated grid holes. These values are then averaged before multiplying by the RAF.

This method gives estimates that are independent of the operator's experience and of the microscope, grid type and magnification used, and it

is quick and simple, requiring *ca.* 5 min per sample compared with several hours for counts from micrographs. It is especially useful for electron microscope serology tests, or when particles are few, because the proportion of fields of view in which particles are seen can be assessed as conveniently as the number of particles per field of view, thus giving reliable estimates of particle numbers down to *ca.* 20/1000 μm^2.

(I. M. Roberts)

ZOOLOGY

D. L. TRUDGILL

During the year our investigations made steady progress and, with the exception of a small problem posed by the clay coloured weevil, no new areas of work were started.

Control of *Pratylenchus penetrans* in raspberries has again proved worthwhile with yields and cane growth being increased, even in some plantations treated 3 or 4 years ago. Dazomet is the most effective chemical tested but liquid fumigants applied by the Rumptstad Combiject have proved effective at some sites. At others, particularly those which were wet or were treated late, the results with the liquid fumigants have been disappointing. However, at one site control was greatly enhanced by incorporating a small amount of dazomet into the soil surface with the rotary cultivator on the Combiject.

Field trials comparing the tolerance of potato cultivars to damage by potato cyst nematodes have confirmed that there are large differences, with even some resistant cultivars proving intolerant.

The effectiveness of granular insecticides for controlling potato aphid and reducing the spread of leaf roll virus in Scottish seed potatoes was again demonstrated in field trials. Thus it is imperative that insecticides be reserved for use in years when aphids are abundant early, rather than used routinely and thereby hasten the selection of insecticide resistant strains of aphid and squander a valuable weapon for protecting future seed crops.

NEMATOLOGY

05010 *Assessment of the damage caused by potato cyst and other plant parasitic nematodes in Scotland*

Tolerance to damage by potato cyst nematode (Globodera rostochiensis)

Preliminary studies last year (Ann. Rept 1977, p. 121) indicated that some potato cultivars suffer less damage (are more tolerant) than others when grown in heavily infested soil. This year the tolerance of 11 resistant and 13 non-resistant cultivars of potatoes was compared at two sites (Invergowrie and Meigle) by growing them in heavily infested soil, part of which had been treated with oxamyl (Vydate, 56 kg/ha). The degree of tolerance

of each cultivar was determined by expressing the yield in the untreated plots as a percentage of that in the treated.

At both sites cultivars resistant to *G. rostochiensis* tended to be more tolerant than those which were not, probably because the resisting cultivars did not suffer a drain on their food reserves caused by the developing cyst. A study of haulm growth made on some cultivars, supports this suggestion. Initially, the haulm growth of resistant and non-resistant cultivars was depressed equally in untreated soil. However, between 10 and 14 wk after planting the resistant cultivars grew more than the non-resistant and they continued to increase in size between 14 and 18 weeks when the non-resistant cultivars were senescing.

Early cultivars, when grown to maturity were less tolerant than main crop cultivars, especially at Meigle. A resistant early cultivar, cv. Maris Anchor, when grown in untreated soil at Invergowrie and Meigle, yielded only 39% and 6% respectively of that in treated soil; in contrast three main crop resistant cultivars, Cara, Maris Piper and Brio, grown in untreated soil yielded more than 66% of those in treated soil. In treated soil at Meigle the yield of Maris Anchor was 66% that of Maris Piper; in untreated soil it was 6%.

(D. L. Trudgill, L. Cotes)

05003 *Chemical control of virus vector and other plant parasitic nematodes*

Effect of oxamyl on the feeding of Xiphinema diversicaudatum

The behaviour of *X. diversicaudatum* in the presence of seedling plants whose foliage has been treated with the basipetally translocated nematicide oxamyl is being studied on agar plates. In preliminary experiments the behaviour of nematodes, recorded over several days using time lapse ciné photography, showed that nematodes feeding on roots when foliar oxamyl was first applied were not always repelled by the translocated nematicide. Futhermore, nematodes were undeterred from approaching and feeding on the roots of seedlings whose foliage had been pretreated with oxamyl.

(T. J. W. Alphey, W. M. Robertson)

Control of nematodes using liquid soil fumigants

Virus-tested Narcissus sites

A number of potential field sites for the propagation of virus-tested narcissus bulb stocks were examined for nematode transmitted viruses and their vectors. Soil infectivity was assessed by growing bait plants in soil samples and all the sites where infection occurred were rejected. Longidorids and trichodorids were present at all of the sites and the two least heavily

infested were treated with liquid fumigants applied by the Rumptstad Combiject.

The site ultimately selected for planting was treated in late August, 1978, with dichloropropene (Telone II) at 225 l/ha. Five weeks after treatment no longidorids or trichodorids could be found (pretreatment population counts were 155/kg and 1·25kg of soil respectively). The total number of migratory nematodes had been decreased from 12500/kg to 290/kg of soil. At the second site metham sodium (Vond Metam, 200 l a.i./ha) failed to decrease numbers of nematodes.

At a third site, in which tobacco rattle virus (TRV) had been detected, dichloropropene was applied at 330 l/ha in October, 1978. Six weeks later the numbers of longidorids had decreased from 40/kg to 2.5/kg of soil and of trichodorids from 162/kg to 1/kg of soil. In 1979 half the treated area was left fallow and the remainder planted with barley. Eleven months after treatment the number of longidorids and trichodorids had not increased and were similar in both halves.

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

Arable sites

Dichloropropene (Telone II. 225 l/ha) and metham sodium (Sistan, 114 l a.i./ha were applied in October, 1978, by the Combiject in strips across two areas of land to be planted with potatoes. Plots along each strip were left untreated for comparison. Six weeks after treatment dichloropropene had decreased the numbers of migratory nematodes by 98% and 79% respectively at the two sites. Metham sodium decreased the numbers of migratory nematodes by 95% at the first site but only by 23% at the second site where little control was achieved below 20 cm depth. As expected the numbers of potato cyst nematode cysts 6 wk after fumigation were unaffected at both sites. However, the numbers of larvae which hatched were decreased by 98% and 85% by dichloropropene and 96% and 47% by metham sodium respectively at the two sites. The seal to the soil surface remained unbroken until spring when the non-resistant cv. Ulster Prince and the resistant cv. Pentland Javelin were planted at each site. By harvest, numbers of migratory nematodes in samples from treated and untreated plots were similar. Numbers of cysts recorded under the non-resistant U. Prince at harvest had increased in all treatments (88% and 50% after dichloropropene and 52% and 55% after metham sodium) but were decreased (0% and 25% after dichloropropene and 12% and 14% after metham sodium) where the resistant P. Javelin had been grown.

(T. J. W. Alphey)

[1]Virology Section.

Soft-fruit sites

The control of *Pratylenchus penetrans* by dichloropropene (Telone II, 225 l/ha) and metham sodium (Campbell's metham sodium, 160 l a.i./ha and 240 a.i./ha) applied by the Combiject, and dazomet (Basamid, 430 kg a.i./ha) incorporated by rotary cultivation, were compared in a replicated trial prior to planting raspberries. Six months after treatment the numbers of *P. penetrans* had been decreased 99% by the dazomet, 96% by the greater amount of metham sodium, 92% by the dichloropropene and 87% by the lower amount of metham sodium. Nine months after treatment the relative efficiencies of the products had remained the same but the control compared with the untreated had decreased to 91%, 83%, 75% and 59% respectively.

(T. J. W. Alphey, D. L. Trudgill)

At another site the rotary cultivator on the Combiject was used to incorporate a small amount of dazomet (Basamid) 50 kg a.i./ha into the soil surface concurrently with an application of metham sodium (Vond Metam) 200 l a.i./ha. Other treatments at the same site were metham sodium alone and dazomet at 330 kg/ha. Dazomet significantly decreased the number of nematodes but metham sodium alone had no effect. The combined dazomet and metham sodium treatment gave good control and derceased the total numbers of nematodes significantly more than dazomet alone.

(T. J. W. Alphey)

05012 *Ecology and control of Pratylenchus spp. associated with soft fruit*

Pratylenchus penetrans *damage to raspberries*

Each year since 1976 at least one replicated field trial has been started on raspberry land infested with *P. penetrans* (40-200/200 g soil). All the trials have tested the effect on raspberry growth of controlling *P. penetrans* and have included pre-planting treatments with dazomet (Basamid, 220-330 kg/ha) and aldicarb (Temik, 66 kg/ha). In all trials both chemicals decreased populations of *P. penetrans* in the treated layer of soil (20-25 cm) by more than 90%. At the end of the first year the mean length of cane/stool had increased by 50% following treatment with aldicarb and by 73% following treatment with dazomet, compared with no treatment. In the spring of the second year, except in the aldicarb treated plots at one site, the numbers of *P. penetrans* in treated plots had not increased and the growth response to aldicarb and dazomet was even greater; the mean increase at three sites being 62% and 128% respectively. Yields, taken decreased the total numbers of nematodes significantly more than dazomet treatment.

In the third year (two sites) the numbers of *P. penetrans* had increased in all plots but were still less than in the untreated. Mean fruit yields were increased by an amount equivalent to 3·0 and 4·4 t/ha by aldicarb and dazomet respectively. The length of cane/stool before thinning and tipping was increased 30% and 75% respectively. At the first site, where aldicarb was re-applied each autumn, the yield and growth increases were greater than at the second where aldicarb was applied once, just prior to planting.

In the fourth year (one site) yields were increased by an amount equivalent to 2·0 t/ha by the dazomet and 2·5 t/ha by the aldicarb. The numbers of *P. penetrans* were similar in the untreated and dazomet treated plots, but in the autumn there was still 37% more cane after thinning in the dazomet treated plots. In plots which were treated each autumn with aldicarb, numbers of *P. penetrans* were 50% less than in the untreated and the length of cane/stool had been increased 28%.

The results summarised above apply to sites where problems were anticipated either because they were heavily infested with *P. penetrans* (more than 40/200 g soil) and/or because the growth of the previous crop of raspberries had been unsatisfactory. In four other fields, more lightly infested with *P. penetrans*, dazomet and aldicarb were applied in strips prior to planting in spring 1978. Growth in the first year visibly was improved at two sites following dazomet, but not following aldicarb, but in the second year growth was visibly improved following dazomet at one site only.

In a separate trial where dazomet was applied for the ESCA, growth of cv. Glen Clova was greatly improved in the first and second years following replanting with raspberries on land previously cropped with raspberries until 1977, but free from *P. penetrans*.

Additional pathogens

The greater growth of raspberries in soil treated with dazomet (a broad spectrum soil sterilant) compared with aldicarb (a nematicide/insecticide) suggested that, in addition to *P. penetrans*, other unsuspected pathogens might be present. This possibility was tested in a pot experiment using soil from the untreated and dazomet treated plots from four of the replicated field experiments. Each lot of soil was split into four parts, one being treated with a fungicide (benomyl) a second with aldicarb, a third with both chemicals and the fourth left untreated. Small raspberry plants cv. Glen Clova were grown in this soil in pots. In the soil from the dazomet treated plots the combined fungicide/nematicide treatment slightly increased growth in soil from two of the sites. In the soil from the untreated plots the combined aldicarb/benomyl treatment dramatically improved growth (two to five fold increases in mean plant weight) in three of the four soils tested. In soil from the one site growth was also greatly improved

by the aldicarb, but not the benomyl treatment, whilst in soil from another site the reverse occurred. In soil from yet another site, where there had been greatest growth response to the combined treatment, there was only a small response to aldicarb and a slightly larger response to benomyl. As *P. penetrans* was not controlled by the benomyl these results support the suggestion that in addition to *P. penetrans* dazomet may be controlling other harmful organisms, probably fungi at some sites.

In another pot test using soil from a 7 year old raspberry plantation the growth of raspberries was increased by the fungicides quintozene, thiabendazole, benomyl and to a lesser extent by thiram without *P. penetrans* being controlled. Captafol had no effect.

(D. L. Trudgill)

Effect of raspberry, strawberry and black currant on nematode populations at SHRI

The plant parasitic nematode fauna associated with plantations of different ages was compared with that in adjacent grass paths. In the grass *P. neglectus* and *P. crenatus* were most widespread but *P. thornei* was found at one site. The grass also contained large numbers of Tylenchorhynchus, Paratylenchus, Rotylenchus, Helicotylenchus and at some sites, Longidorus (mainly *L. elongatus*).

Under raspberry plantations of increasing age the numbers of *P. neglectus, L. enlongatus* and Tylenchorhynchus decreased until they could not be found in plantations more than 4 years old. The numbers of Paratylenchus also initially declined but in plantations more than 4 years old they tended to be more numerous than in the adjacent grass. The numbers and species of spiral nematode (a mixture of *H. vulgaris* and *R. goodeyi*) differed little between grass and raspberries except in the oldest plantation (more than 7 years old) where *R. goodeyi* tended to predominate. Numbers of *P. crenatus* remained small even in the oldest plantations and except at one site, no *P. penetrans* were found.

In contrast to raspberries, which were a poorer host than grass for several species of nematodes, black currants were an equally good host for most species. The oldest plantation of black currants (7 years old) supported populations of Pratylenchus (mainly *P. neglectus*), *L. elongatus, Rotylenchus* (*H. vulgaris, R. goodeyi,* or *H. digonicus*), Tylenchorhynchus and Paratylenchus as large, or larger than those under the grass.

Strawberries were a poorer host than grass for Paratylenchus, Tylenchorhynchus and *P. crenatus,* but were an equally good or better host for *P. neglectus* and *L. elongatus.* Numbers of Rotylenchus were similar under both crops.

(D. L. Trudgill, S. Kurppa)

05C07 *Ecology on Longidorus and Xiphinema spp. in relation to their role as plant pathogens*

Effect of cropping and nematicides on the number of Longidorus elongatus *and* Rotylenchus robustus

Large populations of *L. elongatus* can be injurious to several crops. However, the results of a 4 year trial showed that numbers decreased under a monoculture of swedes, peas, carrots, potatoes or barley to such an extent that they did not differ greatly from plots which had been under almost continuous fallow. High populations were maintained only under grass. The interaction between grass and *L. elongatus* was therefore examined, using nematicides to adjust populations prior to planting, dichloropropene (Telone II, 225 l/ha) killed more than 90% of the *L. elongatus* and more than doubled the yield of grass in the following year. Aldicarb (10·0 kg a.i./ha) decreased the number of *L. elongatus* to a similar extent and improved the growth of the grass during the summer. Aldicarb (3·31 kg a.i./ha) and benomyl (25 kg a.i./ha) had less effect on the numbers of *L. elongatus* and only slightly improved the yield of grass.

R. robustus is also damaging to several crops and a second experiment with grass, when the soil was treated with dichloropropene (Telone II, 225 l/ha), aldicarb (10 kg a.i./ha) and benomyl (25 kg a.i./ha) prior to planting, gave similar results. At both sites the addition of nitrogen fertiliser significantly increased the yield of grass. Maximum yields were obtained when both dichloropropene and the fertiliser were used.

(B. Boag)

Longidorus elongatus *damage to strawberry*

A previous experiment (Ann. Rept 1976, p. 89) indicated that large numbers of *L. elongatus* might decrease the vigour of strawberry. In 1977 some of the rows in this trial were removed and the soil treated with aldicarb (3·3 kg a.i./ha) and quintozene (88 kg a.i./ha) separately and together prior to re-planting with strawberry cv. Cambridge Favourite. Initial populations of *L. elongatus* ranged from 100 to almost 300/200 g soil. Two years after treatment the numbers of *L. elongatus* were similar in the untreated and aldicarb treated plots but had been markedly decreased in those treated with quintozene. The mean yield of strawberries in 1979 was increased from 231 g per plant in the untreated plots to 290, 327 and 325 g respectively in those treated with aldicarb, quintozene and with both chemicals.

(D. L. Trudgill)

Effect of temperature on the development of nematode eggs

Nematode eggs were placed in aerated distilled water and their development monitored at a range of temperatures. The eggs of *R. robustus* took 31 days to hatch at 15°C, 16-17 days at 20°C and 14 days at 25°C. No eggs hatched at 30°C and at 10°C the eggs developed very slowly but did not hatch. Eggs of *Xiphinema index* took 9 days to hatch at 25°C and their rate of development was not greatly affected if the distilled water was not aerated or by changing it more frequently than weekly.

(B. Boag, I. E. Raschké)

Effect of temperature on the rate of feeding of three species of nematode

The effect of temperature on the rate of feeding of *R. robustus, Xiphinema diversicaudatum* and *Hemicycliophora conida* on *Lolium perenne* seedlings grown on agar plates was observed. *R. robustus* fed between 0·5°C and 42·5°C, *X. diversicaudatum* between 5·0°C and 37·0°C and *H. conida* between 5·0°C and 34·0°C. Between 10°C and 25°C the rate of pumping by the oesophageal bulb increased directly as the temperature increased. As the temperature increased above 25°C the increase in the rate of contractions of the oesophageal bulb declined until, at the highest temperatures the rate of contractions began to decrease. No differences were observed in the rates of oesophageal bulb contractions between nematodes feeding at different sites on the roots or between males, females or larvae.

(B. Boag)

Distribution of *Xenocriconemella macrodora*

Prior to 1978 *Xenocriconemella macrodora* has been found at only four sites in Great Britain. Using an improved method of extracting this nematode from soils (centrifugation) *X. macrodora* was found at a further 15 sites in Scotland. From the results of this and a similar survey in Spain[1] the distribution of *X. macrodora* was found to be significantly correlated with mature deciduous woodlands, especially those containing oak (*Quercus spp.*).

(A. Bello, B. Boag)

05011 *Migratory plant parasitic nematodes associated with vegetable crops in Scotland*

Survey of nematodes in vegetables

A survey of the nematodes associated with peas grown in Scotland has been completed. The results indicated that *Tylenchorhynchus dubius* was

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the most widely distributed plant parasitic nematode on peas, being present in 78% of the farms, 71% of the fields and 45% of samples examined. *L. elongatus* was the next most frequently encountered species but populations were generally very small. Other species identified during the survey were *L. leptocephalus, L. goodeyi, L. caespiticola, T. maximus, R. goodeyi, R. fallorobustus, Helicotylenchus vulgaris, H. pseudorobustus, H. canadiensis, H. varicaudatus, Trichodorus primitivus, T. similis, T. velatus, T. cylindricus* and *Paratrichodorus pachydermus*. Five species of predatory nematodes were also found.

(B. Boag)

Measurements of nematodes

Nematodes and their internal structures are commonly required to be measured either to identify the species, the population, or the stage of development, etc. The traditional method using eye piece micrometers and taking measurements using a drawing arm attached to a high power microscope is laborious and of variable accuracy.

A new system for measuring nematodes has been devised using a microscope with a drawing arm, together with a digitising tablet linked to a microcomputer. The parts of the nematode to be measured are traced with a cursor, the measurements being recorded automatically by the computer. This technique is more rapid, accurate and reliable than previous methods and provides a basis for identifying nematodes using the computer.

(B. Boag)

05004 *Feeding of* Longidorus *and* Xiphinema spp. *in relation to plant response and virus transmission*

Transmission of viruses by two populations of Xiphinema diversicaudatum

The efficiency with which the Inchmartine and a 'small' population of *X. diversicaudatum* from Lombardi, Italy, transmitted arabis mosaic virus (AMV-type strain) and three serologically distinct isolates of strawberry latent ring spot virus (SLRV) was compared. In transmission tests with groups of two or five *X. diversicaudatum* from the Inchmartine population all the bait plants were infected by nematodes previously exposed to AMV or the type (T39) strain of SLRV. None were infected by nematodes previously exposed to two Italian isolates of SLRV. In contrast the Lombardi population infrequently transmitted all four viruses; infecting four of 50 bait plants with each of the Italian SLRV isolates and one of 50 with AMV or SLRV (T39).

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

Effect of the bait plant on transmission of viruses by Longidorus and Xiphinema spp.

In previous tests using *Petunia hybrida* bait plants (Ann. Rept 1976, p. 92) *Longidorus macrosoma* proved to be an inefficient vector of the English strain of raspberry ring spot virus (RRV-E). As RRV-E is the strain it transmits in the field this result was unexpected and we therefore tested transmission of RRV-E by groups of 20 *L. macrosoma* to raspberry, strawberry and *Chenopodium quinoa* seedlings. Again, however, virus was transmitted only infrequently; no strawberry or *C. quinoa* being infected and only two out of 20 raspberries and four out of 20 *P. hybrida* bait plants were infected.

In a similar test groups of 20 *X. index* infected three of 10 grape seedlings with grape fan leaf virus, but none of 20 *Chenopodium amaranticolor* even though *C. amaranticolor* was used as the virus source plant for all the nematodes.

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

Detection of virus in nematode bodies

Last year we described a scheme for assessing the efficiency with which nematodes can transmit viruses (Ann. Rept 1978, p. 120). As part of this scheme the proportion of nematodes that had ingested virus from the source plants was estimated by inoculating their ground-up bodies on to virus sensitive indicator plants (slash test). This technique is, however, nather insensitive especially when Xiphinema spp, are being tested. A new technique, immunosorbent electron microscopy (Virology Section report p. 98) promises to be quicker and more sensitive. With it particles of arabis mosaic, strawberry latent ringspot, grapevine chrome mosaic, and grape fanleaf virus have readily been detected in the ground-up bodies of single Xiphinema spp. Viruses transmitted by Longidorus spp. have also readily been detected within their vectors.

(D. J. F. Brown, I. M. Roberts[1], D. L. Trudgill)

Immunosorbent electron microscopy is also being tested with some success for detecting tobacco rattle virus and pea early-browning virus in trichodorid nematodes and plant tissues.

(T. J. W. Alphey, W. M. Robertson)

Effect of nematode attack on root growth

Using time-lapse photography studies were made of *X. diversicaudatum* feeding on the roots of *Lolium perenne* seedlings growing in agar. When root tips were fed upon by several nematodes further growth was retarded

[1]Virology Section.

and a gall formed. When single nematodes fed upon growing root tips, growth was temporarily slowed on the attack side causing the root to curve. Feeding by single nematodes just behind the root tip, in the region of elongation, stimulated rapid growth even in roots which had stopped growing.

In similar studies with *L. elongatus* the roots of *L. perenne* proved extremely sensitive to nematode attack; a single nematode being sufficient to induce gall formation.

(W. M. Robertson, T. J. W. Alphey)

05005 *Ultrastructure of nematode vectors of plant viruses with reference to their feeding apparatus*

A new embedding technique

A rapid fixation and embedding technique has been developed using PIPES (piperazine-NN-bis-2-ethane-sulphuric acid) buffer for the fixatives, a short dehydration series and EMIX embedding resin. This new procedure has enabled us to decrease the time necessary for embedding nematodes or aphids prior to sectioning from one week to one day. The health hazard associated with the embedding process has also been decreased by using the PIPES buffer and premeasured amounts of resin.

Ultrastructure of Xiphinema index

Using this technique the morphology of the dorsal oesophageal gland cell of *X. index* was compared in nematodes starved for different lengths of time. In *X. index* which had been feeding immediately before being killed and fixed, there were numerous electron dense granules aggregated near the gland ducts. These granules have a single limiting membrane and are thought to be secretory. No similar electron-dense material was found in the lumen of the ducts except for very small amounts at the apices of the folds in the duct lining.

In thin sections through the dorsal glands of *X. index* which had been starved at room temperature for 14 days few electron-dense granules were present and the ducts were reduced in size.

In *X. index* starved for 7 days, there were also few electron-dense granules but two types of electron-dense materials were seen in the lumen of the ducts. There were granular strands associated with the folds in the membrane which form the duct wall and larger aggregations of a fine grained electron-dense material in the duct lumen. The fine grained aggregations had the same shape in section as the secretory-like granules within the gland cell but were larger. They also lacked the single limiting membrane of the granules within the gland cell.

(W. M. Robertson)

05013 *Control of aphids and virus diseases of potato, raspberry and ornamentals*

Potato

The spread of potato leafroll virus (PLRV) was assessed by growing on tubers from a replicated trial grown at SHRI in 1978 (Ann. Rept 1978, p. 124).

In 1978 the main vector of PLRV, *Myzus persicae*, was very scarce compared with the previous 2 years, resulting in little spread of PLRV even though PLRV infector plants had been placed within the trial. The effectiveness of the granular and spray treatment applied in 1978 could not therefore be compared. The time of haulm destruction did have a slight effect on the spread of PLRV; 16 of 2,000 tubers grown from plants whose haulms had been destroyed on 5 September were infected with PLRV compared with 3 of 2,000 from plants whose haulms had been destroyed 2 weeks earlier (23 August). However, as most of these were from plants adjacent to the infectors it seemed likely that virus had spread from the sources within rather than from outside the experiment.

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

The efficacy of granular insecticides in preventing the spread of PLRV was tested in 1978 at five sites in Scotland and one in Cambridgeshire. *M. persicae* was scarce in the experiments in Banff, east Perthshire and at the two experiments in Fife. *M. euphorbiae* was numerous at every site except Banff and Cambridgeshire. Tubers harvested from plants adjacent to PLRV infectors in each plot and from drills some distance away were grown in 1979 to assess the spread of PLRV. There was insufficient spread of virus in the trial in Banff, north Fife and east Perthshire to compare disulfoton and thiofanox or to justify the use in 1978 of granules at these sites. Disulfoton decreased the spread of PLRV in south Fife but was ineffective in Ayrshire and Cambridgeshire. Thiofanox controlled aphids and virus spread in Fife and Ayrshire but gave less satisfactory control in Cambridgeshire. However, as strains of *M. persicae* resistant to insecticides were found in Ayrshire and were widespread in Cambridgeshire the decreased effectiveness of insecticide at these sites can be accounted for.

The results show that provided insecticide resistant strains of aphids are absent granular insecticide applied to the soil at planting will control the spread of PLRV in Scottish seed potato crops.

(J. A. T. Woodford, C. S. Aveyard, S. C. Gordon with M. W. Shaw[1], R. G. McKinlay[2], P. Osborne[2], and G. N. Foster[3])

Toxicity of potato plants treated with granular insecticide

The toxicity of thiofanox (56 mg a.i./m of row), pirimicarb (71 mg a.i./m of row) and ethiofencarb (76 mg a.i./m of row) was measured weekly by placing *M. persicae* on excised leaves from treated field crops. This showed that toxic amounts of both compounds remained in the plant for at least 13 weeks after planting. Ethiofencarb was less persistant providing protection for only 9 weeks.

The toxicity of thiofanox to viruliferous *M. persicae* was also tested in a glasshouse pot (25 cm diam.) experiment. When aphids were placed upon plants treated with 50 mg a.i. 6 and 12 weeks after planting few survived and the percentage of plants infected with PLRV was decreased from 50% in the untreated to less an 10%. On plants treated with a smaller amount of thiofanox (5 mg a.i.) fewer aphids died and 40% of the plants were infected with PLRV.

Transmission of PLRV by Macrosiphum euphorbiae

In contrast to *M. persicae* which was very scarce in 1978, *M. euphorbiae* was very abundant. However, tests showed that three clones of *M. euphorbiae* collected from potato crops at SHRI in 1977 and 1978 transmitted PLRV from infected potato plants to sprouted tubers only very inefficiently; 2·4% of sprouted tubers were infected when *M. euphorbiae* was used, compared with 35% with *M. persicae*. From this result and the result of the 1978 field trial we conclude that in eastern Scotland *M. euphorbiae* is not usually an important vector of PLRV.

(C. S. Aveyard)

05001 *Ecology and control of horticultural and agricultural pests*

Clay-coloured weevil

In the early 1950s damage by clay-coloured weevils (*Otiorhynchus singularis*) was widespread, but with the introduction of DDT it became a pest of minor importance. Following the withdrawal of DDT for use on raspberry plantations the number of reports of weevil damage have

[1]North of Scotland College of Agriculture.

[2]East of Scotland College of Agriculture.

[3]West of Scotland Agricultural College.

increased. Hence, in 1979, a range of insecticide were tested in laboratory experiments to find a replacement for DDT.

In the first experiment cut primocanes (cv. Malling Jewel) were dipped in the test insecticide for 2 seconds, shaken and allowed to dry. Starved adult weevils were added to the test foliage (terminal 15-20 cm) in plastic arenas with 'Fluon' rings round the top to prevent escape. The insecticides tested were fenitrothion (50% e.c.) 0·05% a.i., chlorpyrifos (48% e.c.) 0·096% a.i., DDT (20% e.c.) 0·25% a.i. and 1·0% a.i., azinphos-methyl/demeton-S-methyl sulphone (Gusathion MS) 0·1% product, permethrin (25% e.c.) 0·01% a.i. and NRDC 161 (2·5% e.c.) 0·0007% a.i. After 48 hours few active weevils remained in all the insecticide treatments except in NRDC 161, and all the chemicals, including NRDC 161, significantly reduced the amount of feeding damage compared with the untreated control.

In the second experiment DDT (4% a.i.), chlorpyrifos (0·048% a.i.), HCH (0·01% a.i.) and permethrin (0·01% a.i.) were sprayed onto the soil surface (at a rate equivalent to 1000 l/ha) in pots containing buried adult weevils. Untreated foliage was added to the pots after spraying and the numbers of live weevils recorded 6 days later. Only in DDT treated pots was there any significant reduction in the numbers of weevils.

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

Raspberry Beetle

The effectiveness of synthetic pyrethroids against raspberry beetle (*Byturus tomentosus*) was tested in a field trial. Sprays of NRDC 161 (Hoechst Decis 2·5% e.c., 0·0015% a.i.) and permethrin (ICI Ambush 25% e.c., 0·01% a.i.) were compared with fenitrothion (Accothion 50% e.c., 0·05% a.i.). All the sprays were applied on 12 July at 1000 l/ha and the number of damaged fruits was assessed at four harvests. All the insecticides significantly decreased the amount of damage compared with the untreated plants, but permethrin was significantly less effective than either NRDC 161 or fenitrothion.

(S. C. Gordon)

ESTATE

W. I. A. Jack

Outdoor work was much hindered by the most adverse weather conditions experienced in the last decade; the meteorological records showing that rain, snow and ice-bound conditions were the pattern from January to late March. Cool and wet periods followed during the months of April and May causing growth to be slow in all crops. Harvesting operations were frequently interrupted by rain, which adversely affected the yields and quality of fruit and cereals. Fortunately, however, improved weather conditions during the autumn allowed field work to proceed normally until early December. In summary it was a difficult year for farming operations requiring an integrated team effort by the staff to overcome the many problems caused by the weather conditions.

Farm and experimental crops

Farm crops included 40·5 ha barley, 6·4 ha hay, 5·1 ha grass, 1 ha potatoes, 1·8 ha other crops and 3·7 ha fallow; this is an increase of 6·4 ha from the previous year as more land was released from field experiments and used for rotational crops of cereals and grass.

Barley sowing started on the 14 March and was immediately interrupted by a moderate fall of snow that lay for 10 days and it was not until a 6-day period from 29 March to 3 April that any progress was made. Further cool and wet periods in April and May caused growth to be slow. Heavy rain on 16 July resulted in many fields becoming badly lodged. Outbreaks of mildew (*Erysiphe graminis*) also occurred in some fields. Combining started on 23 August, but progress was slow on the lodged crop and was frequently interrupted by rain, being completed under difficult conditions on 11 September. The yield 5·81 t/ha was up 0·41 t/ha on the previous year. Despite the difficulties encountered during the growing and harvesting season grain samples were in general better than the previous year, with a moisture content of 18·8% and nitrogen averaging 1·4%; 88·1% of the tonnage was sold for malting.

Grass grew slowly in the early part of the spring, but then made rapid progress in June and hay was secured in excellent condition. Cutting started on 28 June and baling was completed by 3 July; the yield of 8·9 t/ha was up 0·9 t/ha from 1978.

Potatoes grew well, but despite routine protective sprays against pests and diseases isolated outbreaks of potato blight (*Phytophthora infestans*) occurred, but infection was low. Haulm was flailed off early in September as an added precaution against disease. Lifting, although starting under difficult conditions early in October, was completed under more favourable conditions on 5 November and despite problems of greening of the tubers, particularly in cv. Maris Piper, a good clean sample was obtained. A yield of 42 t/ha was an increase of 7·2 t/ha on 1978.

Field experiments included 12·7 ha raspberries, 7·6 ha black currants, 2·7 ha strawberries, 1·8 ha blackberries and hybrid berries, 0·1 ha blueberries, 4·4 ha potatoes, 4·1 ha vegetables, 0·5 ha field beans, 0·5 ha ornamental bulbs and 2·1 ha other crops.

The picking of soft fruit commenced with strawberries on 9 July, 21 days later than 1978, followed by loganberries and Tayberries 13 July, blackberries 18 July, raspberries and black currants 23 July, blueberries 27 August and, finally, cranberries 12 November. The late start to the season and frequent showers made picking difficult with the result that a proportion of the soft fruit crop had to be abandoned. Fruit in general was of high quality, but there was a higher incidence of pest and diseases despite the routine spraying programmes due to the weather and few pickers available. The fruit crop sold included 38·61 t raspberries, 12·35 t strawberries, 1·15 t black currants, 0·45 t blueberries, 0·3 t blackberries and 0·02 t longanberries, Tayberries and cranberries. This totalled 12·61 t less than 1978. Marketable produce from vegetable trials totalled 9·59 t and included Brussels sprouts, beetroot, cabbages, calabrese, carrots, courgettes, French beans, leeks and swedes, all of which were marketed locally.

Following harvest, the routine programme of stubble cleaning, subsoiling and spraying was practised. Ploughing was done when conditions were suitable and was almost completed by 6 December. Winter wheat was sown by 24 October and establishment was satisfactory.

Estate

The prolonged spell of inclement weather from January to late March proved a hindrance. However, much has been done to put the estate in good trim by repairing dykes, fences and gates, roads were resurfaced, windbreaks trimmed, and farm machinery renovated and painted. The amenity planting round the buildings was continued and work started on improving the surroundings of the new crop handling buildings, with the sowing of grass and preparation of shrub borders. The completion of the extension to the Dutch barn has provided immensely better facilities for the storage of farm crops and equipment.

A bore-hole was drilled by contractors and yield tests completed in February showed a yield of ca. 45,460 l/hour, and after analysis the water was shown to be suitable for irrigation purposes.

New farm equipment acquired during the year included irrigation equipment and a pressure washer.

Glasshouses

The need to reduce expenditure, together with the difficulty of obtaining supplies of peat, has again necessitated consideration of the possibility of recycling compost; to this end a preliminary examination of once used soilless compost has been initiated, which, while making use of an otherwise expendable commodity could mean savings in cost of raw materials and overcome difficulties of supply.

The production and maintenance of plant material for use by the scientific sections showed a decrease this year. Plant production of 142655 units was down by 4079 on 1978; included were 5,500 raspberry pot plants from 48 cultivars and advanced seedling selections for Institute use, 1800 black currant plants raised from single bud cuttings and grown as single stem plants for a plant breeding project in 1980, and several large sowings produced plants for field trials of brassicas, raspberries, strawberries and black currants.

Other projects included the preparation of plants of calabrese for an exhibit at the Royal Show and forcing into fruiting blueberry cultivars for a stand at the Ayr flower show.

There are serious difficulties in obtaining control of red spider mite (*Tetranychus urticae*), with the continued use of organophosphorus insecticides and alternative insecticides are now in use in an effort to obtain adequate control, not always with complete success. However, the situation is being kept under constant review in collaboration with the Zoology Section. Regular routine spraying and fumigation programmes have been maintained and no other particular pest problems were encountered.

The principal disease under glass has been powdery mildew, but timely applications of fungicides triadimefon (Bayleton), metalaxyl (Ridomil 25 WP) and bupirimate (Nimrod) gave encouraging results.

INFORMATION SERVICES

R. J. A. EXLEY

The effectiveness of both public and private advisory and development services largely depends upon their current awareness. Of particular relevance was the publication during the year of 'Information systems in UK Agriculture,' the final report of the Agriculture Information Review Committee sponsored by the British Library Research and Development Department. As far as the ARS is concerned the highly specific, fragmented, and academic bias of much of the information generated creates a major problem for, in contrast, the users require multi-disciplinary packages of practical information which may be adapted to particular farming situations. Commissioned reviews by selected specialists are seen potentially as a solution for much of this problem, which the information explosion has made acutely urgent to resolve.

In 1975, Visual Aids co-ordinated the first SARI permanent exhibit in the DAFS pavilion at the RHAS showground. This year the group was invited to redesign the exhibit, in collaboration with DAFS and SIO, and it is now organised on a subject rather than on an institute basis. Research in the areas of breeding, culture and disease are considered under the heading of ANIMALS and of PLANTS, accompanied by exhibits concerning ENGINEERING, FOOD and SOILS. The exhibition can be viewed, by arrangement, at the Agricultural Centre, Ingliston.

Visual Aids

Although the amount of monochromes, diazo slides and electron-micrograph prints produced was less than the previous year, the jobs total increased by 61.

		Photography				Graphic
	Jobs	Colour	Monochrome	Diazo	E.M./Prints	Jobs
1978	1438	4065	5550	483	2541	86
1979	1499	4216	4658	394	1412	92

Activities of particular interest during the year include time-lapse sequences to record nematode behaviour during feeding and following nematicide application, on agar cultures, using a 16 mm cine camera, when

a total of 510 m of monochrome negative film was exposed: the use of photography for growth analysis of black currants and potatoes: the u.v. photography of raspberry leaves sprayed with a fluorescent dye, to assess coverage using different spray booms: and during July several raspberry and potato trials were surveyed by aerial photography, to assess the effectiveness of nematicides for controlling respectively the root lesion nematode *Pratylenchus penetrans* and the potato cyst nematode *Globodera rostochiensis;* field bean trials at SHRI were also photographed on the same flight.

In January trials with a scanning enlarger to assess its automatic correction facility, especially in the printing of electron and photo micrographs, gave very successful and impressive results and it was concluded that the installation of such a machine would provide a great advantage in the printing of all monochromes. An automated paper processor was purchased at the end of the year; this machine will prove invaluable in the processing of various monochrome materials and with its high output will cope with the increased processing workload anticipated when the amalgamation of SHRI and SPBS gets under way.

The Tayforth Illustrators Groups visited the section in April when facilities, equipment and techniques used were favourably viewed.

LIBRARY

The financial situation in the library was somewhat easier than in previous years, allowing the purchase of 151 books and one journal subscription. During 1979, 305 book loans and 531 journal loans were recorded from the Institute's shelves as well as 850 inter-library loans. This is a marked decrease compared with last year's figures of 501, 709 and 892 respectively.

After successful trials of the Lockheed/dialogue information retrieval system by Institute research staff, for which grateful acknowledgement is made to HFRO, the Library Committee decided that SHRI should become a subscriber; arrangements were completed by the end of the year, and it is hoped that literature searching, in particular, will become easier and more effective.

The Scottish Agricultural Librarians' Group was formed this year to provide a means for professional contact between Scottish librarians working in all agricultural contexts. Both this year's meetings were attended by the Librarian. The library staff also went to local Scottish Library Association meetings and to the annual Inter-Library Lending Seminar held in Edinburgh in October.

At the end of the year a new Nashua photocopier was acquired.

(Ursula McKean)

SCOTTISH HORTICULTURAL RESEARCH INSTITUTE ASSOCIATION

Committee

Chairman	G. D. Morrison	A. G. M. Forbes	J. G. Porter
	C. A. Acheson	G. M. Hodge	D. W. Purdie
	G. Bruce	C. C. McIntyre	R. J. Smith
	W. S. Courts	P. G. Mitchell	J. S. Whitehead

Events

The 11th Annual General Meeting was held on 25 April.

The traditional summer 'Fruit Walk' was replaced with two meetings: a 'Strawberry Walk' on 7 July and a 'Raspberry Walk' on 21 July. Both events were well attended and it is proposed to continue this arrangement in the future.

Two winter meetings were organised. On 1 March the subject was 'Some aspects of strawberry production', and on 8 November 'Winter cabbage/Brussels sprouts—discussion of varieties, breeding and plant raising'.

Publications

During the year the Association financed the following publications:
Bulletin No. 16 (February, 1979)

'Producing Healthy Seed Potatoes'

Introduction *by* J. L. Hardie, East Craigs, p. 1-3.

Some effects of cultural practices for the control of potato gangrene *by* R. A. Fox and E. P. Dashwood, SHRI, p. 4-9.

Assessment of potential for the spread of airborne blackleg and soft rot bacteria *by* M. C. M. Perombelon, p. 10-13.

Chemical control of some fungal diseases of potato tubers *by* A. E. W. Boyd, Edinburgh School of Agriculture, p. 14-17.

Trends in the distribution of potato cyst nematode in the seed potato growing areas of Scotland *by* T. W. Mabbot, East Craigs, p. 18-29.

The control of aphid-borne viruses in seed potato crops *by* J. A. T. Woodford, SHRI, p. 30-36.

The production of VTSC stocks *by* J. R. Marshall, Dunning, Perth, p. 37-40.

Occasional Publication No. 7

Strawberry Cultivar Trial, 1975-78 *by* M. R. Cormack and J. McD. Brown.

Also, the Association decided to purchase for any members who were interested, copies of the following Institute publications:

Occasional Publication No. 5

Calabrese Cultivar Screening Trial, 1970-76 *by* H. Taylor.

Occasional Publication No. 6

Highbush Blueberries *by* M. R. Cormack.

01046 *Agrometeorological Recording*

MYLNEFIELD

The winter of 1978-79 was colder and more prolonged than the previous one and merged slowly with a cool, wet spring and a dull summer.

Wind

Windspeed for the year was only slightly above average, but March and September were particularly windy, their average windspeeds being 140% of the 15-year mean. This March was the windiest month since January, 1974, and the windiest March since 1967.

Temperature

The winter was very cold, particularly during January, and the minimum air temperature (−11·3°C on 14 January) was the lowest recorded at Mylnefield since 1956 (−15·5°C). The cool spring and early summer were ended by a warm spell of only 5 days from 16-20 June (maximum ⩾20·0°C) and although July was warmer with the highest maximum temperature, 23·0°C, recorded on the 12th, the cool weather soon returned.

Rainfall

After a very wet December, 1978, precipitation in the first 2 months of the year was only 52% of the average, most of this falling as snow. In mid-March a moderate fall of snow lay for 10 days. From March to May rainfall was 142% of the long term average and only in September was rainfall significantly less than average.

The estimated soil moisture deficit during the growing season reached a maximum of 78 mm in mid July.

Sunshine and solar radiation

The total hours of sunshine for the year was 90% of the long term average making 1979 the dullest year since 1954. Only in September was the total of sunshine hours noticeably above average.

(D. K. L. MacKerron, G. C. Nicol)

Auchincruive

Temperature

The year began badly with exceptionally heavy snowfalls on 1, 2, 3, 9 and 10 January, and some even on 1 May. Temperatures continued well below normal through February with hard frosts causing delays to ploughing. Generally it was a cold year with 29 ground frost days more than 1978, October being the only month with an above average mean air maximum.

Rainfall

Apart from March and April, the first half of the year was fairly dry, but fortunately no problems were encountered due to a lack of soil moisture at planting time. From July until December, and especially in August, precipitation was mostly well above average and unless 1980 starts dry, red core disease is likely to severely debilitate many strawberry plants. September rainfall, however, was low allowing autumn cropping selections to fruit without high losses from botrytis.

Sunshine

The pattern of bright sunshine hours roughly followed that of 1978, but with 127 hours less than average. June and July, although not especially wet, were very overcast and this mainly contributed to the deficit.

(R. J. McNicol)

MYLNEFIELD 1979

Month	Temperature								Accumulated Day Degrees		Days Ground Frost	Potential Evap-oration mm	Rainfall		Bright Sunshine hours		Mean daily Solar Radiation	Windspeed km/h	
	Daily Air Maxima		Daily Air Minima		0·1m Soil		0·3m Earth												
	Mean °C	DFA *	Mean °C	DFA *	Mean °C	DFA *	Mean °C	DFA *	Above 6°C	Below 6°C			Total mm	DFA *	Total	DFA *	mWh/cm²	Mean	DFA †
January	2·6	−3·0	−3·3	−3·3	0·2	−1·3	1·6	−0·9	1	198	28	0·0	47·2	−16·0	62·0	+8·8	55	11·8	−0·7
February	3·4	−2·3	−1·9	−2·0	−0·7	−2·3	0·5	−2·1	2	148	28	10·4	10·9	−37·6	72·4	−1·6	114	13·0	+0·4
March	6·1	−1·9	−0·1	−1·8	1·9	−1·4	3·0	−1·2	10	101	23	35·1	57·6	+13·4	116·1	+10·3	221	20·5	+5·8
April	9·9	−1·2	3·3	+0·1	5·7	−0·5	6·3	−0·6	50	32	11	55·9	55·6	+14·3	108·1	−50·9	285+	15·0	+0·1
May	12·1	−1·6	5·1	−0·7	9·1	−1·0	9·3	−0·8	101	20	11	76·0	88·4	+32·3	151·3	−32·5	432	12·9	−0·3
June	16·9	−0·1	9·0	+0·4	14·2	+0·3	13·7	+0·2	209	0	0	84·3	46·6	−2·3	169·7	−13·7	486	10·6	−1·3
July	19·0	+0·6	10·4	+0·3	15·5	+0·3	14·7	−0·4	271	0	0	92·0	67·5	+2·8	164·1	−11·7	466+	10·7	−0·3
August	16·9	−1·0	9·7	−0·3	13·7	−0·6	14·7	−0·1	228	0	0	61·0	71·7	+2·1	108·1	−46·7	328+	8·5	−1·4
September	15·8	−0·1	7·9	−0·6	11·0	−0·5	12·6	0	179	5	6	52·7	20·7	−38·0	145·2	+25·9	278	14·1	+4·0
October	12·5	−0·2	8·0	+1·7	9·0	+0·7	10·7	+0·9	136	5	7	18·1	91·0	+33·5	63·9	−27·1	134	11·0	+0·1
November	8·6	+0·3	1·7	−0·4	3·3	−0·7	5·9	+0·2	38	64	23	9·4	45·7	−10·5	69·5	+2·2	66	12·6	+0·6
December	6·1	−0·2	1·6	+0·7	2·5	+0·5	5·0	+1·5	17	87	23	1·6	80·8	+12·5	42·9	−2·1	37	11·5	−0·8
TOTALS	—	—	—	—	—	—	—	—	1242	660	137	—	683·7	+6·5	1273·3	−139·1	242	12·7	+0·5

* DFA = Deviation from average 1954-1978
\+ = Includes estimated values

† DFA = Deviation from average 1959-1974

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	0·3m Earth Mean °C	0·3m Earth DFA *	Accumulated Day Degrees Above 6°C	Accumulated Day Degrees Below 6°C	Days Ground Frost	Rainfall Total mm	Rainfall DFA *	Bright Sunshine Hours Total	Bright Sunshine Hours DFA *	Mean daily Solar Radiation mWh/cm²	Windspeed Mean km/h
January	3·6	−3·1	−2·5	−4·0	0·7	2·4	−2·5	2	158	25	74·7	−15·6	51·5	+8·8	57·8	11·0
February	4·3	−2·0	−1·1	−2·0	0·6	1·7	−1·9	5	117	25	14·8	−52·7	89·3	+15·4	131·7	13·2
March	6·7	−0·9	1·2	−0·6	2·8	3·9	−1·3	14	69	22	96·8	+57·0	96·2	−8·8	208·8	17·4
April	9·6	−1·5	3·7	+0·5	5·8	6·7	−0·6	49	27	12	58·0	+19·8	136·7	−31·3	332·9	13·3
May	12·2	−1·9	4·9	−1·6	8·9	9·5	−0·7	105	21	13	41·8	−14·9	197·4	+23·5	476·0	10·8
June	16·7	−0·4	9·5	+1·0	13·4	13·3	+0·3	224	0	0	45·9	−5·9	162·4	−43·9	480·9	11·0
July	16·7	−0·9	10·9	+0·3	13·9	13·9	−0·6	250	0	0	83·2	+13·3	102·4	−69·2	365·6	10·5
August	16·9	−0·9	9·8	−1·0	13·3	14·5	−0·1	238	0	0	146·6	+79·0	162·7	+9·7	384·5	8·8
September	15·2	−0·5	9·0	+0·2	11·6	13·2	+0·1	195	5	3	65·1	−4·3	125·9	+0·2	262·9	13·9
October	13·5	+0·5	8·2	+1·7	9·4	11·1	+0·6	159	4	5	115·1	+44·3	78·1	−21·6	128·0	11·5
November	7·3	−1·2	2·9	0·0	4·3	5·4	−2·2	53	29	15	142·0	+43·1	30·2	−25·4	38·8	10·8
December	7·3	−0·5	2·6	−0·4	4·1	6·1	0·0	32	55	20	121·6	+37·7	53·2	+14·9	37·1	13·4
TOTALS	—	—	—	—	—	—	—	1326	485	140	1005·6	+200·8	1286·0	−127·7	—	—

DFA * — Deviation from average, recorded at Weather Station Department of Plant Pathology, West of Scotland Agricultural College, Auchincruive, 1954-1975.

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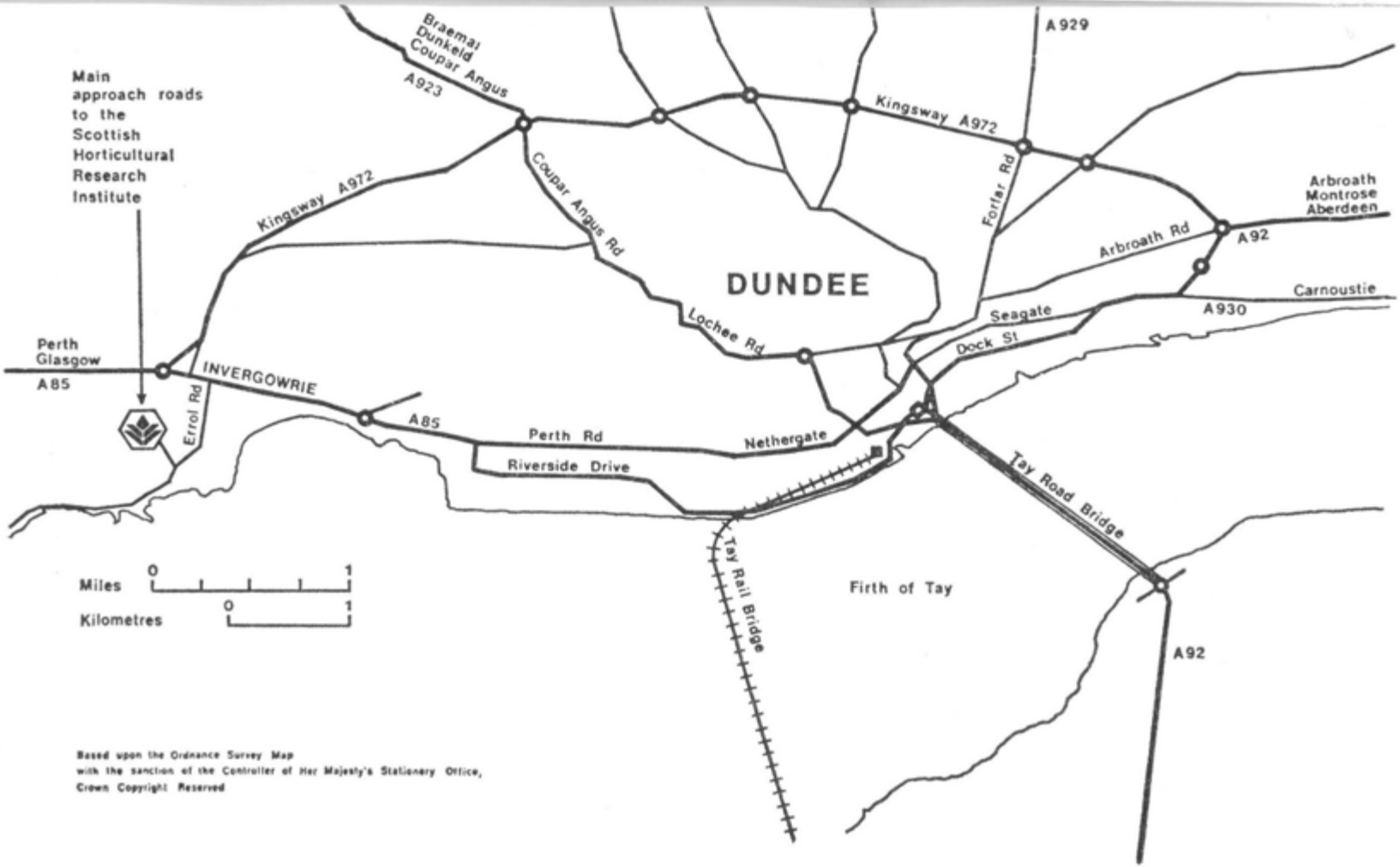
Scottish Institute of Agricultural Engineering	Bush Estate, Penicuik, Midlothian, EH26 0PH
Scottish Plant Breeding Station	Pentlandfield, Roslin, Midlothian, EH25 9RF

ABBREVIATIONS

ADAS	Agricultural Development and Advisory Service
ARC	Agricultural Research Council
ARS	Agricultural Research Service
BA	British Association
BBC	British Broadcasting Corporation
DAFS	Department of Agriculture and Fisheries for Scotland
ERCC	Edinburgh Regional Computing Centre
EHS	Experimental Horticultural Station
ESCA	East of Scotland College of Agriculture
FBPP	Federation of British Plant Pathologists
GMT	Greenwich Mean Time
HEA	Horticultural Education Association
HFRO	Hill Farming Research Organisation
ISHS	International Society for Horticultural Science
JCO	Joint Consultative Organisation
NFT	National Fruit Trial
NIAB	National Institute of Agricultural Botany
NIAE	National Institute of Agricultural Engineering
NSCA	North of Scotland College of Agriculture
NSDO	National Seed Development Organisation
PMB	Potato Marketing Board
RHAS	Royal Highland and Agricultural Society
SARI	Scottish Agricultural Research Institute
SIO	Scottish Information Office
SNSA	Scottish Nuclear Stock Association
SPBS	Scottish Plant Breeding Station
SRC	Science Research Council
UK	United Kingdom
USA	United States of America
USDA	United States Department of Agriculture
VTSC	Virus tested stem cutting
WSAC	West of Scotland Agricultural College



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