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ANNUAL

THE SCOTTISH HORTICULTURAL
RESEARCH INSTITUTE

1978

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The Scottish Horticultural Research Institute

25th Annual Report for the year 1978

The Scottish Horticultural Research Institute
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Governing Body

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T. Martin Clucas, Esq.

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Professor W. D. P. Stewart, B.SC., PH.D., D.SC., F.R.S., F.R.S.E.,
F.I.BIOL.

Professor M. B. Wilkins, B.SC., PH.D., D.SC., A.K.C.

Staff

Director C. E. Taylor*†, B.SC., PH.D., F.R.S.E., F.I.BIOL.

Deputy Director B. D. HARRISON*, B.SC., PH.D.

Crops Research

Head of Section P. D. Waister*, B.SC., PH.D.
R. J. Clark, B.A.
M. R. Cormack, N.D.H.
J. B. Cowan, B.SC., M.I.S.
P. A. Gill.
T. W. Hegarty, B.SC., DIP.AGR.SCI., PH.D.
H. M. Lawson, B.SC., M.AGR.SC., DIP.AGRIC.
D. K. L. MacKerron, B.SC., PH.D.
D. T. Mason, B.SC., PH.D.
Heather A. Ross, M.I.BIOL.
H. Taylor, N.D.H.
R. Thompson, B.SC., M.SC.
Pauline B. Topham, M.A., B.SC., PH.D.
K. N. Weaver, B.SC.
J. S. Wiseman, S.D.H.

Assistants Mrs Janet E. Brinklow.
Mrs Jeanette McD. Brown.
D. G. Cathro.
D. Crabb.
Jane E. Kettles.
G. C. Nicol.
R. N. Wilson.
Mrs Gladys Wright.

Plant Breeding

*Acting
Head of Section* D. L. Jennings†, B.SC., PH.D., S.H.M.
M. M. Anderson, N.D.H., S.D.H., D.H.E.
Eleanor Carmichael.
A. Dale, B.SC., PH.D.
J. R. T. Hodgkin, B.SC., PH.D.
A. J. Redfern, B.TECH.
P. Smith, B.SC.
Barbara M. M. Tulloch, S.D.H.
A. B. Wills, B.SC., M.S., PH.D.
Mrs Eveline M. Wiseman.

Assistants J. N. Dick.
Mrs Norma Dow.
T. P. Reid.
Judith Thomson.

West of Scotland Unit (Auchincruive)

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| <i>Officer-in-Charge</i> | H. J. Gooding, B.SC., PH.D., F.L.S. R. J. McNicol, B.SC. |
| <i>Assistant</i> | Janet H. Young. |
| <i>Secretary</i> | Janet B. Henry. |
| <i>Estate</i> | R. Dorman. C. A. Reid. |

Mycology

| | |
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| <i>Head of Section</i> | R. A. Fox*, B.SC., B.AGR., M.I.BIOL. E. Patricia Dashwood, B.SC., M.SC. J. M. Duncan, B.SC., PH.D. A. J. Hargreaves, B.SC. J. G. Harrison, B.SC., PH.D., M.I.BIOL. Diana M. Kennedy, B.SC. R. Lowe. G. D. Lyon, B.SC., M.SC., PH.D., D.I.C. Isabel G. Montgomerie, B.SC., PH.D. M. C. M. Pérombelon, B.SC., M.SC., PH.D. D. A. Perry, B.SC., PH.D. B. Williamson, B.SC., M.SC., PH.D. H. M. Wilson. |
| <i>Assistants</i> | Mrs Alison M. Campbell. Mrs Norma M. Colliar. Mrs Lisbeth J. Hyman. Teresa McNally. Naomi A. Nyananyo. Alison Savege. |
| <i>Attendant</i> | Mrs Joan Jenkins. |

Virology

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| <i>Head of Section</i> | B. D. Harrison*, B.SC., PH.D. H. Barker, B.SC. J. Chambers, B.SC. G. H. Duncan. A. T. Jones, B.SC., PH.D. J. G. Lindsay, B.SC. M. A. Mayo, B.SC., PH.D., M.I.BIOL. W. P. Mowat, B.SC., DIP.AGR.SCI. A. F. Murant, B.SC., PH.D. J. H. Raschké. I. M. Roberts, DIP.RMS. D. J. Robinson, M.A., PH.D. |
| <i>Assistants</i> | Mrs Margot E. Aveyard. Erica M. Bell. Margaret J. Cannon. Susan Mahoney. |
| <i>Attendant</i> | Mrs Rena Reid. |

Zoology

Head of Section D. L. Trudgill*, B.SC., PH.D.
T. J. W. Alphey, B.SC., PH.D.
B. Boag, B.SC., PH.D.
D. J. F. Brown, B.A.
S. C. Gordon.
W. M. Robertson.
J. A. T. Woodford*, M.A., PH.D.

Assistants Mrs Sylvia R. Dick.
Mrs Sandra A. Husband.
Mrs Sheena S. Lamond.
Mrs Irene E. Raschké.

Estate

Manager W. I. A. Jack.

Experiments Officer G. Wood, B.SC., PH.D.

Supervisors R. W. Reid.
R. D. Taylor.
A. Bruce.
C. C. Carrie.
W. C. W. Jolly.
A. D. Lindsay.
A. W. Mills.
R. Ogg.
D. S. Petrie.
A. Pirie.
D. G. Pugh.
J. Small.
E. L. Allsworth.
D. C. Cameron.
E. A. M. Gardiner.
J. P. T. Grant.
W. W. Killoh.
P. T. Logie.
A. D. MacDonald.
N. McInroy.
L. A. McNicoll.
J. Mason.
Mandy Morris.
A. Nicoll.
B. D. Robertson.
F. Robertson.
D. R. Simpson.
A. S. Spink.
G. Wilson.

Farm Workshop

W. R. S. Batchelor.
G. W. Pollock.

Maintenance

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| <i>Head of Section</i> | J. H. Couttie. J. R. Caithness. A. Davidson. A. Low. R. MacDonald. G. Merchant. D. J. G. Redford. J. Rowe. L. A. Swan. |
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Information Services

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| <i>Information Officer</i> | R. J. A. Exley, C.D.H. |
| <i>Photography</i> | T. G. Geoghegan, A.I.I.P. S. F. Malecki. |
| <i>Graphics</i> | Maureen I. McMaster, D.A. |
| <i>Library</i> | Mrs Margaret Mitchell. |

Administration

| | |
|-----------------------------|--|
| <i>Secretary</i> | N. D. Anderson. |
| <i>Assistant Secretary</i> | A. P. Thomson. D. L. McIntosh. I. A. McLeish. Mrs Freida Soutar. |
| <i>Director's Secretary</i> | Ruby B. L. McGill. Margaret Campbell. Mrs Jean Findlay. Mrs Sheena Y. Lawrence. Mrs Margaret Mauchland. Pamela J. Reid. |
| <i>Stores</i> | Mrs Anne L. Bertie. J. Heeney. |

* Honorary Lecturer in the University of Dundee.

† Honorary Senior Lecturer in the University of St Andrews.

General Report

C. E. TAYLOR

The occasion of the twenty-fifth year of the Institute was marked by Open Days on the 14 and 15 July. At the celebratory lunch on the first day the Lord Provost of Dundee, Mr H. W. C. Vaughan, in proposing a toast to the Institute referred to the importance of research in the development of horticulture in Scotland, particularly in the Tayside region where the Institute's research on raspberries had been vital to that crop. In responding to the toast, Mr W. W. Gauld of the Department of Agriculture and Fisheries for Scotland noted the continuing expansion of the Institute both in its buildings and in its scientific capability and referred to the extension of the Institute's research programme into arable crops, a development which the Department endorsed as making full and appropriate use of the scientific resources at the Institute. Sir William Henderson, Secretary of the Agricultural Research Council, recounted some of the achievements of the Institute in its 25 years of research, which are recorded in its annual reports, in scientific journals and in the agricultural press. Sir William conveyed his personal appreciation of the plant breeding achievements of the Institute by adopting the mantle of the Dundee poet, the late William McGonagall, to deliver the following address to the Director.

'Address to the Taylor of Invergowrie'

'Breathes here a man with soul not dead
Who frequently to himself hath said
"By Glen Clova and Glen Isla to Tantallon by the sea,
With Redgauntlet, Saladin and Troubadour,
I have the finest fruit and all without red core.
If spring frosts are a menace,
Then with Ben Lomond and Ben Nevis
The blackcurrant crop is safe for evermore.
The more humble cabbage, to say nothing of the sprout,
Is much improved by F₁ cultivars,
Of these Gleneagles and the Celtic Cross must count among the stars"
This is his tribute to his staff and to those who have gone before.
Now let us wish them all well on their Jubilee,
And go with the Lord Provost to plant a tree
To mark the Silver Jubilee of the Institute.'

The Lord Provost planted a *Cornus controversa* kindly donated by the Royal Botanic Garden, Edinburgh.

There were two other occasions during the year when the research work of the Institute was reviewed. The Institute responded to the MAFF and ARC reviews of Commissioned Research and Development on soft fruit in February and arable crops in April. In October, DAFS conducted a review of the commissioned research packages on potatoes, other arable crops and horticulture. Both these reviews provided opportunities for relating our research interests to those ongoing at other institutes, to the requirements identified by the JCO, and to our own assessment of productive investigations in relation to the needs of industry.

The work of the Institute was reviewed in a different context in July by the Secretary of State's Working Party on the Future of State-funded Plant Breeding and Crops Research in Scotland. The Working Party examined the arrangements for the commissioning and organisation of research in horticulture, plant breeding and arable crop production at the Scottish Plant Breeding Station and at the Scottish Horticultural Research Institute. In November the Working Party announced their recommendations which were the integration of the research effort of the two institutes under the control of one governing body and one director with a phased capital investment to facilitate the transfer of resources from SPBS to SHRI including the acquisition of Gourdie farm near SHRI to replace the Murrays farm at SPBS. These proposals are considered 'the most effective way of obtaining the optimum results from the scientific resources at the two institutes for the benefit of the agricultural and horticultural industry'.

A general purpose building of 840m² was virtually completed in December and will come into full operation for the centralised handling and recording of harvested soft fruit and vegetables for the 1979 season. The building is equipped with a 10 unit grader, a range of cold stores and specialised laboratory areas.

This report summarises the research work undertaken at the Institute during 1978 and commissioned by the Department of Agriculture and Fisheries for Scotland. Each project is numbered for the purpose of accounting and classification by the Agricultural Research Council Planning Unit.

Governing Body

With regret the death is noted of Professor J. R. Matthews, C.B.E, on 12 April, 1978. Professor Matthews was the Chairman of the Board of Management for the Institute appointed by the Secretary of State for Scotland in April 1952 and became Chairman of the Governing Body when the Institute was incorporated in April 1953.

Appointments

B. D. Harrison was appointed Deputy Director.

D. L. Jennings was appointed Honorary Senior Lecturer in the Department of Botany, University of St Andrews.

G. H. Duncan was appointed in March as HSO to assist with electron microscopy in the Virology Section. Also in the Virology Section J. G. Lindsay was appointed SO in September to work in the team studying virus diseases of raspberry and allied crop plants. K. N. Weaver joined the Crops Research Section in April as SO to work on the effects of soil physical factors on seedling emergence of small seeded vegetable crops.

The following Assistant Scientific Officers were appointed during the year:

| | |
|-----------------|------------------------|
| Susan Mahoney | Virology Section |
| Margaret Cannon | Virology Section |
| Teresa McNally | Mycology Section |
| Janet H. Young | West of Scotland Unit. |

Other new members of staff were Mrs Freida Soutar, Clerical Officer (Accounts), J. Rowe, Boilerman and J. Heeney, Storekeeper. New members of the Estate Section were A. Nicoll at Invergowrie and J. C. Goddard and R. Dorman at West of Scotland Unit.

Resignations

| | |
|---------------------|----------------------------------|
| D. MacIntyre | SO, West of Scotland Unit |
| Mrs Margaret Taylor | SO, Virology Section |
| Linda Cable | ASO, Virology Section |
| Frances Devaney | ASO, Mycology Section |
| T. J. Edwards | ASO, West of Scotland Unit |
| Mrs Eleanor Russell | ASO, Virology Section |
| Mrs Bente Bogan | Librarian, Information Services. |
| Helen D. McGregor | Clerical Officer (Accounts) |
| E. A. Davidson | EW, Estate Section |

T. W. Hegarty resigned his PSO post in the Crops Research Section to take up an appointment in the Chief Scientific Adviser's group in DAFS.

Promotions

| | | |
|-----------------------|---|----------------------------|
| Isabel G. Montgomerie | } | SSO to PSO |
| J. A. T. Woodford | | |
| M. R. Cormack | } | HSO to SSO |
| J. R. T. Hodgkin | | |
| Diana M. Kennedy | } | SO to HSO |
| R. Lowe | | |
| T. G. Geoghegan | | Sen. Phot. to Princ. Phot. |
| S. F. Malecki | | Phot. to Sen. Phot. |
| R. MacDonald | | P & TO IV to P & TO III |

Awards

F. Bem Ph.D., University of Dundee

T. G. Geoghegan A.I.I.P.

D. L. Jennings was awarded the Scottish Horticultural Medal by the Royal Caledonian Horticultural Society.

Retirements

| | |
|-------------------|----------------------------|
| J. Andrews | EW, West of Scotland Unit |
| Mrs Sarah Borland | LA, West of Scotland Unit |
| J. F. McLean | Storeman |
| H. McNeillie | EW, West of Scotland Unit. |

Research Students

R. M. Brook, an ARC Research Student, completed the final year of his study of factors controlling yield and yield components in field beans.

G. Hoogenboom (Wageningen) completed a five-month investigation of flower initiation in field bean, and returned to the Netherlands.

H. M. A. Wahdan (Horticultural Research Institute, Cairo) commenced a three-year study of environmental effects on the growth and development of the strawberry.
(Crops Research Section)

K. Forbes was appointed to an SRC CASE Research Studentship (jointly with the Institute of Animal Genetics, Edinburgh, and the University of Edinburgh) to study the genetics of *Erwinia carotovora*.
(Mycology Section)

Saija Kujala (University of Helsinki) assisted from June to October with the measurement of strawberry characters associated with mechanical harvesting.
(Plant Breeding Section, West of Scotland Unit)

F. Bem, supported by the Greek State Scholarship Foundation, completed his studies on viruses of umbelliferous plants and returned to Greece in September.

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

Lesley Torrance completed her work on grass viruses as a postgraduate student of DAFS and left in November.

P. Waterhouse, an ARC research student, arrived in October to work on aphid-transmitted viruses of umbelliferous plants. (Virology Section)

C. S. Aveyard continued studies on the control of potato aphids in relation to spread of virus, funded by the PMB.

D. J. F. Brown commenced studies on the distribution of *Xiphinema* spp. in Europe and on the variability of *X. diversicaudatum* as a part-time external student with the Open University.

Miss L. M. Cotes commenced studies on the tolerance of potatoes to damage by potato cyst nematode, financed by a grant from the PMB.
(Zoology Section)

Sandwich Course Students

Miss Gael Doig (Dundee College of Technology) assisted from April to September with research on seed germination and establishment.
(Crops Research Section)

G. R. Andrews (National College of Food Technology, Weybridge) assisted from April to August with research into rapid methods of assessing the concentration of ascorbic acid in black currant selections.
(Plant Breeding Section)

Lindsay Jones (Dundee College of Technology) from April to September assisted with research assessing the aggregation of *Longidorus elongatus* in the field.
(Zoology Section)

Visiting Workers

M. F. El Mula Ahmed (Faculty of Agriculture, University of Khartoum) worked for 3 months on techniques in seed germination research, under an award from the Inter-University Council.

A. Nes (Kise Agricultural Research Station, Norway) arrived in February to spend a year studying within-plant competition and its effects on yield components in black currants. (Crops Research Section)

A. Ghanekar, holder of a Training Fellowship from the International Atomic Energy Agency, completed his studies on the role of potato lectin in host-pathogen interactions in potato decay and returned to the Bhabha Atomic Research Centre, India, in September. (Mycology Section)

Dr E. L. Halk completed his postdoctoral year working on carrot mottle virus and returned to the USA in August.

Dr R. I. Hamilton, from the Agriculture Canada Research Station, Vancouver, arrived in July to spend a year working on nepoviruses and virus nucleic acid under a transfer of work arrangement.

Mr A. Kurppa, University of Helsinki, is spending six months on a Kellogg Foundation Fellowship learning virological techniques, and studying tobnaviruses. (Virology Section)

Dr A. Bello (Instituto de Edafologia y Biologia Vegetal, Madrid) worked from October until December on the creation of survey data files to be used in the production of nematode distribution maps. (Zoology and Crops Research Section)

Mrs S. Kurppa (University of Helsinki) spent from August until January 1979 studying methods in nematology and the response of plants to feeding by longidorid nematodes.

Dr F. Roca (Laboratorio di Nematologia Agraria applicata ai Vegetali, Bari, Italy) spent from July until September studying the methods employed in testing for nematode transmission of viruses. (Zoology Section)

Sabbatical Leave

A. T. Jones returned in April from New Zealand where he studied lucerne and raspberry viruses for a year at the Department of Scientific and Industrial Research, Plant Diseases Division, Auckland, during the tenure of a Senior Fellowship of the National Research Advisory Council.

W. P. Mowat returned from the Victorian Plant Research Institute, Australia, in March, having worked there for 6 months on viruses affecting bulbous ornamentals.

P. D. Waister spent 4 months in the State Universities of Washington and Oregon, at the invitation of Pacific Northwest soft fruit research workers. He was involved in research on yield components in raspberries and strawberries, and was asked to report on the organisation of co-operative research and development in soft fruit in Washington, Oregon, Idaho, and British Columbia. Expenses of the visit were met by growers' organisations in Washington and Oregon.

Visits Abroad

T. J. W. Alphey attended the first meeting of the sub-committee on the Taxonomy of the European Soil Fauna, held in Hamburg 6-7 November as the nematology and UK representative.

T. J. W. Alphey, B. Boag, W. M. Robertson and D. L. Trudgill attended the 3rd International Congress of Plant Pathology held in Munich from 14-23 August.

R. A. Fox attended a meeting of the Council of the European Association for Potato Research and its Section Chairmen, held in Wageningen, The Netherlands, 9-12 January, *inter alia* to finalise the programme for the Association's 6th Triennial Conference held in Warsaw, Poland, 25 June-2 July. Whilst in Wageningen he also visited the Institute of Phytopathological Research to discuss research on soil-borne diseases and diseases of potato.

R. A. Fox attended, as Chairman, a meeting of the Disease Assessment Committee, Pathology Section, European Association for Potato Research, held in the Research Institute of the Swedish Seed Association, Svalov, and whilst there had discussions on the Institute's potato breeding programme.

B. D. Harrison visited the Caribbean Agricultural Research and Development Institute in Trinidad and Barbados for a week in November as scientific assessor for Ministry of Overseas Development projects on yam virus diseases. He then travelled to the University of Florida, Gainesville, for discussions on plant virus research.

B. D. Harrison, M. A. Mayo, A. F. Murant and D. J. Robinson attended the Fourth International Congress of Virology at The Hague, The Netherlands, from 30 August-6 September. Murant also visited Wageningen for discussions at the Institute for Plant Protection Research, and the Department of Virology of the Agricultural University. Harrison and Mayo received DAFS travel grants.

A. T. Jones and A. F. Murant attended the Third International Congress of Plant Pathology at Munich from 16-23 August. Murant received a DAFS travel grant.

M. A. Mayo visited the Institut de Biologie Moleculaire et Cellulaire, Strasbourg, from 11-21 July for discussions and experiments in collaboration with Dr Christiane Fritsch on the translation of nepovirus RNA species.

M. C. M. Pérombelon attended the Third International Congress of Plant Pathology held in Munich, 16-23 August 1978 and the Fourth International Congress of Plant Pathogenic Bacteria held in Angers 27 August-1 September 1978. He also spent 24-26 August at the Laboratoire de Génétique des Micro-organismes (INRA), Versailles, in connection with collaborative work between the SHRI and Versailles on the genetics of erwinias.

W. M. Robertson spent a week in March at the Institut für den Wissenschaftlichen Film, Göttingen, W. Germany, analysing film of *Xiphinema index* feeding.

R. Thompson attended an EEC Protein Group meeting on *Vicia faba* held at Bari, Italy, from 24-27 April.

C. E. Taylor attended three meetings of the Consiglio Scientifico del Laboratorio di Nematologia agraria, Bari, Italy, on 16-17 March, 27-30 June and 18-20 December. Also, he attended the 3rd International Congress of Plant Pathology at Munich on 15-24 August. He also visited the Rijksuniversiteit, Gent, 27-28 November to discuss with Professor A. Coomans and colleagues research on the ultra-structure of nematodes as it relates to the SHRI programme of work and to give a lecture to students.

A. B. Wills visited Holland from 23-27 April for discussions on breeding problems and methods. His itinerary included the Institute for Horticultural Plant Breeding (IVT), the Institute for Research on Varieties (RIVRO), and the Foundation for Agricultural Plant Breeding (SVP), Wageningen; also the General Netherlands Inspection Service for Vegetable and Flower Seeds (NAKG), Roelofarendsveen, and the Vegetable Breeding Companies of Royal Sluis, Bejo, Nunhems Zaden and A. R. Zwaan.

Courses Attended

T. J. W. Alphey, B. Boag, D. L. Trudgill and Mrs I. E. Raschké attended the Association of Applied Biologists Workshop on Spiral and Stunt Nematodes at Rothamsted Experimental Station on 21 September.

J. R. T. Hodgkin attended 28th Easter School in Agricultural Science at the University of Nottingham, School of Agriculture, 18-22 September.

Conferences at which papers were given

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| 4-5 January | Society for General Microbiology Virus Group, London. |
| | B. D. Harrison New diagnostic methods in plant virology. |
| | B. D. Harrison The nucleic acid of maize streak and cassava latent viruses. |
| 5-6 January | ADAS and Wisbech and District Fruit Growers' Association, Merchants and Manufacturers Conference on 'Strawberries for Processing'. |
| | H. J. Gooding Strawberry Breeding. |

- 21-23 February National Farmers' Union ' British Growers Look Ahead ' National Conference and Exhibition, Harrogate.
H. J. Gooding New varieties of strawberry, blackcurrant, hybrid berry and raspberry—mechanical harvesting, productivity and market opportunities.
- 28 February National Farmers' Union, Soft Fruit Committee, Conference on Soil-borne Pests and Diseases of Strawberry, London.
I. G. Montgomerie Red Core.
- 4-7 April Fifth ARC Conference on Electron Microscopy, Bristol.
I. M. Roberts Studies on the structure of the disk-like aggregates of tobacco rattle virus protein.
I. M. Roberts Electron microscopy — the occupational hazards.
- 10-14 April Association of Applied Biologists, Norwich.
D. L. Jennings Breeding Logan-like *Rubus* hybrids.
- 11-13 April ARC Photographers Conference, Aberdeen.
T. G. Geoghegan Recording of nematode feeding behaviour using cine, television and video.
- 11-14 April Association of Applied Biologists, Norwich.
M. R. Cormack Blueberries and cranberries in Scotland.
- 24-27 April EEC Protein Group: *Vicia faba*.
R. Thompson Crop growth and partition of assimilates in field bean (*Vicia faba*): response to elimination of some major constraints.
- 6-7 July Federation of British Plant Pathologists Virology Group, Aberystwyth.
A. T. Jones Two new viruses of lucerne in New Zealand.
L. Torrance Properties and relationships of phleum mottle group viruses found in Scotland.

- L. Torrance The sensitivity of serological techniques for detecting some grass viruses.
- 13 July Micro 78 International Symposia and Exhibition, London.
I. M. Roberts Electron microscope diagnosis of plant viruses.
- 15-24 August Third International Congress of Plant Pathology, Munich.
T. J. W. Alphey Mapping the distribution of nematodes in ecological studies.
B. Boag The use of surveys in ecological studies.
A. F. Murant Heracleum latent virus, a new closterovirus.
M. C. M. Pérombelon Population dynamics of some pectolytic bacteria in relation to soft rot of potato tubers.
W. M. Robertson Ultrastructure of the oesophageal bulb in *Longidorus* and *Xiphinema* spp.
W. M. Robertson Salivation in *Xiphinema* spp.
C. E. Taylor Vector capacity of nematodes.
D. L. Trudgill Feeding behaviour of *Xiphinema diversicaudatum*.
- 27 August-
1 September Fourth International Congress of Plant Pathogenic Bacteria, Angers, France.
M. C. M. Pérombelon Developing a mating system in *Erwinia carotovora*.
M. C. M. Pérombelon Contamination of potato crops by air-borne *Erwinia carotovora*.
M. C. M. Pérombelon Dispersion and deposition of air-borne *Erwinia carotovora*.
- 28 August-
1 September Autumn Conference of Horticultural Education Association. 'The Winter Factor in British Horticulture, Edinburgh.'
C. E. Taylor The winter factor in relation to the incidence and control of crop pests and diseases.

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| | P. D. Waister | Hardiness of some fruits and vegetables. |
| | J. A. T. Woodford | Raspberry pests in winter. |
| 30 August- 6 September | Fourth International Congress of Virology, The Hague. | |
| | B. D. Harrison | Properties of viruses favouring their survival in different plant communities. |
| | B. D. Harrison | Interactions in protoplasts of strains of raspberry ringspot virus. |
| | M. A. Mayo | Translation <i>in vitro</i> and <i>in vivo</i> of tomato black ring virus satellite RNA. |
| | M. A. Mayo | Tobacco rattle virus-induced proteins in infected tobacco protoplasts. |
| | D. J. Robinson | Photosynthesis in leaves infected with a yellow variant of tobacco rattle virus. |
| 18-22 September | Seed Production. 28th Easter School in Agricultural Science, University of Nottingham. | |
| | D. A. Perry | The concept of seed vigour and its relevance to seed production techniques. |
| | D. A. Perry | Deterioration of barley seed and its effects on field performance. |
| 21 September | Association of Applied Biologists Workshop on Spiral and Stunt Nematodes. | |
| | B. Boag | The identification and biology of spiral nematodes (Hoplolaimidae) in the British Isles. |
| 26-28 September | European Discussion Group on <i>Phytophthora</i> Diseases of the Strawberry, Dundee. | |
| | H. J. Gooding | Some problems of breeding strawberries for field resistance to red core disease. |
| | R. J. McNicol | A new source of resistance to <i>Phytophthora cactorum</i> in strawberries. |
| | I. G. Montgomerie | Present and future control of red core by fungicides. |

- 8 November Sixth Scottish Symposium on Electron Microscope Techniques, Glasgow.
G. H. Duncan Spreading and electron microscopy of nucleic acids.
- 21 November Society of Chemical Industry Agriculture Group, London.
T. W. Hegarty The effects of soil impedance on the emergence of calabrese, carrot, onion and sugar beet seedlings.
- 13-15 December FBPP/AAB/BMS Conference on Plant Health, London.
I. G. Montgomerie Official control of red core.
- 13 December Association of Applied Biologists, London.
T. J. W. Alphey The development of computer mapping of nematode distributions.
B. Boag Observations on the life cycle and seasonal fluctuations in the numbers of *Rotylenchus robustus*.
D. L. Trudgill Damage caused by *Pratylenchus penetrans* in Scottish raspberry plantations.
- 19-21 December Society for Experimental Biology.
D. K. L. MacKerron The relationship between growth and yield in raspberry as influenced by water stress.

Conferences Organised

M. C. M. Pérombelon was a member of the sub-committee of Section VII, Post-harvest Pathology, and Organiser and Chairman of Session 2 (Section VII), Physiological factors influencing susceptibility and resistance to post-harvest diseases of tubers, of the Third International Congress of Plant Pathology, Munich, Federal Republic of Germany, 16-23 August 1978.

I. G. Montgomerie organised a meeting of the European Discussion Group on Strawberry Diseases caused by *Phytophthora* spp., which was held at SHRI from 26-28 September.

C. E. Taylor organised a meeting of the European Science Foundation Group to discuss the European Plant Parasitic Nematode Survey during the Third International Congress of Plant Pathology at Munich, 15-24 August.

C. E. Taylor was chairman of the organising committee for the Autumn Conference of the Horticultural Education Association, 28 August to 1 September, at Pollock Halls, Edinburgh, entitled 'The Winter Factor in British Horticulture'.

Editorial Duties

- R. A. Fox Member of the Board of Editors of *Potato Research*.
- H. J. Gooding Member of Board of Editors of *Horticultural Research*.
- B. D. Harrison Editor of *Journal of General Virology*.
Editor of *Commonwealth Mycological Institute/ Association of Applied Biologists Descriptions of Plant Viruses*.
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*.
- 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 *Cruciferae Newsletter*.

Service on Committees

- T. J. W. Alphey European Science Foundation Sub-Committee on the Taxonomy of the European Soil Fauna.
- B. Boag Nematology representative on the European Invertebrate Survey Committee.

- A. Dale NFT Scottish Sub-Committee.
- R. J. A. Exley Tayside and Fife Branch Committee of the B.A.
- R. A. Fox Chairman, Pathology Section, European Association for Potato Research (to July 1978 and then Vice Chairman).
Council member, European Association for Potato Research.
- H. J. Gooding City and Guilds of London Institute Standing Committee for Tropical Agriculture and Agricultural Engineering.
Fruit Working Group Committee.
NFT Scottish Sub-Committee.
NFT Strawberry Sub-Committee.
- B. D. Harrison Association of Applied Biologists, Vice-President.
British National Committee for Biology,
Member of Microbiology Sub-Committee.
Genetic Manipulation Advisory Group:
Subcommittee on Genetic Manipulation in Plants.
JCO, Member of Plant Science Committee.
Section of Virology, International Association of Microbiological Societies, Member of Advisory Council.
- T. W. Hegarty JCO, Member of Field Vegetables.
Committee Working Group on Crop Physiology.
- D. L. Jennings NFT Raspberry Sub-Committee.
NFT Scottish Sub-Committee.
- A. T. Jones Virology Group of Federation of British Plant Pathologists, Member of Committee.
- H. M. Lawson Association of Applied Biologists Weeds Group.
- 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.
- HEA Scottish Branch.
- Potato Marketing Board—Member of Research and
Development Committee.
- R. Thompson NIAB Vegetable Trials Advisory Committee.
SHRI/Scottish Colleges Liaison Group.
- Pauline B. Topham Convener ERCC PLU 2980/370 Service Committee.
- P. D. Waister JCO, Member of Fruit Committee.
NFT Scottish Sub-Committee.
Dundee University Botanic Garden Committee.
Tayside and Fife Branch Committee of the B.A.

Exhibitions

Four new strawberry cultivars bred at SHRI West of Scotland Unit, their qualities and micropropagation, were exhibited during the year at the ADAS and Wisbech and District Fruit Growers Association 'Strawberries for Processing' conference in Wisbech, at the National Farmers' Union 'British Growers Look Ahead' conference in Harrogate, at Chelsea Show in London, and at The Grower sponsored 'Fruit Focus' meeting in Tonbridge.

Radio and Television

H. J. Gooding answered questions on the new SHRI strawberry cultivars for the BBC External Service, recorded on 3 July.

P. D. Waister discussed progress in mechanical harvesting of raspberries on BBC Radio Scotland on 11 July.

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CROPS RESEARCH

P. D. WAISTER

Assessment of the relative performance of genotypes of a crop species would ideally be based on comparisons made when each genotype is grown under its optimum method of culture. This year there have been striking illustrations of the importance of the interaction between genotype and method of culture, in a number of different species.

In raspberries, control of cane vigour has been particularly successful in enhancing the yield of cv. Glen Clova but not of other cultivars; cv. Malling Admiral has responded particularly well to the biennial cropping system, while cv. Malling Jewel, the standard commercial cultivar, does not appear to have the capacity to respond well to either of these new cultural methods.

Defoliation of the strawberry cv. Saladin after fruiting in 1977 resulted in its producing double the yield of the non-defoliated control in 1978, but the same treatment applied to cv. Jurica halved its yield.

In annual crops, population density is probably the major factor affecting plant form and growth rate. Its differential effects on three field bean genotypes were apparent both in total yield and its components.

Such interactions have always bedevilled cultivar trials, but they also pose problems for the agronomist or physiologist who aims to provide assistance to plant breeders in the construction of model plant types. On the other hand, with knowledge of the potential plasticity of form in response to cultural methods, it should be possible to decrease the stringency of the genotype specification for the models.

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

Crop response to shelter

The responses of strawberries to shelter from wind have been examined for several years and to facilitate the recording of plant growth the crop was grown as rows of single plants. Matted rows are the more usual commercial practice and these are being used in a new shelter experiment planted this year.

At the end of the growing season counts were made of plant survival, of stolons produced and of rooted crowns and there were no significant differences attributable to shelter.

Differences in strawberry growth were found in a shelter experiment on a grower's plantation near Aberdeen. Shelter improved plant survival by 5% (99% compared with 94%), increased runner production by 18%, and rooted runners by 37%. However, the amount of runnering was low by normal standards with averages of 4.6 and 3.9 runners per plant in sheltered and exposed plots respectively, which suggests that the problems of establishing matted rows at that site arose from environmental factors other than wind exposure.

Measurements of photosynthesis on damaged and undamaged leaves from potted strawberry plants were continued during the summer. Light compensation points were between 5 and 9 $\mu\text{E}/\text{m}^2/\text{s}$ at 20°C. Maximum observed rate of photosynthesis by undamaged leaves was about 200 $\mu\text{g}/\text{CO}_2/\text{cm}^2/\text{h}$. Damaged leaves gave a range of maximum observed rates, between 70 and 130 $\mu\text{g}/\text{cm}^2/\text{h}$. As previously observed, rates of dark respiration were higher in damaged leaves than in undamaged ones.

Irrigation and water use

During the spring of 1978 the experiment on water use by raspberries was terminated. Final measurements were made on soil moisture, water tables, and root distribution. Examination of roots exposed in the face of a pit cut across the line of a row revealed a much more uniform exploitation of the inter-row space than had been expected. Although there was a general increase in yield in the irrigated plot over the life of the experiment, yield increases reached statistical significance in only 4 out of 8 years. Since the raspberry cane is a biennial structure, irrigation can affect yield in two ways. Irrigation during the year of harvest increases berry size (8-14%), but the other components of yield are determined earlier and may be influenced by irrigation in the first year of a cane's life. The most consistent effect of irrigation is to increase cane growth, although in some cases this may lead to a reduction in other components of yield, such as laterals per cane.

(D. K. L. MacKerron)

Frost damage in black currants

The degree of spring frost damage sustained by black currant cultivars varies greatly both within and between seasons. Some of this variation is related to season of flowering and though the later cultivars tend to escape frost this is not invariably so, because of the erratic timing of frosts.

There have been reports of inherent differences in tissue susceptibility, but the evidence is often equivocal. An investigation has been started to determine susceptibility to frosts of known severity at specific development periods.

Seven cultivars including Baldwin, Ben Lomond and Ben Nevis, together with one seedling N43/6 were artificially frosted in containers, using a portable frost chamber. A minimum air temperature of -3°C was applied at regular intervals from early April until late May, during which time the majority of the cultivars had passed from pre-grape stage to 50% flowering. Damage, showing as browning of the tissue, was assessed 3 days after frosting by transversely sectioning the flowers. Most cultivars showed maximum injury between grape and first flower, the main exception being the seedling N43/6 which suffered most damage with 43% of buds affected, prior to grape stage. The greatest bud death occurred in cv. Brodtop (60%), most other affected cultivars having 20-30% of buds killed.

Bud death was especially low in Ben Lomond, not exceeding 5% until grape stage was well past and then increasing to a level similar to Baldwin.

Brodtop appeared especially prone to injury to the apex of the stigma in open and partly opened flowers, and this would probably reduce fertilisation.

Overall there was a large variation in injury between adjacent nodes and even within strigs, similar to that found under natural frost conditions in the field.

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

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

Winter survival of onions

Nine cultivars (seven of which were Japanese short day types) were sown during mid-August, 1977. A series of artificial frost treatments were given at monthly intervals from October until April, the temperature applied being the 20 year monthly grass minimum. There were clear differences between cultivars in tissue susceptibility to frosting in October, but not in November when all had developed an adequate degree of hardiness. Thereafter frost-heaving in response to the natural winter weather made it difficult to establish changes in the relative tissue susceptibilities of the cultivars. Overwinter survival in the untreated controls varied from 29% in cv. Presto to 75% in cv. Keep Well. Corresponding mean values for the artificially-frosted plots of these cultivars were 27% and 61%.

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

Light interception in canopies of pea

The cultivars Vedette and Filby were used to provide contrasting types of canopy. At the end of April, the crops were sown in 9 blocks, 3 of which were used for regular measurement of light profiles. The remaining 6 blocks were sampled on 6 or 7 occasions at fortnightly intervals. Plastic netting was used for support to prevent lodging. The canopy was sampled using stratified clipping to give information about leaf area distribution within the canopy, and its rate of development. The plant densities achieved were 121/m² and 101/m² in Vedette and Filby respectively at which levels it was expected that the yields of both cultivars would be insensitive to small changes in density. Final yields were determined at the end of August for Vedette, and in early September for Filby, when each cultivar was fully mature. On a dry weight basis the yields of peas were 306 g/m² and 370 g/m² in Vedette and Filby respectively (LSD 5%=44.5).

Total 'leaf' area indices ('leaf' meaning all plant organs) reached a maximum at the fourth or fifth harvests i.e. mid to end of July. In Filby the mean maximum LAI (leaf area index) achieved was 4 which is comparable with that achieved by many crops. Vedette, however, gave a mean maximum LAI of 11 which may be supra-optimal and lead to reduced net growth rates. Analysis of relative growth rates and of the relationship between canopy structure and light interception are not yet completed.

As an aid to explaining differences in growth performance between the two cultivars, measurements were made of photosynthesis as a function of quantum flux. Attached leaves or tendrils, and pods from potted plants were used.

Preliminary results indicate that Filby has a higher light compensation point than has Vedette, but also a higher level of light saturated photosynthesis (approximately 140 $\mu\text{g}/\text{cm}^2/\text{h}$ in Vedette and over 260 $\mu\text{g}/\text{cm}^2/\text{h}$ in Filby).

Stomatal frequency on several organs of both cultivars was examined using the plastic replica method. The frequencies on leaves and stipules were similar, and appreciably higher than on tendrils, petioles and stems. There were no significant differences between cultivars.

(D. K. L. MacKerron)

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

Seedling emergence and soil moisture content

Calabrese and carrot seeds, untreated or dusted with a fungicide containing benomyl and thiram, were sown in soils at a range of moisture contents from 6% to 17% and held with minimum evaporative loss for 14 days

at 15°C. Water was then added to the soils to give an average 17% moisture content and further seedling emergence was noted over a further 14 days. Finally an attempt was made to retrieve any ungerminated seeds to check their viability. There was no effect of fungicide on calabrese seeds. After 14 days, seedling emergence was progressively reduced at 10% and 9% moisture content and was zero in drier soils. However, total viability averaged 92% at all moisture contents. Carrot seedling emergence was affected at higher soil moisture contents than calabrese and there was a significant reduction in emergence due to the fungicide seed treatment at 11% and 12% soil moisture content. However, viability was not affected by the fungicide although there was evidence that it was reduced at the lowest soil moisture contents. A reduction in carrot seedling emergence in dry soil conditions due to captan fungicide was noted in a field experiment in 1977 (Ann. Rept 1977).

(T. W. Hegarty, Gael Doig¹)

Seed germination and seedling growth under moisture stress

Inhibition of germination and seedling growth by water stress, immediately after germination was investigated in a range of species using polyethylene glycol 6000 solutions. The water potential at which seedling growth was inhibited (R_{50}) was significantly lower than that which inhibited germination (G_{50}) in calabrese, chicory, clover, cress, leek, lettuce, lucerne, onion, parsnip, radish, red beet, spinach, sweet pepper, tomato and turnip.

The differences between R_{50} and G_{50} varied from 6 to 8 bar for the four Cruciferae but were not always consistent within the other families. The difference was 6 bar for parsnip but only 0.6 bar for carrots (not significant), and this lack of difference in carrot was confirmed in four other seed stocks. Cucumber was the only other crop tested that failed to show a significant difference between G_{50} and R_{50} .

(Heather A. Ross, T. W. Hegarty, M. F. El Mula Ahmed²)

Treatment of lettuce seeds to counter high-temperature and moisture-stress-induced dormancy

Just as seeds of some species, once germinated, can grow at water potentials lower than those that permit germination, so some can also grow at temperatures higher than permit germination. In the lettuce cultivars Hilde and Avondefiance germination was inhibited at 25.4°C and 29.2°C respectively in the dark whereas root growth continued up to

¹ Sandwich Student, Dundee College of Technology.

² University of Khartoum.

37.2°C and 35.4°C. Treatment of the dry seeds for 24h in acetone containing 0.50 mM kinetin together with 0.25 mM gibberellic acid (GA₃) before drying back raised the upper temperature limits for germination in the light to 37.0°C and 36.1°C for Hilde and Avondefiance, respectively, indicating that the specific block to germination in both cultivars had been overcome by light together with this particular combination of growth regulators. The effects of light and growth regulators were additive.

However, light and the same combination of growth regulators failed to overcome the block to germination in response to PEG-induced water stress at 20°C, although both were partially effective. In Hilde the G₅₀ in the dark was -3.1 bar and the R₅₀ was -16.0 bar. Germination in light reduced the G₅₀ to -8.3 bar, growth regulator treatment reduced it to -9.3 bar, and both together reduced it to -10.2 bar. The effects of light and growth regulators were also partially effective but non-additive in Avondefiance. Although germination at high temperature and low water potential was stimulated by the growth regulators, growth after germination was reduced, indicating separate mechanisms governing the initiation of germination and subsequent growth.

(T. W. Hegarty, Heather A. Ross)

Treatment of red clover and calabrese seeds to counter moisture-stress-induced dormancy

In preliminary experiments clover seeds were germinated at 20°C in PEG solutions free of, or containing combinations of, kinetin, GA₃ and 2-(chloroethyl) phosphoric acid (ethrel). Germination was increased from 12% at -9.5 bar without growth regulators to an average 82% at -13 bar in solutions containing 0.3 mM kinetin with 0.7 to 3.5 mM ethrel. Gibberellic acid proved to be ineffective on clover seeds. In a more detailed investigation of germination and seedling growth the G₅₀ and R₅₀ of clover seeds and seedlings in the absence of growth regulators were found to be -8.0 bar and -14.5 bar respectively. Incorporation of 2.0 mM ethrel and 0.3 mM kinetin in the germination medium lowered the G₅₀ to -14.9 bar, indicating that the moisture-stress-induced block to germination had been completely overcome. As with lettuce (above) the same combination of growth regulators which promoted germination also reduced growth after germination.

Preliminary experiments with calabrese seeds have shown separate responses to kinetin, ethrel and GA₃ but no combination has been found which will completely remove the block to germination.

(T. W. Hegarty, Heather A. Ross, M. F. El Mula Ahmed)

Crust watering experiment

Because soil crust strength is dependent on moisture content, seedling emergence through a crust may be improved by preventing the crust from drying, or by re-wetting a dried crust, though the time of re-wetting the crust may be important.

Seeds of calabrese cv. Pacifica were sown by hand on 19 May and 26 June. All rows were given a standard compaction treatment and, apart from unwatered control rows, were also given a standard initial watering treatment of 5 mm applied with a watering can. All plots were protected from natural rainfall by corrugated, clear plastic covers. Rows were either kept moist at the surface by regular watering, were allowed to dry, or were allowed to dry for periods of 3, 6, 9, 12 or 15 days in the case of the first sowing or for 3, 6, or 9 days for the second sowing and thereafter kept moist at the surface by regular watering.

All watering treatments which were allowed to dry produced a soil crust.

For the first sowing, graded seeds of 1.75—2.00 mm were compared with seeds of 2.00—2.25 mm, all sown 2.5 cm deep, while for the second sowing seeds of 1.75—2.00 mm were sown either 2.5 cm or 1.0 cm deep.

Final emergence was recorded and for the second sowing germinated seeds which had failed to emerge were retrieved and counted.

Results for the first sowing showed no difference in mean emergence between the two sizes of seed (39.3% and 39.9%). The highest mean emergence from a crusted treatment was 37.3% which was significantly lower than the control (77.2%). There were no significant differences between any of the watering treatments which ranged from 33.3% to 37.3%. The dried crust gave a slightly lower emergence (27.7%) but this was not significantly lower than the watering treatments.

Results for the second sowing showed a significant difference in final emergence between the shallow rows (70.2%) and the deep rows (51.0%). For all crusting treatments emergence was improved by sowing at 1.0 cm rather than at 2.5 cm. In the absence of watering, emergence of the shallow seeds was 42.3% compared with 72.0% for the deep seeds. With adequate moisture, shallow sowing gave slightly higher emergence even through a crust than deep sowing gave in the absence of crusting.

Figures for the retrieval of germinated seeds which failed to emerge showed significantly more non-emerged seedlings from the deep sowing (35.2%) than from the shallow (2.7%). For the deep sowing only, fewer

seeds failed to emerge in the uncrusted rows (15.0%) than in any of the crusted rows (32.7%-44.7%).

The improvement in emergence to be gained from watering a crust formed by compaction and heavy rainfall on this soil type was small. It was possible to compensate for high soil strengths by sowing at shallow depths when there was sufficient water for germination, but emergence of shallow-sown seeds in dry conditions was as poor as that of deep-sown seed with applied water.

(K. N. Weaver, T. W. Hegarty)

01052 Effects of seed production conditions on germination and establishment of vegetables

Outcrossing in field beans

A check was made on the degree of outcrossing to be expected in field bean crops grown in Scotland where insect activity might be suspected to be less than further south. White-hilum seeds (*mn*) were separated from 10 stocks of cv. Herz Freya which had been produced in previous experiments at the Institute. The proportion of white-hilum seeds ranged from 0.09 to 0.13. The seeds were sown in the spring and the proportion of plants bearing seeds with a white or black hilum were ascertained at harvest for each seed stock. The proportions of white-hilum-seeded plants ranged from 0.43 to 0.68. Using the model of Fyfe and Bailey (*J. Agric. Sci., CE*, 371, 1951) the estimated percentage of natural outcrossing ranged from 48% to 84% with a mean of 60%. This compares with data from the Plant Breeding Institute (PBI Ann. Rept 1972) showing a range of from 23% to 68% with a mean of 42% for winter beans grown in the south.

(T. W. Hegarty, J. R. T. Hodgkin¹)

WEED INVESTIGATIONS

01021—01024 Weed ecology and control in soft fruit, vegetables and flower bulbs

Herbicide evaluation

The addition of ethofumesate to lenacil applied as a residual post-planting treatment or to phenmedipham applied after weed emergence (at combined rates recommended for the sugar beet crop) considerably improved the

¹ Plant Breeding Section.

duration of effective weed control in maiden strawberries. A propachlor/chlorthal dimethyl mixture introduced in 1978 for use in brassica and onion crops gave much better weed control than propachlor alone when both were applied shortly after planting strawberries. The results were equivalent to those obtained with a programme involving trifluralin incorporated pre-planting followed by propachlor after planting. The mixture could be useful on soils or in seasons where incorporation of herbicides is impracticable or undesirable. More information is needed on crop tolerance to all three mixtures.

Evaluation of dinoseb-in-oil as a herbicide treatment for maiden raspberries showed that pre-emergence applications were safe and effective, but application after cane emergence had severe effects on crop establishment.

01029 Weed control in crop rotations

Volunteer crops

Field observations continued in 1978 on the germination, growth and tuber yield of potato plants arising from seed from berries produced by a 1971 crop. Tubers produced by these seedlings will be assessed for virus and disease incidence, and for ability to survive over winter. Long-term pot experiments have been established to study longevity of seeds and periodicity of emergence under more controlled conditions. Factors involved in germination are also being investigated.

Investigations in 1977 showed that pre-emergence residual herbicides varied considerably in their ability to control potato seedlings. This was confirmed in 1978 in a field experiment in which the majority of pea and bean herbicides normally used in the UK were applied at recommended rates. Application of cyanazine or simazine pre-emergence gave a high degree of control, but results with other residual herbicides were less satisfactory. Post-emergence treatment with dinoseb amine gave good control but bentazone was relatively ineffective. Further evaluation in the field and glasshouse will be carried out to establish guidelines for herbicide usage in other crops on soils known to have a potato true seed population. Effects of soil sterilants on seed survival will also be monitored.

Pot experiments have been established to examine the germination patterns for seeds of a number of other crop species which can create volunteer problems, including field bean, oil seed rape, barley, perennial ryegrass, wild white clover, black currant, raspberry and strawberry.

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

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

Calabrese: measured maximum (MM) yield*

This year's studies in MM plots were intended to determine the effects of sowing date on growth and yield. Unfortunately, the high level of spear rot (soft rot of immature buds) common throughout Scotland made it impossible to obtain reliable yield data. Growth rates of the crops were measured up to the stage when the spears were approaching maturity but before spear rotting began.

Spear rot was first found at the beginning of August, in the crop sown on 1 May, with 8% and 55% respectively of the plants from the control and MM plots affected. The control plot reached maturity 5 days earlier than the MM plot, and this seems to have been sufficient to enable a high proportion of spears from the control plot to mature before the onset of the cool wet weather, with which this disorder is associated. From the second sowing on 22 May, all of which matured under cool wet conditions, about 96% of both the MM and control plots were affected by spear rot.

Ignoring the later stages of development because of the spear rot, growth analysis showed enhanced growth for plants in the MM plot compared with the control, from an early stage. Between 60 and 80 days after sowing growth rates for plants sown on 1 May and 22 May in the MM plot were both about 15.8 g/m²/day. Values for plants from the control plot were 11.6 and 13.2 g/m²/day respectively. At 80 days after sowing total plant weights for the two sowings of the MM plot were about 627 g/m² compared with 396 g/m², and 561 g/m² for the controls for the first and second sowings respectively. Dry conditions following the first sowing probably account for the poor growth of the controls.

Calabrese maturity

Processing and prepack markets require supplies of calabrese over a long period, and successful programming of production relies on an understanding of the way in which sowing date influences date of harvest. Previous work has shown that the time to harvest decreases in a regular fashion with sowings from the end of March until the middle of June, when it is at its minimum. This year, sowings after mid-June were examined with particular reference to a processing need for supplies from late August to the end of September. Ten sowings of cv. Corvet between

* Annual Report 1977, p29.

7 June and 10 July all gave similar yields of 11 t/ha. Sowings between 7 and 27 June gave 50% harvest dates from 29 August to 27 September, the earliest sowing requiring 83 days to reach maturity and that on 27 June taking 92 days. (R. Thompson, H. Taylor)

Potatoes—seed treatment

In collaboration with the University of Bath, studies have started on the relationship between seed treatment, tuber metabolism during storage, and subsequent field performance. The seed treatments involved variations in lifting date and storage temperature.

The cultivars Maris Piper and Pentland Crown were lifted on five occasions between 11 August and 6 October and stored at 2°C, 5°C, 9°C and 16°C. Levels of reducing sugars, insoluble carbohydrates and total soluble sugars were assessed on five occasions during storage. Only storage temperature had a marked effect on carbohydrate levels, both total soluble sugars and reducing sugars declining as temperature was increased.

Yields for tubers stored at 5°C were greater for both cultivars (56 and 68 t/ha for Crown and Piper respectively) than from any other storage temperature. When averaged over cultivars, yields from tubers stored at 2°C, 5°C, 9°C and 16°C were 51 t/ha, 62 t/ha, 55 t/ha and 38 t/ha respectively. (R. Thompson, P. P. Rutherford¹)

Potatoes—measured maximum (MM) yield

Seed of cv. Pentland Crown (FS1) with an average tuber weight of 107 g was sprouted at 15°C in late April; the temperature was then slowly decreased to 5°C and held there until planting. Tubers were planted on 5 May on the flat at 30 cm × 30 cm spacing in a MM plot and in an adjoining control plot of normal field soil. Both crops were irrigated when the soil moisture tension reached 25 centibars and were provided with high levels of mineral nutrients. Yields from the MM and control plots on 20 October were 95 t/ha and 76 t/ha respectively, the major difference between the two crops being in the substantially greater number of tubers produced by the MM plot.

Different patterns of growth were indicated from an early harvest on 1 September when yields were 46 t/ha and 65 t/ha for the MM and control plots respectively. Total dry weight was also greater for the control (16.8 t/ha) than for the MM plot (11.5 t/ha), but the proportion devoted to top growth was 16% greater for the MM plot (4.4 t/ha c.f. 3.7 t/ha). Bulking was earlier in the control than in the MM plot, but this was associated with earlier senescence. (R. Thompson, H. Taylor)

¹ University of Bath.

Field bean—flower initiation

There is variability in the flowering and pod setting profiles in *Vicia faba*, both between cultivars and between different crops of the same cultivar. An important component of this variability is the number of vegetative nodes produced before the first flowering node occurs. Studies have started on the effects of daylength, temperature and ripeness of the seed on flower initiation.

The winter cv. Maris Beaver and the spring cv. Herz Freya were grown in photoperiods ranged from 8 to 20 hours. Plants were grown either at 15°C for the duration of the experiment or were grown for the first 3 weeks in a diurnal cycle of 0–14°C, then followed by constant 15°C. Maris Beaver was the more responsive to variation in photoperiod; in short days at constant 15°C the lowest initiated node was the 28th whilst in long days the first buds were initiated at the 16th. Three weeks at low temperature during early growth caused flower initiation at about node 14 in any daylength. In contrast Herz Freya showed little response to photoperiod or treatment at low temperature, initiation always occurring between nodes 9 and 13, although initiation at the lowest node (9) was again produced by the low temperature treatment.

Vernalisation of seed on the mother plant has been reported in some species. Since field beans are often harvested late in the season in northern latitudes they may be exposed to vernalising temperatures. Immature (55% seed moisture content) and mature (16% seed moisture content) seed of Herz Freya was stored at 12°C or 2°C prior to sowing or sown immediately upon harvest in pots in a heated glasshouse. The position of the lowest flowering node (approximately node 13) was not affected by any of these treatments.

(R. Thompson, G. Hoogenboom¹)

Field bean—genotype × population density

By manipulating cultural methods it has been possible to improve the total dry matter production of conventional field bean varieties, but without a corresponding increase in grain yield. Two novel genotypes were examined this year to see whether their responses to variation in plant density gave promise of higher yields. A standard cultivar, Herz Freya, was compared with a mutant (TI) that ceases growth after several nodes have set pods, and with a dwarf self-fertile type (CH421). Yield and

¹ Agriculture University, Wageningen.

yield components were compared at four densities in the range 20-160 plants/m².

The three cultivars differed in response to changing plant density. Yields for Herz Freya, which averaged 4.2 t/ha, did not differ significantly over the range of densities used. However, as density was increased from 20 to 40 plants/m², yields of both novel genotypes increased, from 1.7 to 3.1 t/ha for CH421 and from 1.7 to 2.6 t/ha for TI. Above 40 plants/m² yields of all three cultivars were unchanged.

The stability of the components of yield in relation to plant density varied between cultivars. For Herz Freya only podding nodes/stem and pods/podding node were influenced by density, with 47% and 93% increase for plants from the lowest density over those from the highest respectively.

For CH421, low densities gave 120% more stems than high densities and 30% more podding nodes/stem.

By far the most responsive cultivar to changes in density was TI, which at low density gave 209% more stems, 30% fewer podding nodes/stem, 20% more pods/podding node and 30% more beans/pod, than at high density.

Field bean—competition and pod set

Increased competition between plants in a crop reduces the number of pods each plant produces. Effects of competition for light on pod set and development are being studied in plants grown in pots with non-limiting levels of water and nutrients. By changing the spacing between pots at several different stages of growth, a measure is obtained of the effect on pod set of competition during specific periods.

In this pilot experiment plants were held for varying periods at close (50 plants/m²) and wide (2.5 plants/m²) spacing. When grown continuously at wide spacing about 22 mature pods/plant were produced and at close spacing this value was reduced to about 9. Plants grown until all pods were set at wide spacing and then transferred to close, produced 16 mature pods/plant, but transfer to close spacing at any stage prior to this reduced pod number to at most 12 mature pods/plant.

A more comprehensive experiment is planned for next year.

(R. Thompson, H. Taylor)

Field bean—assimilation and pod growth

Following from experiments in 1977, various aspects of the carbon economy of field beans cv. Minor were studied. The 1978 summer was wetter and much duller than 1977, and the crop took 3 weeks longer to mature. Seed growth rates were lower in 1978, dry matter accumulating

at 11 g/m² per day, compared with 20 g/m² per day last year. The final seed dry weight was 368 g/m², which was 82 g/m² less than in 1977, and total dry matter production for the season was 1137 g/m² (including taproot and abscised leaves). Decrease in stem dry weight during pod filling was less marked than last year, suggesting that stored carbohydrate reserves were not being so extensively mobilised for seed growth. This was supported by autoradiography of plants that had assimilated ¹⁴CO₂ prior to flowering; no label was found in pods or seeds.

A comparison of CO₂ exchange rates in leaves and pods, using infra-red gas analysis, showed that leaves took up CO₂ at light levels of 500 μE/cm²/s at rates of 1.1 to 2.0 g/m²/h. In contrast CO₂ exchange for pods always remained a net efflux.

It was again demonstrated that in a crop canopy a single defoliated node is not likely to produce a lower yield than an adjacent node with its leaf intact. Furthermore, halving the total leaf area by removing leaves from alternate nodes reduced seed yield by only 36% indicating some increase in efficiency of the remaining leaves, and suggesting that assimilation in the intact plants was below their potential. Conversely when the number of nodes allowed to develop pods was restricted, the surplus assimilate was utilised to increase seed size and numbers of pods/node. Numbers of seeds/pod were unaffected.

(R. M. Brook, R. Thompson)

Field bean—measured maximum (MM) yield

Because cv. Herz Freya is no longer commercially available it was decided to continue agronomic and physiological experiments on the currently most popular cv. Maris Bead. Yields in 1978 were low, but on the basis of past comparisons it seems unlikely that the change of cultivar caused this. The lower level of solar radiation in 1978 than in 1977 seems the more likely reason.

On the basis of evidence from other crops it appeared possible that the density giving the highest yield would differ according to fertility. This year therefore, a systematic spacing design was used to examine the effects of density on growth and development in MM and control plots. Last year irrigation had a marked effect on the growth but not yield of a field crop. Three soil water regimes were included this year in both MM and control plots to explore the contribution of irrigation to the enhanced growth found also in last year's MM plot.

Although analysis of the data is not yet complete it is clear that the MM plot gave a higher yield (4.2 t/ha) than the control (3 t/ha), when averaged over all treatments. Total dry matter production was much

greater (57% more) for the MM than the control plot indicating, in agreement with last year's results, that changes in total dry matter are not necessarily associated with proportional changes in seed yield. Moreover, for the irrigated MM plots, yields (3.8 t/ha) were lower than for the non-irrigated (5.1 t/ha), whereas total dry matter yields were similar. No such effect was found in the control plots.

Over the density range 20-70 plants/m² yields from the MM plot increased from about 4 to 5 t/ha, whereas over the same density range yields for the control were similar at just over 3 t/ha.

Field beans—EEC joint cultivar trial

Ten cultivars of *Vicia faba* were grown at seven sites in the EEC, the northernmost one of which was SHRI. The objective is to identify cultivars that perform well in a wide range of environments. At SHRI yields ranged from 4.5 t/ha for cv. Maris Blaze to 1.6 t/ha for cv. Russian. The latter cultivar and cv. Felix suffered from severe chocolate spot (*Botrytis fabae*) infection. Average seed size ranged from 0.28 g for cv. Russian to 0.93 g for the broad bean cv. Wierboon.

Field beans—desiccation

In some years, prolonged growth in the autumn delays ripening and hence harvesting. It has been suggested that spraying with diquat may, through its desiccant effect, cause earlier ripening and enable earlier harvesting. Spraying on four occasions between 15 August and 26 September, when seed moisture contents were 70% and 16% respectively, had no effect on the rate at which the seed dried on the plant compared with untreated control plots. However, the sprays effectively killed the foliage, and this may make for easier harvesting under commercial conditions.

Field beans—cultivar observation plots

Fifty cultivars or breeding lines of *Vicia faba* from various European sources and covering a wide range of seed sizes from that of *V. faba minor* to *V. faba major* as well as spring and winter types, were examined in small plots. Among the more promising were some experimental lines (WFT) from the Plant Breeding Institute. Autumn-sown plots of the new white seeded cv. Polar (NSDO) produced a good yield of beans of high quality when harvested immature for processing (freezing) as well as giving a high yield (4.5 t/ha) when harvested dry at maturity. The average seed dry weight of cv. Polar was 0.62 g compared with 0.55 g for cv. Throws M.S. (3.6 t/ha), 1.02 g for cv. Triple White (1.5 t/ha) and 0.48 g for cv. Beryl (2.1 t/ha).

(R. Thompson, H. Taylor)

Mixed cropping

Mixed cropping of a legume and a non-legume was common some years ago for forage or grain production, but there appears to be no information on the performance of mixtures of two legumes. A combination such as beans and peas may exploit the soil environment more effectively. Further, the problem of poor drying associated with dry pea production may be alleviated by the physical support provided by the beans.

Mixtures of the field bean cv. Maris Bead and each of the pea cultivars Maro, Rosakrone and Minerva were grown in the proportion of about 40 pea plants to 50 bean plants as well as single species cultures. Yields from pure cultures of Maris Bead, Maro, Rosakrone and Minerva were 4.7, 3.1, 2.2 and 1.2 t/ha respectively. Total seed yields for combinations of the cv. Maris Bead with the peas Maro, Rosakrone and Minerva were 3.6, 2.9 and 2.8 t/ha respectively and the contributions of the peas to these yields were all 2.4 t/ha.

The ratio of bean to pea plants clearly gave the peas a competitive advantage which was reflected in the proportion of pea and bean seeds in the mixed yield. The enhanced yields of Minerva and Rosakrone grown in mixed culture may have resulted from the support provided by the bean plants, which markedly reduced lodging.

The level of dominance of the peas in the mixed cultures was also reflected in nodule activity. Whereas in monoculture the activity of bean nodules about the end of June was $507 \mu \text{ mol C}_2\text{H}_4/\text{m}^2/\text{hr}$, in mixed culture their activity did not exceed $164 \mu \text{ mol C}_2\text{H}_4/\text{m}^2/\text{hr}$. Total nodule activity for the mixed cultures of Maris Bead with Maro, Rosakrone and Minerva were 358, 257 and $184 \mu \text{ mol C}_2\text{H}_2/\text{m}^2/\text{hr}$ respectively. Improved growth and nodule activity may be encouraged by increasing the proportion of beans in the mixed cultures.

(R. Thompson, J. Sprent¹, H. Taylor)

Peas—sowing rate and yield

Assessment of yield and feeding quality in collaboration with the Rowett Research Institute are being made for cv. Filby and a numbered high protein line (I3) obtained from the USDA. Protein levels were about 22% for Filby and about 30% for I3.

Yields of dried peas (15% moisture content) were determined from four population densities ranging from 65 plants/m² to 400 plants/m². Maximum yield for Filby of 3.4 t/ha (0.64 t/ha total protein) and for I3 of 2.0 t/ha (0.51 t/ha protein) were both obtained from about 120 plants/m². Thus the higher protein content of I3 compared with that of Filby was associated with a substantially reduced yield.

(R. Thompson, H. Taylor)

¹ University of Dundee.

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

National Fruit Trial 1975

This report deals only with results from plots given conventional management. Effects of cane vigour control treatment on part of the experiment are reported elsewhere. 2476/123 was again the highest yielding selection (26 t/ha) with cv. Leo in second place (23 t/ha). M32 and cv. Glen Clova came next with 19 t/ha, followed closely by most of the other cultivars and selections. Lowest yields were produced by the control cultivar Malling Jewel (13 t/ha) and 2488/36 (8 t/ha). 2476/123 also gave the highest yield per cane — more than twice that from Glen Clova or Malling Jewel. Glen Clova produced many more canes in 1977 than the other cultivars and selections, many of whose higher yields per cane in 1978 were offset by low numbers of canes retained for fruiting. In October 1978 the NFT Scottish sub-committee recommended the release of 2476/123 because it fulfilled the need for a high-yielding late cultivar in the south of England.

(M. R. Cormack, H. M. Lawson)

Control of cane vigour

This technique has now been applied annually to a plantation of cv. Glen Clova for 5 years in succession. 1978 is the first year in which plots with young canes removed once at 10 or 20 cm height have not considerably outyielded those given traditional management. Plots treated at later dates showed a progressive reduction in yield compared with the standard, due to inadequate production of canes in 1977. Cumulative yields over the 5 years for plots with canes removed annually at 10 cm or 20 cm are over 40% greater than that for untreated plots.

Vigour control was introduced in 1978 to a biennial cropping experiment on Glen Clova. Plots hitherto grown with traditional management showed a 28% increase in fruit production following removal of the first flush of young canes at 15 cm. This compared with a 66% greater yield by canes in the 'fruiting-only' phase of biennial cropping. Effects on yield of vigour control in the 'vegetative-only' phase will be assessed in 1979.

In another experiment nitrogen has been applied in 3 consecutive years at 38, 100 or 163 kg/ha to traditionally managed plots of Glen Clova, without any measurable differences in fruit production. Vigour control was introduced to half of each plot in 1978 but although this produced a

19% increase in overall yield, there was no interaction with rate of nitrogen.

Two successive years of cane vigour control in part of the raspberry National Fruit Trial produced no consistent pattern of results. However, most of the new selections in the trials have not shown yield increases following removal of the first flush of young canes at 15 cm.

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

Biennial cropping

In their fruiting year, biennially-cropped plots of six cultivars gave an average yield of 28.4 t/ha, 86% higher than the mean of the conventionally cropped plots. Cultivars differed in the magnitude of their responses, which ranged from a 41% increase in cv. Malling Landmark to a 122% increase in cv. Malling Admiral. Yields in these biennial plots were the highest ever recorded at the Institute, but from past results there seems to be no obvious link between absolute yield and level of response to this cropping system.

Raspberries may be cultivated in the conventional way, or with the first flush of canes removed, or on the biennial system with all young cane removed in the cropping year. There is increasing evidence that cultivars differ greatly in their responses to these three systems, but it remains to be seen which combination of genotype and system has the greatest yield potential or the greatest year-to-year stability of yield.

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

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

Raspberry harvesting

In 1977 cane numbers were reduced by about 25% in machine harvested plots. This was appreciably higher than previously recorded and was thought to be linked with operation of the machines at higher forward speeds. Three forward speeds were tested in 1978, in combination with catching plates only or catching plates plus picking drums. Analysis of damage patterns and their origins is not yet completed, but the harvesting performance confirmed previous observations that at lower forward speeds the percentage of green fruit removed is increased without a proportional increase in ripe fruit recovery.

A replicated comparison of cultivars for suitability for machine harvest did not identify any cultivar significantly superior to the standard, cv.

Malling Jewel. In the United States cv. Meeker is widely used for machine harvesting, but in this experiment it showed the lowest percentage recovery of ripe fruit of the seven cultivars tested.

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

Raspberry Harvest Model

A raspberry harvest model was constructed from smoothed values for the daily changes in berry weight with age, the daily production of ripe fruit, the rate of loss of ripe fruit with age and harvester efficiency.

The model was used to simulate the effects of harvesting the red raspberry cv. Malling Jewel at intervals of 2, 3 or 5 days starting 4, 6, 8, 10, 12 or 14 days after the first fruits had ripened. Harvesting every 2 days was more effective at each delay than harvesting every 3 or 5 days because, although more fruit was harvested green, less was lost through being over-ripe. The maximum amount of fruit harvested was achieved in each of the three harvest interval programmes when the first harvest was delayed until the cumulative percentage of ripe fruit had reached the high proportion of 33%. A 1 day increase in the retention time of ripe berries on the plants before they start to fall off increased the maximum yield of harvested fruit by approximately 7% of the potential crop for the 2, 3 or 5 day harvest intervals.

The optimum combination of harvest starting time and interval between harvests removed 63.5% of the potential crop as ripe fruit.

It is clear that while manipulation of harvest schedules can effect some improvement in harvesting efficiency, the major advance must come from changes in plant and machine which allow better discrimination between removal of green fruit and ripe fruit.

(P. B. Topham, D. T. Mason)

Fruit retention strength

Not all the ripe berries are removed when raspberry plantations are harvested by machine. It is possible that the berries left on the plants received less shaking than those located at a different position on the same lateral or on another lateral and which were harvested. Alternatively, ripe berries may differ considerably in their retention strengths and the forces applied by the machine in normal operation are insufficient to remove the more strongly attached berries.

In order to measure possible variations in fruit retention strength all the ripe berries were removed twice weekly, throughout the cropping period, from plots of cv. Glen Isla and cv. Malling Jewel. Fruit retention strength and titratable acidity were measured for each berry.

At the early harvests, 19, 24, 27 and 31 July for Malling Jewel and 27 July for Glen Isla, there was a wide spread in the fruit retention strengths of individual berries. At this stage it would have been impossible for a machine to remove all the ripe berries. Later in the cropping periods of both cultivars fruit retention strengths became very low with little spread and therefore at this stage in the season a harvester would appear highly efficient.

Although cropping of Malling Jewel was more advanced than that of Glen Isla, the drop in mean fruit retention strength occurred at approximately the same date for both cultivars. This suggests that the change in fruit retention strength was caused by a weather factor rather than by some condition related to the position of the harvest on the cropping curve. This was the first time such a complete study of fruit retention strength has been made throughout the season. A smaller investigation in 1973 suggested that the fruit retention strength of Glen Isla and Malling Jewel remained relatively constant throughout the harvest period. If these year-to-year differences are substantiated, they will support the idea that a weather fluctuation is the controlling factor.

Since all the berries were judged to be ripe by colour, and titratable acidity only changed slightly, it appears that the changes which result in increased ease of fruit removal are not necessarily closely linked to the colour and acidity changes normally associated with ripening.

(D. T. Mason)

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

National Fruit Trial 1975

Some very high yields were recorded in this experiment which was cropped for the last time in 1978. Eight cultivars produced in excess of 30 t/ha, including Cambridge Favourite and Redgauntlet, while the recently named cultivars Tantallon, Troubador and Saladin, yielded *ca* 40 t/ha on defoliated plots. Defoliation resulted in large increases in yields of Troubador, Saladin, Silver Jubilee and 65G67; Jurica was the only cultivar to show a marked negative response. With the exception of 66R115, JI3722 and Jurica, all cultivars and selections produced larger fruits than did Cambridge Favourite; those of Hapil, averaging 19 g/berry on defoliated plots, were again the largest recorded. Jurica produced exceptionally large numbers of flower trusses per plant, but although they set fruit, a high proportion did not develop sufficiently by the end of the season to be worth picking.

(M. R. Cormack, H. M. Lawson)

Runner control

The success at SHRI of techniques for controlling cane vigour or unwanted suckers in raspberries using the desiccating effects of dinoseb-in-oil has led to consideration of other possible uses for this herbicide in perennial crops.

Runner control in strawberries is one such potential application and experiments have been carried out on cv. Cambridge Favourite to examine factors such as dose, water volume, timing and effects of weather conditions on speed and efficacy of desiccation and rate of recovery. Excellent results have been obtained using a 25% w/v formulation of dinoseb-in-oil applied at 2.50-3.75 kg a.i. in 500-1000 l water per sprayed hectare. The higher rate proved necessary for applications made in cold weather, while the lower rate is that currently recommended for effective control of annual weeds. Comparisons with paraquat at 1.1 kg a.i./ha have been very favourable in warm weather, but dinoseb-in-oil is slower to take effect than paraquat under cold conditions.

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

Runner production

The number of runners produced by cv. Cambridge Favourite was recorded at two sites, Invergowrie (SHRI) and Auchincruive (WSAC). In 1977 both sets of parent plants were grown in an identical peat/sand compost; the plants received supplementary irrigation and fertilisation so that neither water nor nutrients were limiting growth. At lifting in spring 1978, each parent plant at WSAC had produced 32.4 large runners and 19.6 small (but commercially acceptable) runners. Parent plants at SHRI produced 22.6 large and 19.2 small runners.

The growing season at Auchincruive was both warmer and sunnier than at Invergowrie. Productivity per unit area at Auchincruive was about double that achieved in the best commercial runner beds.

The cropping of the runners produced at WSAC and SHRI will be compared with that of runners produced commercially in Scotland and England.

(D. T. Mason, P. J. Dudley¹)

01012 Ecology of new crops for Scotland

Within-plant competition in black currants

Using three cultivars, an examination was made of the effects on yield components of varying the fruiting load. The treatments involved factorial combinations of removal of half the number of fruiting shoots, half of the

¹ West of Scotland Agricultural College, Auchincruive, Ayr.

buds per shoot, and half of the flowers per strig. The cultivars were Baldwin, Ben Nevis and Ben Lomond.

Of the main effects, only the within-strig pruning gave any increase in percentage fruit set. Fruit size was increased in Baldwin but not in the other cultivars following removal of half of the fruiting shoots. Analyses of interactions, and of the effects of patterns of flower removal within strigs, are not yet completed.

(A. Nes¹, P. D. Waister)

Rubus species

Biennial plots of cv. Ashton Cross blackberry which cropped in 1978 produced a mean yield of 21 t/ha, some 56% more than the annual plots. Cv. Bedford Giant cropped at 12 t/ha on the annual system and cv. Himalayan Giant at 7.5 t/ha.

The continued success of Ashton Cross, a seedling of *R. bartonii*, has prompted examination of other indigenous blackberry species. These will crop for the first time in 1979, and it is already apparent that the vigour of some of them is much greater than that of introduced cultivars. We are grateful to Mr A. Newton, Hale, Cheshire, for information on species likely to meet our specifications for plant form and for season of fruiting. He also kindly supplied planting material.

Vaccinium species

In a trial planted in 1969 the highbush blueberry Bluecrop yielded 9 t/ha while the other cultivar, Berkeley, yielded only 1.5 t/ha. Poor flower production appeared to be the main cause of this low yield. The consistent performance of Bluecrop and the erratic yield of Berkeley are in accordance with observations in the United States.

Like most other *Vaccinium* species, the North American cranberry (*V. macrocarpon*) is slow to establish. In a small trial planted in 1971, the cultivars CN, Franklin and Bergman all produced yields in 1978 in excess of 10 t/ha, but it will be some years before consistency of performance under our conditions can be estimated.

Windbreaks

An experimental windbreak was planted in 1971 to assess the suitability of a number of tree species in terms of growth rate, plant habit, pathogen susceptibility and reaction to trimming. A hybrid poplar (*P. trichocarpa* × *P. tacamahaca*) although susceptible to canker, grew fastest, reaching a height of 9.1 m by winter 1978. The fastest growing

¹ Kise Agricultural Research Station, Norway.

evergreen was *Cupressocyparis leylandii* which has now reached a height of 5.2 m.

Salix alba coerulea appears to be very well suited for windbreak use both in terms of vigour and of growth form. This willow is proving the most satisfactory one in an experimental windbreak planted in 1975 which comprises a range of *S. alba* cultivars, some of which have been specifically selected for windbreak purposes.

(M. R. Cormack)

STATISTICS AND COMPUTING

01044 Statistics (service)

The figures for computer usage give some indication of the extent to which the scientific staff increasingly avail themselves of the wide range of techniques and facilities now available. It is a pleasure to record that those who have sought assistance have been very ready to involve themselves in both the rationale and the logistics of the analysis of their data, and to accept suggestions which may help to display the features of interest therein.

The visit of A. Bello, mentioned elsewhere in this report, brought the opportunity for co-operative work on the classification of nematode distributions. Among the techniques explored were association analysis, and the use of mean centres taken over from statistical geography and extended to include other bivariate distribution parameters, which could then form the basis of hierarchical clustering.

Data on the survival of various nematode species at different temperatures were analysed using several models, none of which was a good fit, so that in the end simple life table techniques were used; however, it is hoped that a change in experimental technique will improve matters.

We are glad to acknowledge the willing assistance given by many people, among others, J. Bryan-Jones, E. A. Hunter and others at ARCUS, R. Hunt and I. Parsons for help with their growth analysis program, and N. Alvey for advice on GENSTAT applications, especially on his diallel macro.

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

01045 Use of computing facilities

There has been much discussion this year about the provision of data-processing equipment and the balance between local facilities and those centrally provided at the Edinburgh Regional Computing Centre. Dr Thomas, the director of ERCC, and several members of his staff visited

the Institute in March and took part in an open discussion with members of all scientific sections. This was of considerable help in clarifying our aims and ensuring that we achieve an appropriate mix of different types of computing.

An MSI 6800 System One microcomputer was purchased. It has twin mini floppy disk drives and uses a Teletype 43 as its console. This choice of equipment was aided by consultations with L. F. Marsh of NIAE and A. J. Breame of AVRI.

The Wang programmable desk calculator which this equipment will replace continued in steady use; in a period of 9 months it was used for 258 hours on 366 occasions. The number of jobs 'run batch' at the ERCC rose by 17% to 1123; Genstat jobs formed 55% of this total. The number of variates subjected to analyses of variance fell by 16% to 8032. The advantages of the Remote Job Entry Terminal can be gauged by the drop in the average time taken to produce usable output from a job: 7.6 days (1976), 3.9 (1977), 0.79 days (1978); the mean number of submissions remained almost the same (2.6) so that users were getting at least 2 to 3 turn-rounds a day if they required it.

The set of locally written EMAS commands was extended to include a program to check that the number of fields per line in a file is constant and another to exchange characters in a file.

The manual system of calculating the pay of soft fruit pickers was replaced by a computerised system. The care taken to make it fail-safe and to cover all contingencies was rewarded and both hardware and software proved reliable in operation. Some 600 pickers were employed, though the maximum on any day was less than 200. As well as different rates according to a picker's age, the system handles mixtures of time and piece rates.

Off line data capture from electronic balances using an ASR33 teletype became routine for several users and error checking routines were written for the paper tapes. The usage of EMAS terminals increased as a result.

Computer jobs put through the batch terminal:

| | 1977 | | 1978 | |
|----------------|-------|------|-------|------|
| | Jobs | % | Jobs | % |
| Crops Research | 582 | 60.4 | 589 | 52.5 |
| Plant Breeding | 200 | 20.2 | 244 | 21.7 |
| Mycology | 130 | 14.4 | 161 | 14.3 |
| Zoology | 31 | 3.1 | 125 | 11.1 |
| Virology | 17 | 1.9 | 4 | 0.4 |
| | <hr/> | | <hr/> | |
| | 960 | | 1123 | |

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

Information retrieval

Thanks to support from both the ERCC and the Program Library Unit, and to improvements in the 2980 Service, there has been considerable development in the various local information retrieval projects, with the exception of BOTBIB, the botrytis bibliography, which has not been updated since its conversion to FAMULUS. The photographic slide index reached 2500 entries in 3 years and has been closed; another index has been opened in continuation. The index of raspberry reprints has reached the letter W and 1650 entries; now that the backlog has been cleared and its potential uses assessed it might be possible to reconsider the type of entry made.

A. Nes, whose experimental work on black currants is reported elsewhere, made use of the FAMULUS system to build up a black currant bibliography of approximately 1850 entries, all of which he keyworded. Since the computer program is used at his computing centre in Norway the work will be available in both countries; it is also hoped to publish it.

Following an introductory seminar at the ERCC several files of virus references held on EMAS using the REFER program were converted to CATALOG, a program which uses the same input format as FAMULUS.

Two new projects have been under discussion. One, a proposal to use a data-base management system to maintain records of virus-free narcissus stocks, their origin and ultimate destination, was finally rejected as being too demanding for the resources available. We are grateful to A. Nolan of the ERCC for discussing the project and clarifying the issues involved. The other, virtually a report-generating program for strawberry cultivar descriptions, has been developed gradually by discussion between C. Lessels of RES and the workers involved. The characters recorded and the descriptions used have been systematised and the project is going ahead.

(R. Clark, P. B. Topham)

PLANT BREEDING

D. L. JENNINGS

All the plant breeding projects made notable progress in 1978. The value of the section's work of developing isoenzyme techniques for assessing the sib content of brassicae seed crops is already widely recognised; but information is now coming forward on the genetics of the isoenzyme systems used and is providing the essential scientific basis for the method to be used with confidence on a wider range of F_1 cultivars. In both brassicae and fruit crops a better understanding of yield components promises to lead to more effective selection for higher yielding cultivars.

In the fruit crops, the continued good performance of the black currant Ben More in another year of widespread and severe spring frosts has stimulated considerable demand for the cultivar by growers, and in raspberries the consistent high yield of M30 in regional trials indicated that it is a candidate for release as a new cultivar. Progress was also made in projects concerned with disease resistance: in strawberries a technique for evaluating resistance to *Phytophthora cactorum* was developed and used to identify sources of resistance; in raspberries studies were undertaken on promising resistance to two diseases which cause serious problems in machine-harvested crops—cane blight (*Leptosphaeria coniothyrium*) and fruit mould (*Botrytis cinerea*); and in black currants new introductions of wild Swedish forms provided a valuable new form of resistance to American gooseberry mildew.

The prospects for breeding a spineless raspberry-blackberry hybrid were improved by the successful transfer of a dominant factor for spinelessness from *Rubus parviflorus* to diploid and tetraploid raspberries.

03001 Strawberry: breeding and associated genetic studies

Screening for disease resistance

Assessment of red core (*Phytophthora fragariae*) field resistance based on scores of vegetative vigour and foliar symptoms of the disease up to September, 1978, were highly significantly correlated ($r=0.744$, d.f. 22) with first main crop yields, the latter being from replicated plots except for two entries which were averages from a large number of observation plots. Only

cultivars or selections of potential cultivar status were included. The mean red core score of 2.8 corresponded with a yield of 10.4 t/ha, which was close to the yields of Cambridge Favourite and Silver Jubilee.

Red core was more severe in the 1978 screening trial than in the 1976 trial, the likely explanation being the 20% higher rainfall during the winter of 1977-1978. Marmion was as resistant as usual but several of the newer Dutch cultivars were highly susceptible, especially those bred from Gorella and Redgauntlet. The two most resistant SHRI selections were both derivatives of 53Q13, one from a cross with Tioga and the other from a cross with Gorella.

The linear growth rate (LGR) of *Phytophthora cactorum* on detached strawberry leaves was found to provide a rapid measure of resistance to crown rot. The fungus grew on all leaves tested but most rapidly on those of Tamella, Cambridge Favourite, Marmion and Saladin, and least rapidly on those of Templar, Silver Jubilee and Troubador. In contrast, the LGR on leaves of *Fragaria vesca* was extremely low. A decaploid hybrid involving *F. vesca* (diploid) and the cultivated strawberry (octoploid) was tested together with its parents for resistance to crown rot using this method. Although the octoploid parents showed little resistance the tetraploid, hexaploid and decaploid hybrids showed a level of resistance comparable to that of the original *F. vesca*, which is a seed-propogated line used at Auchincruive for virus indexing selections.

Advanced selections

An outbreak of red core at NFT Brogdale unavoidably delayed the assessment of 12 selections. Most of them, however, are at Mylnefield and several are at the ADAS Farm Development Project in eastern England where machine harvesting tests are in progress.

A late-fruiting selection, G108, which shares a common parent, MdUS2650, with all the newly released Auchincruive cultivars, produces large, uniformly shaped, well-flavoured fruit in Scotland and has recently been reported upon favourably in France. In UK trials it has so far only averaged 12 t/ha. Another recent selection of promise, GU94, is a red core field resistant derivative of *Fragaria virginiana* I × Gorella. It crops well and the fruits decap easily and develop a markedly red flesh prior to developing an external appearance of ripeness. Early tests indicate that if it has adequate bruise resistance it could have commercial value for slicing and freezing. With the development of PYO growing there is an increasing demand for late cropping selections and EW30, bred from Talisman, Templar and C. Favourite, shows potential for meeting this, being 3 days later and higher yielding than the late fruiting Troubadour at Auchincruive.

Propagation

Following the release of four cultivars there was an inevitable increase in service activities associated with virus-testing, propagation of disease-free plants, inspection and dispatch of planting material. Micro-plantlets where possible, or plants raised from them, were sent to Australasia (two centres), the Americas (three centres) and Europe (ten centres).

Tantallon, Silver Jubilee and particularly Saladin have proved difficult to propagate *in vitro* using the standard medium, because the micro-plantlets became chlorosed in the presence of 1 mg/l of 6-benzylaminopurine (6-BAP). A modified medium with only 0.5 mg/l of 6-BAP in the multiplication phase and none in the rooting phase reduced the problem.

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

03003 *Strawberry: breeding systems*

Fragaria vesca programme

The decaploids bred so far are only moderately fertile, produce small soft fruit and appear to be highly sensitive to virus infection. Nevertheless they are easily decapped and possess a high level of resistance to *Phytophthora cactorum*. Whilst these latter qualities coupled with the 'wild type' flavour justify their continued use in breeding it is clear that considerable breeding will be necessary to obtain selections with commercial qualities.

Recurrent selection programme

Parents for breeding were selected from four-plant units fruiting in walk-in polythene tunnels. Among family G derivatives, sib crosses of Tantallon (G48) × Silver Jubilee (G95), Tantallon × G67, and Saladin × G67, were the best. They were surprisingly vigorous for close-breds and had large fruit, but difficult decapping was a universal fault. Field selections from S₁ families of DZ95 and DZ66 looked sufficiently promising in the tunnels to be tested as parents in crosses with the family G sibs. These DZ selections were darker fleshed, firmer and more easily decapped than the G selections and, although they lacked vigour, their progenies should combine many desirable characteristics.

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

03006 *Raspberry breeding and associated genetic studies*

M30 gave exceptionally good yields in regional trials in England and Scotland in 1978. This selection has previously given only average yields, but it is early ripening and has a good growth habit and so must now be regarded

as a potential new cultivar for Scotland. Selection 6820/54 maintained its promise in a trial at SHRI, showing excellent fruit qualities though ripening rather late; its sister seedling 6820/64 was superior to it at a site in England, however. These three selections, together with 7210/204, will be included in further regional trials in 1979 and are also being propagated for large scale commercial appraisal.

A notable feature of the progenies studied in 1978 was the progress being made in breeding plants with erect compact canes. Such plants occurred in progenies of 6820/54, 7331/1 and a derivative of the Canadian cultivar Haida. Their canes frequently bore a high number of lateral-bearing nodes and showed a potential for high yield without the need for vigour control.

(D. L. Jennings, A. Dale, Eleanor Carmichael)

Yield components

Morphological characteristics of laterals vary with their position on the fruiting cane. All of the characteristics measured were analysed by principal component analysis because several of them were inter-related. The first vector of such analyses always described general lateral vigour where lateral length, diameter and numbers of nodes and fruit were associated. A second vector described reproductive vigour and contrasted the number of fruits per lateral and the proportion of lateral nodes which had buds or fruit with the number of buds which did not form fruit.

The values of the vectors varied with the position of the lateral on the fruiting cane. The reproductive vigour of the lateral was usually greater for laterals at the top of the cane than for those at the bottom. General vigour was in some clones less for laterals at the top of the cane than for those at the bottom, *e.g.* in cv. Malling Jewel, while in others it was similar for all laterals, *e.g.* in cv. Leo.

(A. Dale, Pauline B. Topham¹)

The way the relationships described above are inherited is being studied in six outcrossed families of a diallel. Preliminary results suggest that where a genotype had a large number of laterals per cane the lower laterals were much longer and more fruitful than the upper ones. But in genotypes where canes had few laterals per cane the differences were less marked.

When young canes are removed from cv. Glen Clova in late April new ones emerge and grow vigorously but at the end of the season are shorter than canes from untreated plants. This treatment of canes results in increased yield. We speculate that plants bred with young canes that emerge late and grow vigorously would yield more fruit than plants whose

¹ Crops Research Section.

young cane emerge early, even if both types of plant were to fruit at the same time. This is because young canes which emerge late would compete less strongly with the fruiting canes. Accordingly, in a range of plants, the dates when the first young cane emerged and first flowers opened on the fruiting cane were recorded. In four experiments only canes of 6820/54 consistently emerged later than Malling Jewel. On average emergence was 3.3 days later and the fruiting canes flowered 6.0 days later.

Data from selections showed a close negative correlation between un-tipped cane height and the number of nodes present on the lowermost 150 cm of the cane. But no such relationship occurred in two progenies derived from 60-43-3, a selection obtained from Germany. Here the node numbers varied discontinuously, suggesting that this effect was determined by a major gene.

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

Disease and pest resistance

Further study of the inheritance of resistance to *Leptosphaeria coniothyrium* was made in eight field-grown progenies. Five inoculations per plant were made on up to 50 plants from each progeny on 16 August and the resultant lesions measured on 14-19 December. The mean lesion length in five progenies derived from cv. Latham ranged from 19.2 to 34.2 mm, contrasting with a range of from 47.6 to 52.9 mm in three control families. Analyses indicated that the resistance of Latham had been inherited as a dominant character and in an essentially additive way with no evidence of major gene segregation; there were significant parental interactions, however, and the cross Latham \times M29 was the best combination. Concurrent tests on clonal material of the parents showed that M29 was intermediate for resistance.

When these results are compared with those of previous years it appears that resistance derived from Latham tends to increase during the growing season, being inadequate in early July but generally augmented by mid-August, which is consequently the most discriminating time to test resistance. However, the value of the resistance remains untested, because many infections occur in wounds inflicted by the passage of machine harvesters from mid-July to mid-August.

In further glasshouse tests, the resistance of the species *Rubus pileatus*, *R. mesogaeus* and *R. coreanus* was again confirmed, but their F_1 hybrids with the raspberry were as susceptible as the susceptible raspberry controls. Possible explanations are that resistance from these sources was inherited as a recessive character, or that resistance in the species was conferred only by the hard texture of their canes. These interpretations are being tested, because it is unlikely that resistance due to the latter could be used in raspberry breeding.

The inheritance of cane resistance to *Botrytis cinerea* was studied in a diallel cross involving the parents Malling 1473/35, Latham, M29, 6820/54 and Malling Orion by scoring the incidence and intensity of symptoms on the canes in September, 1977, and again in May, 1978. Data on the autumn symptoms indicated that the best sources of resistance were Malling 1473/35 and Latham, and that resistance was determined by dominant additive genes. The spring symptoms gave a similar ranking of parents but the correlation between scores given for the two symptoms was low ($r=0.355$; d.f.=634), the spring symptoms emphasising the susceptibility of Malling Orion and the recessiveness of its genes. Probably different genetic factors determined the two kinds of symptom.

Cane resistance to *B. cinerea* was tested on 16 plants per family for each family in the diallel using a mycelial inoculation technique on 8 August, 1978, and measuring the resultant lesion 4 weeks later. The data showed that resistance was conferred by Malling 1473/35 and by Latham, but provided equivocal evidence on the mode of inheritance: it was not possible to determine whether resistance was conferred by minor genes or by a major gene such that lesion length was about 55 mm when the gene was homozygous, about 75 mm when it was heterozygous and about 110 mm when it was absent.

In tests on glasshouse plants using mycelial inocula, previous observations of resistance in *R. pileatus*, *R. coreanus*, *R. mesogaeus* and *R. lasiocarpus* were confirmed and the resistance of their F_1 hybrids with the raspberry was found to be nearly as high.

Fruit samples from 15 genotypes were compared for the incidence of fruit rots on two harvest dates by holding three replicates of 30 fruit at 20°C for 5 days. Weather conditions favoured *B. cinerea* and a mean of 80.4% of all fruit showed infection. The most interesting comparisons were in the rate of symptom development, which was slowest in five selections notable for the firmness of their fruits. There was again no indication of resistance in material which has shown high resistance in British Columbia. The incidence of *Rhizopus* and *Cladosporium* species was low and was not influenced by genotype. Fruits from up to 16 genotypes of each family in the diallel mentioned above were also assessed for resistance to *B. cinerea* on two harvest dates. Evidence of resistance was found in the progenies related to 6820/54 and particularly in the progeny 6820/54 × Malling 1473/35, possibly because it had inherited a unique combination of firmness of fruit texture from 6820/54 and intrinsic resistance to the pathogen from 1473/35. This idea prompted work to combine the intrinsic resistance discovered in canes of other *Rubus* species with firmness of fruit texture to determine whether this results in higher levels of resistance in the fruit.

Scores of the incidence and intensity of symptoms to *Didymella applanata* in the diallel indicated that Malling 1473/35 was resistant to this pathogen as well as to *B. cinerea*, and that the two resistances were independently inherited. Attempts to use mycelial inoculation methods to assess resistance were unsuccessful, the mean lesion lengths being similar for all the raspberry genotypes tested.

(D. L. Jennings, Eleanor Carmichael)

Studies were continued of the segregation of genes *Ls* and *Lm*, which respectively determine the ability of raspberries to react to raspberry leaf spot and leaf mottle viruses. The results from further families studied support previous evidence for the existence of these genes even though all segregating families have shown deficiency of *Ls* genotypes. However, aberrant segregation is common in the raspberry. This work is being prepared for publication.

A total of 111 plants from seven F_2 progenies of the cross red raspberry \times black raspberry were graft-tested for their reaction to black raspberry necrosis virus. To date, 100 of them have behaved like their red raspberry parent and failed to show symptoms, while 11 showed a mosaic symptom similar to that of some of the F_1 generation. None of them has produced a tip necrosis like their black raspberry ancestor. The segregation observed occurred in the progenies of two out of three F_1 s studied which showed the mosaic symptoms, and in two out of four F_1 s which failed to show this symptom. It therefore seems unlikely that the different reactions of red and black raspberries to this virus are inherited simply.

Although cv. Lloyd George is highly susceptible to bushy dwarf virus and cv. Glen Clova is apparently immune from it, preliminary work suggested that the segregation which occurred in progenies obtained by selfing these two cultivars and by crossing between them could not be adequately described in terms of immunity and susceptibility, and that intermediate classes may have to be considered. Further work to clarify this situation was started.

(A. T. Jones¹, D. L. Jennings)

03008 Breeding early erect blackberries and other *Rubus* berries

Three years' observations have shown that cultivars of diverse origin differ in their response to spring and summer temperatures and hence vary considerably in their time of ripening in different years. Ripeness date is determined by two components—the date of flowering and the time required for the fruit to ripen—and it was found that seasonal influences were

¹ Virology Section.

relatively small for either early flowering or rapid ripening forms, apparently because they have lower heat requirements. This emphasised the need to select for earliness in a cool season, because it is only in this environment that differences between genotypes are fully expressed.

The severe frosts of winter 1977-78 caused heavy losses of canes in all blackberry progenies, but particularly in those related to parents obtained from the more southern latitudes of North and South America. Few canes of the *R. glaucus* × tetraploid raspberry progenies survived and these were largely infertile.

Further study was made of the colour change from black to red in frozen fruit of 10 blackberry cultivars. The mean percentage incidence of red fruit after freezing was higher than in 1977, and only the cv. Bedford Giant samples had a significantly higher incidence than the others. In contrast to the 1977 result, there was no significant correlation between the percentage of red fruit present after freezing and the pH of the fruit before it was frozen. It therefore seems that breeding is unlikely to produce cultivars capable of maintaining an improvement in all seasons.

As part of the programme to breed spinefree hybrids of the Tayberry type a dominant factor for spinelessness is being transferred from *R. parviflorus* to tetraploid raspberries. First backcrosses to the raspberry were successful at both diploid and tetraploid levels, and spinefree parents were selected for a second backcross.

(D. L. Jennings, Eleanor Carmichael)

03009 Breeding black currants for northern regions of the UK

Twenty selections submitted for trial to Brogdale NFT included 11 cv. Ben More hybrids, three cv. Ben Lomond derivatives and four cv. Westra hybrids. Fifteen clones were also sent for trial to Luddington EHS. Although this practice of submitting selections for regional trials at an early stage of development is open to criticism, the current dearth of suitable cultivars to replace or complement the highly frost-susceptible cv. Baldwin justifies this attempt to minimise the period between the primary selection of potentially new cultivars and their commercial exploitation. It necessarily throws an added burden on staff of ADAS regional trial centres, though it is pleasing to record their unfailing support and co-operation.

Productivity, plant habit and branch strength

A limiting feature to further advances in productivity is the lack of a sufficiently strong supportive framework of branches to carry heavy crops in a more or less upright posture. Even in moderately productive Westra-

type plants the branches are borne down by the weight of crop to an unacceptable degree, and in non-Westra types they are commonly borne to the ground. Hybridisation within *Ribes nigrum* alone has produced crop weights in excess of what conventional branch systems can support, but it has so far failed to produce the desired combination of plant habit characters: more emphasis in breeding is therefore being placed on derivatives of *R. bracteosum* and *R. sanguineum*. The excessive vigour of *R. bracteosum* hybrids has been overcome by selection, and two of its hybrids outstanding for a number of useful characteristics have already been used as parents. A strongly-branched, fully self-fertile, first backcross hybrid from the cross Westra \times (Baldwin \times *R. sanguineum*) has also been used. The F₁ hybrid of this cross was sterile and had a 'hard' quality in its two- and three-year-old wood which resembled that of *R. sanguineum*. The first backcross hybrids were fully fertile but did not inherit this quality. Attempts are therefore being made to obtain a desirable combination of characteristics by crossing these hybrids with the sterile F₁ and other *R. sanguineum* hybrids. Such improved Westra type hybrids would probably require the minimum of winter pruning.

Derivatives of Ben Lomond and Ben Nevis also continue to present similar problems, largely because the thin, flexible branches of their *R. ussuriense* ancestor are inherited as a dominant character. Improvements are being sought by further back-crossing to hybrids of *R. nigrum* \times *R. dikuscha*, *R. nigrum* \times *R. grossularia* and the hybrids described above.

American gooseberry mildew

Observation on progenies derived from two wild Swedish types of *R. nigrum*, Sunderbyn II and Matkakoski, supported Swedish experience that the major-gene for resistance obtained from Sunderbyn II is greatly superior to all other known resistance genes from *R. nigrum*. Matkakoski was slightly inferior to Sunderbyn II but superior to Ojebyn.

The forms of resistance controlled by genes with complementary effect at two separate loci in *R. dikuscha* and Primorsk Champion (Lija Plodorodnaja \times *R. dikuscha*) have been combined with high ascorbic acid content and intense juice colour in selection 243/7 (Seabrook's Black \times Janslunda) \times (Anger von Oeffelt \times Sztahanovka = (Goliath \times Primorsk Champion)) and, additionally, with leaf spot resistance and good flavour in selections 252/28/3 (Anger von Oeffelt \times Sztahanovka) and 71EA/7/65, a complex *R. dikuscha* third back-cross hybrid. All three selections were used in further breeding.

Mildew resistance in Luddington I (a moderately resistant clone found as a rogue in a plot of Baldwin at Luddington) is probably controlled in the same way: in a cross with the highly susceptible cv. Westra the progeny segregated in the second growing season for plants with a much improved

form of resistance. Similarly, in a progeny of Westra \times 243/7 one in eight of the plants were of this type.

Genes for mildew resistance from accessions of *R. americanum*, *R. hudsonianum*, *R. glutinosum*, *R. laxiflorum* and *R. sanguineum* have been introduced into *R. nigrum* hybrids, and their value in breeding is being assessed.

Black currant leaf spot

Selection over 3 years for juicing qualities among *R. nigrum* \times *R. dikuscha* derivatives reduced the number of elite leaf spot resistant selections to three, all of which have been used in breeding to combine leaf spot resistance with good fruit quality. Kantata, a leaf spot resistant cultivar from the USSR, was also used as a donor parent.

Fruit quality

Analysis of juice samples from 344 genotypes revealed similar inter-relationships between the various fruit quality components as those noted in 1977 (Ann. Rept 1977). Multiple regression analyses showed that 23% of the AAsg (ascorbic acid adjusted to standard specific gravity) variance was accounted for by variation in juice yield (volume/100 g fruit), sugar/acid ratio and gross polyphenols, and that 67% of the Lovibond red colour variance was accounted for by differences in Lovibond yellow values, gross polyphenols, juice yield and specific gravity. Some of these relationships were further analysed by principal component analyses. These described three important relationships: (1) the acidity of the juice, where high acidity denoted by AAsg and pH was associated with a low sugar/acid ratio; (2) the effects of dilution, where a high juice yield was associated with a low content of AAsg, Lovibond red and a low sugar/acid ratio; and (3) a relationship where high juice yield and Lovibond red were associated with a low sugar/acid ratio.

Of 36 samples of juice outstanding for juice colour or ascorbic acid content submitted for flavour tests to an experienced testing panel (Beecham Products) only two received favourable reports, one of which was obtained from 252/28/3.

A selection outstanding for juice colour, M48/2 (Baldwin \times (Goliath \times Ojebyn)), is being intensively propagated for extensive trials to supply bulk fruit samples for juice processing.

In 1977, fruit samples for juice analyses were taken from 350 genotypes in progenies of Westra, Ben Lomond, Ben More, 243/7 and 252/28/3.

Juice samples from 91 genotypes differed in their response to pasteurization (75°C for 20 mins.): the change in AAsg ranged from -155 to +16 mg AAsg/100 g juice (-67 to +7%), that of the Lovibond red values

from -12 to -0.1 (-36 to -0.3%) and that of the Lovibond yellow values from -10 to +4 (-91 to 100%). Substantial differences also occurred in titratable acidity, % sucrose and gross polyphenols. Analyses showed that the changes in AAsg were positively correlated with the changes in Lovibond red ($r=0.59$) and pH ($r=0.21$) and negatively correlated with AAsg before pasteurization ($r=-0.40$). The reductions in Lovibond red colour were positively correlated with both Lovibond red values after pasteurization ($r=0.47$) and changes in % sucrose ($r=0.22$), and negatively correlated with pH before pasteurization ($r=-0.21$).

(M. M. Anderson, J. Thompson)

NEW BLACK CURRANT CULTIVAR
BEN MORE

The Scottish Horticultural Research Institute and the National Seed Development Organisation Ltd. have applied for Plant Breeders Rights for a new black currant cultivar, Ben More, bred at the Scottish Horticultural Research Institute.

Stocks are being multiplied by the Scottish Nuclear Stock Association Ltd. and the National Seed Development Organisation Ltd., and one-year-old bushes will be available in limited numbers for commercial planting in autumn/winter 1979.

| | |
|----------------------------|--|
| <i>Breeder's number</i> | 238/36/14. |
| <i>Origin</i> | (cv. Goliath × cv. Ojebyn) o.p. |
| <i>Habit</i> | Moderately vigorous, forming medium-sized bushes at maturity. Bush cup-shaped at conventional spacings (9 ft × 4 ft), branches upright; at closer within-row spacings branches upright but flexible and tending to spread outwards with the weight of fruit. |
| <i>Season of flowering</i> | Very late, 12-25 days later than cv. Baldwin. Entirely escaped frost damage at Luddington EHS in 1977 and 1978. |
| <i>Fruit</i> | Berries large and ripen uniformly on short strigs. Fruit ripens about the same season as Baldwin but does not 'hang' so well. Present indications are that it is acceptable for processing, but much wider testing is required. |
| <i>Productivity</i> | More productive than Baldwin. Can be relied upon to give a crop in seasons when severe spring frosts devastate Baldwin. |
| <i>Disease</i> | Resistant to American gooseberry mildew but not to leaf spot, gall mite or reversion disease. |

Partial self-compatibility in Brassica oleracea

The level of partial self-compatibility in *B. oleracea* breeding material is estimated by counting pollen-tube numbers or seed set after test self-pollinations. However, with seed production under field conditions, both self and cross pollen is present on the stigmas of flowering crops, giving inbred and hybrid seeds in the same pods at harvest. The amount of self seed produced by an inbred line may be affected by the pollen mixture present on the stigma, and we have therefore begun to investigate this.

In each experiment, the effect was tested of mixing different amounts of cross pollen from a plant homozygous for a dominant seedling marker gene, fern leaf, with pollen from three inbred cabbage breeding lines. Mixtures containing 0, 25, 50, 75 and 100% cross pollen were applied to flowers between 1 and 3 days old. For each inbred line over 50 flowers on at least four plants were used for each pollination treatment.

The results showed that the addition of 50% self pollen to outcross pollen did not reduce total seed set in two of the inbred lines but in the third there was a drop of from 12 to 9 seeds per pod. The mixture containing 25% cross pollen reduced total seed set in all lines by up to a half. Seed germination levels were constant over all treatments except for one line where seed germination from the 0% cross pollen treatment was 20% lower than in the others.

Seed production on selfing (0% cross pollen treatment) ranged from 0.4 to 4.5 seeds per pollinated flower. The addition of 25% cross pollen did not prevent the occurrence of self seed in any of the inbreds although the 50% mixture did not give any self seed for one of them. The most interesting finding was that in two of the lines more self seed was obtained per flower pollinated from the 25% cross pollen mixture than from pollination with self pollen alone. This suggests that the presence of cross pollen may have stimulated the growth of self pollen, resulting in a higher set of self seed than was expected from routine partial self-compatibility tests.

Self-incompatibility mechanism in flowering plants

The possibility that phytoalexins might be involved in pollen-style incompatibility is being examined. *Solanum* species proved more useful than *B. oleracea* for the experiments because the phytoalexin rishitin was readily available, pollen germination *in vitro* was usually good, and a well defined incompatibility system was present. Rishitin at 50 µg/ml considerably reduced the percentage germination and germ-tube length of *Solanum* pollen *in vitro*, and inhibited germination completely at concentrations higher than 100 µg/ml. Additional callose was deposited in the pollen grains and tubes, the latter appearing contorted, with constrictions and swollen tips which eventually burst.

(T. Hodgkin)

Yield components

An important yield component in Brussels sprouts is sprout number per plant, which depends on the number of sites at which leaves develop on a plant (nodes), and the proportion of these which produce marketable axillary buds. Several years data have now been analysed on the inheritance of final node number prior to floral initiation, and their rate of production in a half diallel between 10 F_1 cultivars.

The results from each year were very similar. In 1976 final node numbers ranged from 121 to 160 for the 10 parental cultivars and from 116 to 153 for the half diallel progenies. Between mid-June and mid-September the production rate was more or less constant for each progeny, ranging from 0.8 to 1.3 nodes per day. The analyses showed that both final number and rate of production were highly heritable and largely under the control of additive genes. For final node number it appeared that the parent cv. Gleneagles had some dominant genes for high number and cv. King Arthur some dominant genes for low number. Gene interaction effects were not significant for either character and the selfed progenies showed little or no inbreeding depression. The 10 parental GCA constants for rate of node production and final node number were closely correlated ($r=0.92$, $P=0.001$), any difference present being largely attributable to variation in the time of termination of node production.

Residual seed of the half diallel was sown in 1978 to provide additional data on sprout yield (weight and number), uniformity of size on the stem at maturity, stem length and certain quality components, for comparison with data obtained in 1976/77. These will be analysed during 1979, but preliminary results show average yields of 20 t/ha which are higher than in 1976, a reflection of improved growing conditions and absence of drought in 1978.

Progenies obtained by intercrossing selections from certain half diallel progenies (Ann. Rept 1977) were grown in a replicated trial and sprout yield, uniformity and stem length were measured. Although there was considerable variation, both between and within progenies, the mean yield of 24 t/ha and mean stem length of 0.67 m, exceeded by 15-20% the means of the grandparental F_1 cultivars from which the progenies were derived. However, sprout quality was often poor and there were high percentages of blown and rotten sprouts at a December harvest. The best of these progenies will be further multiplied to provide non-inbred material with potential for high productivity.

(T. Hodgkin)

Improvement of glossy inbred lines

The decision to produce a second generation of hybrids in the cyclic single-cross selection programme from crosses between plants heterozygous for glossy marker genes was unexpectedly difficult to accomplish. It was necessary to maintain possible parent plants while progeny tests for heterozygosity were made and 15 of them were lost from stem rots during this period. Six were discarded because they were male-sterile and a further group was eliminated after testing for S-allele identity and for self-incompatibility by fluorescence microscopy.

Synchrony of flowering period, flower colour and plant habit are all characters that could effect the success of crossing between lines in the field and these were considered before pairs of cross-compatible plants were selected from crossing families.

Each suitable plant was bud self-pollinated and crosses were made at the bud stage. In all, 48 new hybrids were produced in addition to 15 made in 1977. These will be compared with suitable hybrids in a trial in 1979.

(A. J. Redfern)

03013 *Brassicas: isoenzyme analysis in Brassica oleracea*

Work has continued on the evaluation of inbred lines and F_1 hybrids and the assessment of sib frequencies in seed crops of some commercial and experimental hybrids. Fifteen hybrids and eight inbred lines were analysed in 1978.

The convention followed in previous Annual Reports for describing stained electrophoresis gels has now been changed to follow procedures recognised elsewhere. Accordingly zones of enzyme activity, and the bands within zones, are now enumerated in increasing numerical order from the most to the least mobile.

Segregation of cotyledon acid phosphatase bands in zone 1 (previously zone 7) gave further support to the hypothesis that they are determined by a series of alleles at a single locus. The absence of some combinations of bands among those that might be expected to occur in this zone has previously been noted (Ann. Rept 1977). One such combination, of bands *a* and *b*, was investigated in appropriate progenies. In four families the allele controlling band *b* was dominant to that of *a* but two types of *b* band, having identical mobilities but different interactions with *a*, segregated in other families derived by selfing and crossing plant 200. Some plants in the self family, presumed to be homozygous for the anomalous b^1 allele, gave a weaker staining reaction than others. In the outcross families b^1 was not fully dominant to *a*, the heterozygotes producing a diffuse, weakly stained

area that was not resolved into distinct bands. The second absent band combination, *c d*, has not yet been investigated.

In view of this allele interaction in the control of cotyledon zone 1 isoenzymes it is essential to ensure by adequate testing that the F_1 does not give an anomalous banding pattern when considering its suitability for sib analysis by these isoenzymes.

The standard procedure of sample preparation for isoenzyme assay of seeds involves destruction of the whole seed. An alternative but more laborious procedure is to excise the outer cotyledon from each seed for immediate analysis and to sow the remaining part, comprising the inner cotyledon and attached embryo, for further analysis after germination. Independent segregation of seed *acp-1* and cotyledon zone 1 isoenzymes was demonstrated in two small families by this procedure. Investigations of linkage relationships with other genes is reported under Project 03015.

Acid phosphatase isoenzymes are found in seed extracts in a zone having approximately the same electrophoretic mobility as zone 1 of cotyledon extracts. Their intensity of staining varies but is usually too weak to permit consistent analysis except in a few cultivars such as calabrese cv. Corvet. Experiments were done in an attempt to trace changes in isoenzyme expression during the course of germination in Corvet and the weaker staining Brussels sprout cv. Nelson and the cabbage cv. Celtic. Most changes in the patterns observed usually occurred after radicle emergence although there was much variation in the time of expression and only Corvet gave sufficiently consistent resolution. Seeds primed with polyethylene glycol 6000 (PEG) so that their development was stopped just before radicle emergence did not produce any of the normal post-emergence changes.

Acid phosphatase isoenzymes were compared in the diploid species *B. oleracea* and *B. campestris* and their natural amphidiploid hybrid *B. napus*. Similar isoenzyme systems were found in the three species for seed zone 2 and cotyledon zone 1. The diploids had some bands in common and other bands unique to each species for each system. Neither the full range of bands represented in the diploids nor any new primary bands has been found in either system in the amphidiploid. Nevertheless some cotyledon zone 1 phenotypes of *B. napus* were more complex than either parent species as a result of the duplication of loci and increased possibilities for heterodimer formation.

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

03015 Brassicac: genetics and cytology of Brassica oleracea

Families were raised for linkage studies of 21 different combinations of 11 seedling markers. None of these revealed new linkages but confirmation of linkage was obtained for five combinations already known. Among the

new combinations, a hairy-leaf gene (Hr^D) was shown not to be linked to dominant glossy foliage ($Go-2$), leaf excrescence (le) or anthocyanic (A). Also, fused cotyledon (fc) was not linked to fern leaf (Fn), hairy first leaf ($Hr-1$) or glossy foliage ($gl-3$). Expression of fc again proved to be so variable that it can have no practical value as a marker for inbred lines.

Joint segregation of isoenzymes and some major genes indicated that acid phosphatase of seed zone 2 ($acp-1$) was not linked to $Hr-1$. Acid phosphatase in cotyledon zone 1 (now provisionally designated $acp-3$) was however loosely linked to $Go-2$ (recombination $37.62 \pm 4.79\%$) but not to $Hr-1$, pale green leaf ($pg-2$) or Fn .

The genes studied have been derived both from annual and biennial forms, and most progenies now segregate for this characteristic. As a consequence, extensive differential plant losses occurred during the severe winter and flowering characters could not be recorded in many families. Among these families showing moderate survival one segregated anther spot (An), white petal (Wh) and crinkly petal (cp) in addition to le , fc and $gl-1$. The only linkage detected was between le and An , although cp and An have previously been found to be linked (Ann. Rept 1976). Data from other families indicated no association of cp with Fc , $Hr-1$, $Go-2$ or Hr^D , nor between An , Hr^D or $Go-2$.

A group of 18 aneuploids, obtained by crossing diploid and triploid plants, was self-pollinated and outcrossed to selected euploids to provide suitable material for the establishment of trisomic lines. Bud pollinations gave a mean of 7.7 seeds per flower pollinated when aneuploids were used as the male parent in outcrosses, and only 1.1 for the reciprocals. Selfing was less successful, yielding 0.4 seeds per bud pollinated. Further diploid \times triploid crosses have given 286 more seeds from which another group of aneuploids will be established.

(A. B. Wills, P. Smith)

03012 Cabbage breeding

One hundred and seventy eight partially inbred white cabbage and savoy-cabbage lines which had been selected for superior combining ability with 'S' and 'DK' tester lines were grown in an overwintering observation trial. Survival, seed production potential, flowering period and *Alternaria* infection were assessed visually during spring and summer. The trial was late planted (June) to favour winter survival, but despite this and heavy selection against susceptibility to stem rotting in earlier generations there were considerable losses following the severe winter. Plants that did not suffer from head rotting produced primary stalk inflorescences and bore more seed, but other plants produced only axillary inflorescences which

tended to break at the junction with the stump and be lost. *Alternaria brassicicola* infections developed on siliquae of all the lines, but it appeared that some were more severely infected than others, especially those with lodged inflorescences. A further generation of hybrids was obtained from crosses with the 'S' line using these and combining-ability criteria to select the parents. The lines were also evaluated for their tendency to produce sibs by hand selfing of open flowers.

One of the hybrids obtained from pollen received from Asmer Seeds Ltd. was resynthesised to produce seed for growing here and at Ormskirk.

The partial half diallel (Ann. Rept 1977) was sown in April, 1978, and transplanted in two randomised blocks. Sample harvests were made in October, November and December. Another will be completed in January, 1979, and standing ability will be recorded on the remaining plants.

A second partial half diallel was made between 32 of the inbred savoy and white cabbage lines related to those used in the first half diallel, and 11 inbreds previously found to combine well with 'DK' and 'S' lines.

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

03019 Calabrese breeding

One hundred and twenty progenies were obtained from crosses between F_2 breeding material and the F_1 hybrid lines Bravo and Corvet (Ann. Rept 1977) and grown in three randomised blocks with the control cultivars Corvet, Bravo, Early One and RS 73378.

The plots were harvested twice weekly from early August to late September and on each occasion all mature spears were cut 15 cm long. Spear weight and number of attached leaves were recorded, together with scores for colour, bud uniformity, general quality and the incidence of rots and hollow stem. Analyses of these data are not yet available. Bud rotting on immature spears was a particular problem. It was most prevalent during high rainfall and appeared to be associated with the central buds in flat-topped spears. It was not clear whether death of these buds prevented elongation of the inflorescence branches in the area and so created a flat appearance, or whether the flatness of the spear was predisposing to the rot because it encouraged water accumulation.

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

MYCOLOGY

R. A. FOX

An interdisciplinary pesticide application working group was formed during the year chaired by the Head of Section. Work is well in hand with the design of an all-purpose experimental spray rig following advice sought from expert opinions elsewhere. The value of such a rig was well demonstrated during the year when a fluorescent tracer was used in a spray tank and various commercial procedures used to spray raspberries; it was found that coverage could vary from barely adequate to almost useless. The continuing work on prospective chemical control of red core root disease of strawberries caused by *Phytophthora fragariae* has reached a successful stage where recommendations can be made for commercial use.

Further investigations of non-pathogenic parasitism by *Phoma exigua* var *foveata*, the potato gangrene fungus, have failed to demonstrate any effects on growth of barley when this host is extensively invaded symptomlessly. Similar symptomless infection has been demonstrated here in *Chenopodium quinoa* which is grown as a grain plant in association with potatoes in their centre of origin in South America and where it has recently been found as a natural alternative host for this pathogen. However, in South America it causes a clearly defined stem disease in grain-producing genotypes of *C. quinoa* suggesting that the pathogenicity spectrum of South American and European isolates of the var *foveata* may have diverged.

SOIL MICROBIOLOGY AND ROOT DISEASES

02017 Biology of potato gangrene

Lesion development in planted tubers

The slow spread in May, 1977, of gangrene lesions on seed tubers inoculated with *Phoma exigua* var *foveata* and planted in April, was thought to be associated with warm dry soil conditions because observations from previous years indicated that such lesions at that time of year had the potential for rapid spread. The influence of soil temperature and moisture on lesion development was therefore investigated by planting inoculated tubers in the field and in field soil or sterile sand in pots stored at 5 or 10°C. Half the

pots were kept dry and half moist for 6 weeks, after which the lesions were measured. In the field, sample tubers were uncovered and the lesion sizes recorded at fortnightly intervals. Lesions spread fastest in the 10°C treatments particularly in the tubers from the dry pots. Moist conditions induced greatest pycnidial development on the surface of lesions which were larger in tubers planted in moist soil than in those planted in moist sand, a result which supports previous suggestions of a synergistic role of some soil bacteria in aiding tissue penetration. The mean soil temperature in the field during the 6 week period was *ca.* 12°C and little rain fell. The rate of extension of rots in the field-planted tubers was similar to that of the 10°C/dry treatment tubers. Between the early May planting date and the final sampling date in mid-July, lesions increased steadily in size except for a static period in mid-June coincident with exceptionally high mean soil temperatures (17°C at 0900 h).

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

Survival of the pathogen in soils

Estimating soil populations of *P. exigua* var *foveata* using selective media is a more sensitive technique and gives more reproducible results than using potato tuber baits. For estimates on selective media of the number of Colony Forming Units (CFU) samples must be dry so that the soil can be directly distributed quantitatively onto agar plates by a standardised peppering technique. Moist soil samples are therefore routinely air-dried 24 h at room temperature before testing them, a procedure which may enhance the detection rate by reducing viability of some fast-growing Phycomycetes and other microorganisms particularly sensitive to drying. Although soil inoculated with spores of the var. *foveata* and stored dry may remain infective for over 2 years, routine drying may nevertheless adversely affect also the pathogen's propagules. This possibility was investigated by wetting a spore/sand mixture after various periods of dry storage and then either distributing it on selective media after the routine drying time or mixing it with field soil for survival tests after further storage to assess the effects of the pre-treatment on survival of the pathogen. The amended soil was stored moist at 10°C for 9 weeks. Wetting the spore/sand mixture immediately (0 h), after 24, 48, and 120 h and 3 weeks and then re-drying it reduced the number of CFU in all treatments to approximately half those of the unwetted controls and there was a continual decrease in detectable populations with increases in storage time. Corresponding changes occurred also in the amended field soil and the numbers of CFU detected in the individual treatments declined slowly over the 9-week storage period, the rate being fastest in the samples from the 0 and 24 h pre-treatment samples.

Some anomalous results were observed in this experiment. Diluting sand/spore inocula with soil in a 1:3 ratio did not produce a proportionate re-

duction in CFU numbers; indeed they remained at similar levels indicating a spurious three-fold increase in propagules. The anomaly could be due to the procedure used to prepare test samples for direct plating. To ensure their even distribution, samples must be both dry and finely powdered, achieved by pulverisation in a mortar. To pulverise to the required fineness takes longer for sand than for soil and proportionately does more lethal damage to microorganisms and reduces *pro rata* the potential CFU count. Another batch of 1:3 spore/sand inoculum: field soil mixture was prepared and the CFU recovery rate determined from this mixture, from equivalent dilutions made from sand or sterile soil and from a further series of mixtures of 1:30 dilutions.

The mixtures were moistened, stored at 9°C, and sampled at intervals up to 13 weeks. The sand dilutions initially developed slightly fewer than expected CFU, the field soil less than half but the sterile soil over twice the number. After 3 weeks there were three times as many CFU in the field soil as in the sand, and 100 times as many after 6 weeks. The CFU levels in the sterile soil dilutions remained very high throughout the experiment, the highest dilution, 1:30, increasing with time to exceed that of the 1:3 dilution presumably as the fungus progressively colonised the sterile soil as it must also have done in the other series with sterile soil as a diluent. In contrast, the CFU level of sand declined too rapidly to be accounted for solely by the effects of pulverisation, its damaging action possibly being enhanced by water stress.

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

Alternative hosts

Phoma exigua var. *foveata* has recently been found in the uplands of South America as a pathogen of an alternative host, *Chenopodium quinoa*, grown there as a grain plant in association with potatoes. Preliminary studies elsewhere have indicated that European strains of the pathogen were not pathogenic to *C. quinoa* but new world isolates of the fungus were as pathogenic as European isolates to potato tubers. Since Scottish isolates have been shown to exhibit non-pathogenic parasitism to a range of crop plants and weeds, some were inoculated to the dwarf mildew-resistant strain of *C. quinoa* routinely used at SHRI as a virus test plant. Four weeks after toothpick inoculations to their stems with six isolates of the var *foveata* and one of *Phoma exigua* var. *exigua*, plants of *C. quinoa* remained symptomless when growing in a cool glasshouse. When stems were serially sectioned, surface sterilised and plated on agar, the fungus was readily re-isolated and infection commonly appeared to be restricted to a zone within 20 mm of the point of inoculation. However one of the isolates of var. *foveata*, characterised by rapid pycnidial production and spore formation, had spread within

stems for up to 100 mm. When spore suspensions of the fast sporing isolate were used to inoculate leaves and roots by dipping, and compost by drenching, and stems again inoculated with toothpicks, little spread was detected. However, abundant pycnidia developed in concentric zones on an inoculated leaf which nevertheless remained green other than in the concentric target zones and the fungus could readily be re-isolated from the symptomless stems after 8 weeks.

Barley seedling can be infected by *P. exigua* var. *foveata* and when grown under various controlled environmental conditions do not exhibit symptoms or gross growth effects. To further study the extent of symptomless infection and to attempt to detect any effects of infection on growth, seedlings were subjected to high levels of inoculum and grown at sub-optimal temperatures in growth cabinets. Pre-germinated seed was sown in pots of sand infested or not with a spore suspension and with pieces of cellophane bearing pycnidia of var. *foveata*. The pots were placed in root boxes held at 12°C, the boxes in turn were sited in growth chambers held at 15°C. Emergence plant height and rate of tillering were assessed at intervals over a period of 12 weeks and drainage water from the pots was periodically tested to confirm the continuing infectivity of the sand. The plants were harvested, washed, and samples tested for infection by plating tissue after surface treatments. Despite the infectivity of the sand remaining high until harvest, no differences were detected between the growth of plants in infested or non-infested pots, nor were any symptoms detected on the tillers or the roots. Yet all 16 of the sampled inoculated plants were found to be infected. After surface sterilisation with 0.1% HgCl solution for 3 minutes, the pathogen grew from 31% of the root pieces (n=287), 84% of the tiller base pieces (n=87), and 26% of the stem pieces (n=270). The corresponding percentages after washing with sterile water alone were 98, 98, and 57 respectively. The pathogen was not isolated from expanded leaves following either surface treatment and it was similarly not detected in tissue pieces (n=ca. 1000) from the control plants except for three water-washed pieces of root from one plant. These all yielded an isolate strikingly different in appearance to, and differing physiologically from that used to inoculate the pots and was presumably a random — though interesting — contaminant.

The results confirm previous work that barley seedlings may be apparently extensively infected symptomlessly indicating that parasitism causes little disturbance to host physiology. Fungal hyphae are usually difficult to detect histologically in symptomless plants indicating that the density of invasion is not high. However, adequate convincing evidence for their presence was obtained from the barley plants examined.

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

Survival of oospores in soil

Oospores from infected roots were placed between 20 mm squares of monofilament nylon cloth (20 μ m mesh), joined along one edge, which were then buried in soil either in the field or in small plastic cups. The moisture content of the soil in the cups was adjusted to range from 10% to 100% moisture holding capacity (MHC) and they were stored at temperatures ranging from -20 to $+30^{\circ}\text{C}$. The nylon squares were recovered after 6 weeks and the oospores freed of surface contamination by treatment with weak mercuric chloride solution followed by repeated washing with sterile distilled water. The germination rate of the oospores before burial was very low ($<1\%$). It remained low after all treatments except following burial in the field soil and in soil adjusted to 80% MHC held at 5°C where germination was 8% and 5% respectively. The appearance of the non-germinated oospores remained unchanged except for those held at -20°C where ca. 30 to 40% appeared non-viable.

Using plants of *Fragaria vesca* clone VSI, infectivity levels were examined of soil samples similarly treated but where oospores had been added directly. Overall, the levels were very low although again they were highest in the field soil samples. No infectivity was detected in check field samples indicating that the infectivity detected by the bait plants in the treated samples was due to the added oospores.

(J. M. Duncan)

Survival of mycelium in soil

An experiment designed to examine the survival of mycelium of the fungus on squares of nylon cloth buried in sterilised and non-sterilised soil was continued (Ann. Rept, 1977, p.71). In the non-autoclaved soil series, the fungus survived longest in moist soil held at 3°C (137 days). In autoclaved soil, the fungus survived for at least 256 days. However, in non-autoclaved naturally infested field soil which contained oospores, infectivity persisted for much longer periods than those recorded for the mycelial mats indicating that oospores and not vegetative mycelium are responsible for long term survival of the pathogen in soil.

(J. M. Duncan)

Effect of pH on the infectivity of naturally infested soil

Investigations of the effect of altering soil pH on the infectivity of naturally infested soil were continued by altering the pH of autoclaved field soil with the addition of 4N H_2SO_4 , 4N NaOH or sterile distilled water. One volume

of this adjusted soil was mixed with two volumes of naturally infested field soil to produce samples with initial pH values ranging from 3.23 to 10.29. Soil samples were also treated with 4N Na_2SO_4 ; they were little altered in pH and provided a check on the effects on infectivity of adding Na^+ and $\text{SO}_4^{=}$ ions.

The soils were stored at 15°C and at intervals samples were assessed for infectivity by baiting a dilution series prepared from them with *Fragaria vesca* clone VS1. The pH value of each adjusted soil sample and of its mixes with the dilution compost was checked at each sampling and it was found that regardless of the initial adjusted pH, the ranges within any one dilution series rarely varied by more than 0.5 pH units. Thus there was no effect of initial pH on the baiting procedure.

Eight samples were taken over a period of 18 m and the fungus was detected in unamended soil initially of pH 6.35 on all but one occasion (13 m) when baiting failed in all samples. It was detected readily in seven of eight occasions in soil with initial pH values of 3.25 and 4.46 and, at lower intensities, at pH 8.32, but it was not detected after 5.5 months in soil with an initial pH of 10.05. Addition of Na_2SO_4 had little effect on infectivity. The results indicate that infectivity declines rapidly at high pH and is unaffected at low pH values.

(J. M. Duncan)

Selective medium

A selective medium incorporating the new fungicide Hymexazol has been successfully used to isolate *P. fragariae* directly from infected strawberry roots. The medium consists of french bean agar with Hymexazol (50 ppm), primaricin (10 ppm), penicillin G (200 ppm) and quintozone (PCNB) (100 ppm).

(J. M. Duncan)

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

Biology of Botrytis fabae in bean

Fungi were isolated from 50 randomly-selected surface-sterilized leaf lesions taken on 55 occasions from various commercial crops during the last 4 years. *Botrytis fabae* was absent or was recovered from only a small proportion of leaves until early June, but by mid-July it was isolated from most lesions and by the end of the season it was often isolated from all 50 lesions taken on any one occasion. Despite these high levels of *B. fabae*, chocolate spot disease was not considered to be a problem in any of the crops which were sampled, possibly because fungal activity remained at a low level until after a substantial amount of seed has been set.

Five *Vicia sativa* plants, grown in pots, were inoculated with a suspension of *B. fabae* conidia on 25 October, 1977, and kept in polythene bags at 15°C in a glasshouse. Ten days later when sporulating lesions were present the bags were removed and the plants transferred to a cold frame. They were placed outside on 11 November. One stem lesion from each plant was surface-sterilized and placed on agar on 1 December; this was repeated on 14 April, 1978. Pieces of stem from five uninoculated control plants were similarly placed on agar on each occasion. *B. fabae* was recovered from all five stem lesions on 1 December and from four out of five on 14 April but was absent from uninoculated control plants. Conidiophores and conidia of *B. fabae* developed on stem lesions when overwintered plants were kept for 7 days at high humidity, demonstrating that the fungus can overwinter on *V. sativa* and produce infective spores in the spring. *B. fabae* was isolated from two out of 20 surface-sterilized leaves of *V. sativa* occurring in a bean crop during August, 1978, showing that the fungus infects common vetch in the field.

On 4 April, 1978, *B. fabae* was isolated from 32, 12 and 4% of leaf lesions taken from an autumn-sown crop of cv. Throws MS at three sites, adjacent to, ca. 50 m and ca. 100 m from an area where both volunteer seedlings and debris from a previous crop were heavily infected with *B. fabae*. Large numbers of *B. fabae* conidia were observed on sclerotia on the stem trash from November, 1977, until the following April, when debris and seedlings were ploughed in, but despite thorough searching they were not found on lesions on the volunteer seedlings. This result indicates that the *B. fabae* in the new crop originated from the nearby debris.

An attempt was made to develop a rapid method of screening new cultivars for chocolate spot resistance. Eighteen lines of *Vicia faba* obtained from D. A. Bond¹, were grown in a glasshouse. After 2 months, 10 leaves with a short length of stem attached were cut from each line and the stems placed individually in small McCartney bottles containing water. The leaves were arranged so that the laminae were horizontal and the bottles put in the base of germination trays containing water to a depth of ca. 10 mm. A 0.01 ml drop of water containing 5×10^5 conidia of *B. fabae*/ml was placed near the centre of each lamina, the lids placed on the germination trays and each tray was sealed in a plastic bag. After 4 days at room temperature the diameter of each lesion was measured. There were significant differences ($P < 0.001$) in mean lesion diameter between lines, but they did not correlate significantly with severity of chocolate spot in field plots at Cambridge.

Injection of a solution containing 100 µg wyerone acid/ml into healthy field bean leaves caused the rapid development of dark grey lesions. Epidermal cells were killed by incubating them for 4 h in 50 µg wyerone acid/ml. Lower concentrations of wyerone acid and solutions containing

¹ Plant Breeding Institute, Cambridge.

100 $\mu\text{g/ml}$ wyerone and wyerone epoxide reduced the fluorescence compared with controls after immersion in fluorescein diacetate, clearly demonstrating the phytotoxicity to bean leaves of these phytolaexins. The concentrations of several phytolaexins in the heat-stable ethanol-soluble phytotoxic fraction obtained from leaves infected with *B. fabae* were determined by J. W. Mansfield¹, using high pressure liquid chromatography. No phytoalexins were detected in the extract, demonstrating that the toxic component is not wyerone acid or a closely related compound. Several dilutions of a crude extract containing the toxin from infected bean leaves were injected into leaves of 15 different plant species and necrosis recorded after 24 h. At the lowest concentration only field bean leaves were affected, while at the highest, which was $8 \times$ the lowest concentration, necrosis was absent from eight species and was severe in only field bean and *Vicia hirsuta*.

(J. G. Harrison)

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

Barley emergence and yield

Application of urea and Benlate to maturing ears of barley cv. Golden Promise had no effect on seed quality in 1977 (Ann. Rept 1977, p.78), but delaying harvest from 24 August to 10 October reduced germination from 98 to 79% respectively and seedling growth potential was reduced from 7.80 to 5.35 cm/seed. The fungal flora, determined after surface sterilization and plating on malt extract and malt extract + 10% NaCl agars, were similar for seed from both harvests except that contamination by Mucoraceous forms increased from 1.0 to 7.5% in the later harvested lot. In field sowings in March, relative emergence (emergence expressed as a percentage of viability) was less for the seeds from the delayed harvest than from the timely harvest (86 and 96% respectively), while in May and June sowings, it was similar for both lots.

Seeds from the timely and from the delayed harvest, along with two commercial lots of low vigour, were sown with an Øyjord drill in plots 5 m \times 1.35 m at four sowing rates adjusted to provide four population densities between 400 and 50 plants/m². The experiment was sown on 7 April and relative emergence was high for all lots. There were significant differences in total grain per plot due to sowing rates and plants at the lower rates compensated by significantly increased numbers of ears per plant and grains per ear. However, in contrast to previous results, there were no significant differences in grain yield obtained from the different seed lots. The high emergence figures indicated that environmental conditions after sowing imposed no stress on the seedlings and, as a result, plant performance from high and low vigour seeds was similar.

(D. A. Perry)

¹ University of Stirling.

Causes of barley seed mortality in wet soil

Seeds of cv. Golden Promise which had deteriorated when stored at 20% m.c. and 30°C, but whose viability was >85%, were sown in field soil containing 16 or 32% water (wet weight basis) in petri dishes. Seeds recovered at daily intervals and placed on damp filter paper in germinators showed that mortality in wet soil at 20°C increased to a maximum at 2 days, after which time surviving seeds germinated normally. The viability of non-deteriorated seeds and seeds in dry soil was not affected. When deteriorated seeds were sown in soil at 16% m.c. and subjected to high water levels at increasing times from sowing, the lethal affect of water declined with the length of time seeds were in moist soil, until after 3 days they were unaffected.

The cause of seed mortality was investigated by sowing seeds in soil or on filter paper and keeping them under H₂ in anaerobic jars. When seeds were removed at daily intervals and set to germinate in air, mortality of deteriorated seeds in anaerobic conditions increased with time to 100% after 3 days. Non-deteriorated seeds survived at least 4 days anoxia.

The proportion of deteriorated seeds which died after 4 days in soil at 32% m.c. was less in autoclaved than in non-autoclaved soil and after treatment with Hg-containing fungicides. Inoculation of seeds in sterilized soil showed that bacteria isolated from dead seeds did not increase mortality, while some fungi, viz. *Fusarium equiseti*, *F. culmorum*, *Mortierella* sp., and *Chaetomium* sp., also isolated from dead seeds, were associated with significantly increased mortality at high soil moisture contents. Removing the lemma and palea with 50% H₂SO₄ reduced the viability of deteriorated seeds and greatly increased mortality in field soil. Cutting off the distal end of the endosperm also increased mortality, while hand dissection of the lemma covering the embryo had no effect. Non-deteriorated seeds were not affected by any of these damaging treatments. (D. R. Ellerton)

02025 *Rhizosphere and allied phenomena affecting plant health*

Potatoes

Preliminary attempts were made to try to label anaerobic microsites on roots using an obligate anaerobe and immunofluorescence techniques. Euchrysin 2GNX was the best of the fluorescent stains tested giving a strong reaction on the stained bacteria with a minimum of background fluorescence when excited at 400 m μ (filter BG12) with a barrier filter giving a cut off at 470 m μ . Antisera to the bacterium, a *Clostridium* sp., have not yet been produced but the technique should enable the quantification of anaerobic microsites on roots and the study of microbial interactions associated with them. (A. J. Hargreaves)

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

Potato leaf epidermal strips were killed within a few min after suspending in 1% Evans blue containing 300 μg rishitin/ml. Evans blue, a stain normally excluded from viable plant cells by its high molecular weight, accumulated throughout each cell and was concentrated in the nuclei, showing that the permeability or integrity of the plasmalemmae had been affected. Lysis of many, but not all, chloroplasts was observed. Lower concentrations of rishitin (100 $\mu\text{g}/\text{ml}$) did not effect these changes within 30 min of its addition to leaf tissue.

Approximately 30% of isolated potato leaf chloroplasts suspended in 0.15 M phosphate buffer pH 6.5 lysed after the addition of 300 μg rishitin/ml and showed vesicle formation similar to that observed with rishitin-treated protoplasts.

The effect of rishitin on the permeability of artificial membranes (liposomes) to various non-electrolytes was measured by following changes in light absorbance (450 nm) after mixing liposomes with hypertonic solutions of the non-electrolytes. The rate of movement of urea and ethylene glycol through liposomes prepared from mixtures of phosphatidylcholine plus cholesterol and either phosphatidic acid, stearylamine or cetylphosphate was increased by prior incubation of liposomes with rishitin.

These results support the hypothesis that rishitin acts directly on cell membranes *in vivo*.

(G. D. Lyon)

02015 Disorders of vegetables*Cavity spot of carrots*

Cavity spot was widespread and severe in Scottish crops in 1978. August rainfall was 22 mm greater than average and exceeded calculated evaporation by 29.5 mm for the first 2 wk when wind run and sunshine hours were below average. The data support the previously observed association between wet growing seasons and high incidence of cavity spot.

In continued studies on the distribution of anaerobic pectolytic *Clostridium* spp., soil samples were collected from 10 fields of a mixed arable farm where carrots in one field were severely affected by cavity spot. When incubated on carrot disks under anaerobic conditions, soils

from south-facing arable fields caused more rotting than those from north-facing fields under grass ley. Very little rotting occurred after the soils were incubated on disks in air for a similar period.

The conventional isolation technique of streaking droplets of dispersed tissue on agar has rarely detected *Clostridium* spp. in lesions on field-grown roots collected in the autumn. When 440 pieces of unbroken small lesions ca. 8 mm³ from eight different farms were surface sterilized and placed on Lund's P1 pectate medium, areas of pectate dissolution were noted around 22% of them after anaerobic incubation, and *Clostridium* spp. were isolated. Pectate dissolution was found around 6% of a similar number of unblemished tissue pieces. The failure to isolate *Clostridium* spp. from old lesions was simulated when roots were inoculated with soil slurry from a field outbreak and incubated in sealed pots for 5 days at 20°C. The roots developed extensive soft rot lesions and anaerobic pectolytic bacteria were isolated from all of 36 roots tested. The roots were placed in aerobic conditions and 4 wk later the bacteria were recovered from 19 out of 33 roots but after 8 wk from only seven of 36 roots.

The susceptibility of 13 carrot cultivars to root lesion development after inoculation with soil slurry or a suspension of *Clostridium* spp. was tested by incubating for 5 d at 20°C in sealed pots. Cultivars exhibited significant differences in lesion severity but none was resistant or immune. Cv. Feonia was least susceptible, cv. Chantenay was among the most affected and the F₁ hybrid cv. Spartan was intermediate.

(D. A. Perry)

02018 Diseases of potato tubers

Pectic enzymes production by Erwinia carotovora

The levels of polygalacturonic acid transeliminase produced by nine strains of *Erwinia carotovora* var *carotovora* and eight strains of *Erwinia carotovora* var *atroseptica* in pectate broth at 15, 25 and 30°C were assayed spectrophotometrically. Enzyme production by all strains of var *atroseptica* was high at 15°C and low or absent at 30°C. Enzyme levels produced by seven of the var *carotovora* strains were high at both temperatures while in the remaining two strains they were low at 15°C and high at 30°C. Most strains of both varieties of *E. carotovora* produced high levels of enzyme at 25°C.

(M. C. M. Pérombelon, A. Ghanekar)

Detection of Erwinia carotovora in tubers

Routine detection of *E. carotovora* in potato stocks is usually carried out by the tuber incubation method in which the test tubers are first induced to rot under anaerobic conditions followed by detection/isolation of the bacteria from the rot lesion (Ann. Rept 1966, p34). However, when naturally contaminated tubers and tubers inoculated with both var. *carotovora* and var. *atroseptica* were tested, detection of *E. carotovora* was poor from extensive lesions and at temperatures of 25°C or above. Furthermore, detection of var. *atroseptica* was more frequent than that of var. *carotovora* at temperatures below 22°C in tubers contaminated by both organisms, whereas at higher temperatures the reverse was true. Only within a narrow temperature range, close to 22°C, was there an equal chance of detecting both varieties. (M. C. M. Pérombelon, R. Lowe)

02027 Studies of plant pathogens

Genetics of Erwinia carotovora

When *Escherichia coli* AB1157 RP₄ and *E. carotovora* var. *carotovora* 44 were crossed on filter membranes, 20% of the transconjugants were sensitive to the male specific phages PRD1 and PRR1. Plasmid transfer from phage sensitive R⁺ strains to strain 44 Str^r after 2 h at 28°C occurred at a frequency of 10⁻⁸ per donor cell, some 10⁵ times greater than from phage resistant R⁺ strains. Transfer frequency in a backcross to AB1157 Str^r was <10⁻¹ per donor cell within 1 h at either 28 or 37°C. Only one out of 18 other var. *carotovora* strains tested and two out of 10 var. *atroseptica* strains had similar frequencies. Transfer frequency in homologous and heterologous (similar and different strains of var. *carotovora* and var. *atroseptica*) crosses between the best *E. carotovora* strains was equally high (10⁻⁸ to 10⁻⁴) and 10² to 10⁵ times greater than in crosses with the other *E. carotovora* strains.

E. carotovora is normally resistant to infection by bacteriophage Mu but following the introduction of plasmid R68: :Mu C⁺Δ 445-7 to strain 44, spontaneous phage production was obtained at 4 × 10⁻⁴ per cell within 18 h in an L-broth culture. In a cross between strains 44R68: :Mu and 44 Rif^r, integration of Mu into the chromosome of the receptive strain following zygotic induction was detected by selecting for a thymine requiring mutant in the R⁻ bacteria. Phage Mu was produced spontaneously by this new strain at 6 × 10⁻⁵ per cell within 18 h in culture in an L-broth supplemented with thymine. An F prime-like system was then obtained by introducing the plasmid R68: :Mu into the strain 44 Rif^r Thy⁻ (Mu). Preliminary results suggest that although only a small proportion of the donor cells is probably involved in the mating process, gene transfer occurs and if it is polarized mapping in *E. carotovora* should be facilitated. (M. C. M. Pérombelon)

Phoma exigua

To provide information on survival during, and the potential for long term storage at low temperatures, eight isolates of *Phoma exigua* var. *foveata*, differing in cultural characteristics, were inoculated to slices obtained aseptically from tubers of cv. Pentland Crown. After incubation at 10°C to allow lesion formation, the slices were sealed individually in plastic bags and stored, after being frozen either slowly or rapidly to -18°C or to -40°C. Samples were removed at monthly intervals over a period of 13 months and thawed either slowly or rapidly before examining their morphology microscopically and checking their viability by plating. All isolates survived and grew normally; their cultural characteristics remained unchanged, there was no increase in sectoring and their pathogenicity was unimpaired. Freeze drying has proved unsuccessful for preserving many isolates of *Phoma* spp. in the culture collection but a minor modification of the above deep freeze process is now being satisfactorily used as a routine. A similar schedule with spores of *P. exigua* var. *foveata* suspended either in water or buffered saline has also proved superior to freeze drying with germination rates of ca. 60% after 13 months.

Survival of the fungus is affected by melanization of mycelium and pycnidia, a character that confers resistance to lysis, and by the extent of pycnidial and spore production. Three isolates were grown on cellophane squares for 3 days from spore suspensions before the squares were transferred to tap water agar at 3 and 10°C—within the normal ambient range—and 27°C—close to the upper limit for growth. Melanization of hyphae and pycnidia was most rapid at 27°C although hyphae growing into the agar were not so affected but their growth was abnormal, the cells becoming markedly vacuolate and subdivided into chlamyospore-like structures. There was little melanization at 3°C, the condition at 10°C being intermediate, but at both lower temperatures pycnidia developed and became fully mature as evidenced by the presence of pycnospores, though more slowly at 3°C. In contrast, the abundant melanized pycnidia formed at 27°C were distorted, partially coalesced and had ill defined walls consisting of loose swollen cells that spread into the inter-pycnidial spaces. The size of the pycnidia was significantly greater at 27°C than at the lower temperatures in one isolate, but size in the others was not affected. More pycnospores developed at 10°C than at 3°C the increased proportion varying with the isolate tested, but at 3°C all pycnospores were significantly larger than those found at 10°C and a greater proportion were septate. Spores from both temperature regimes germinated normally, the resulting colonies having no morphological differences.

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

Botrytis spp.

During 1978, many cultures of *Botrytis* spp. became non-viable. Microscopic examination showed large numbers of dead spores and that the hyphae were often invaded by an *Acremonium* sp. After 24 h growth on an agar plate this fungus inhibited the germination of spores of *B. fabae* indicating that its initial action was that of an antagonist rather than a hyper-parasite.

(A. J. Hargreaves, G. D. Lyon)

Cylindrocarpon ianthothele Wr.

Isolations of fungi from roots of raspberry plants in an experiment to test the effects of various nematicides and fungicides on raspberry growth, yielded a range of fungi of which the most common were *Pythium* spp. and *Cylindrocarpon radicolica*. One isolate, however, was identified as *Cylindrocarpon ianthothele*, reputedly the imperfect stage of *Nectria rubi* Ost (C. Booth, personal communication), which has been implicated in a dieback disease of raspberries. This is the first time *C. ianthothele* has been isolated from raspberry roots at this Institute.

(J. M. Duncan)

Phytophthora megasperma var. *megasperma*

While examining a range of *P. megasperma* isolates obtained by a variety of baiting techniques from soil from Auchincruive, a wide variation was observed in the proportion of viable oospores that each isolate produced in culture. Of two isolates studied further, isolate D39 consistently produced a higher proportion of apparently viable oospores (>90%) on a range of culture media, i.e. the oospores had a thick wall, finely granular cytoplasm and usually a small ooplast and distinct pellucid bodies, while only ca. 25% of the oospores of isolate D72 were of this type, the remainder having disorganised or lysed contents. A similar result was obtained when 20 single zoospore isolates of D39 and 19 of D72 were compared.

(J. M. Duncan)

EPIDEMIOLOGY AND ETIOLOGY

02003 Shoot disorders of cane and bush fruits

Cane diseases of raspberry

Cane blight

Young canes of cv. Malling Jewel, growing in the field, were inoculated on scalpel wounds with mycelium or pycnosporangium suspensions of *Leptosphaeria coniothyrium* at 2 wk intervals from 22 July to 16 September, 1977. When

examined on 15 May, 1978, all lesions arising from mycelial inoculations, except those from the last date had prevented lateral shoot growth because they had girdled the stele. Pycnospore inoculations induced girdling lesions only when done on dates before 18 August. These experiments suggest that canes become resistant to cane blight with maturity. Pycnospores are the most likely form of natural inoculum and the harvest period is the most probable time for their production and thus for canes to be infected.

(B. Williamson, A. J. Hargreaves)

Because *L. coniothyrium* can survive saprophytically on dead wood, it is possible that old cane stubs are an important inoculum source in plantations with a past history of the disease, even though young canes may not have been attacked in the previous year.

Old cane stubs and machine-harvester wounds on fruiting canes from a 9-year-old plantation of the four cultivars Glen Isla, Glen Clova, Malling Jewel and Malling M were sampled on 17 May, 1978, to screen for perithecia and pycnidia. Because they are indistinguishable by superficial microscopic examination and often occurred intermixed on stubs, single fruit bodies were mounted and squashed in 50% glycerol for identification by spore type. Of 36 cane stubs examined, 24 had mature pycnidia, and 25 had perithecia of which 16 had already developed ascospores. The development stage of the perithecia suggested that ascospore dispersal would probably begin within 2 wk of sampling. The significance of ascospores in the epidemiology of cane blight is unknown, but the sexual phase is a source of genetic variation. No perithecia were observed at harvester wounds on 34 fruiting canes examined, but mature pycnidia were present on all of them. These observations suggest that the perithecial stage develops on dead cane only after its fruiting year. Mature pycnidia have been observed on fruiting canes from March to October.

Fresh or autoclaved filtrates from 4 days old shaken cultures of *L. coniothyrium* grown in darkness at 25°C on Pfeffer's medium supplemented with 3% sucrose were phytotoxic to detached raspberry leaves cv. Malling Orion.

(B. Williamson)

Spur blight and cane botrytis

Evidence that some cultivars (e.g. Glen Clova) are relatively tolerant of infections by *Didymella applanata* and *Botrytis cinerea* at nodes in the cropping region of canes (Ann. Rept 1976, p.64) was again supported by node counts in a range of established plantations in 1978. Bud failure was moderate or severe in cv. Malling Orion (spur blight, 45%, botrytis, 68%) and cv. Malling Jewel (spur blight, 43%; botrytis, 50%) but only slight in cv. Glen Clova (spur blight and botrytis, 14%). The length of primary

lateral shoots which grew from nodes infected by either disease did not differ significantly from uninfected nodes in Glen Clova, Malling Jewel or Malling Orion. The potential yield (number of fruits and flowers) of laterals which grew from nodes affected by spur blight was significantly lower, although only slightly so, than that of unaffected nodes but botrytis had no significant effect. Therefore, *D. applanata* and *B. cinerea* seem to have relatively little effect on initiation and differentiation of laterals and flowers.

(B. Williamson, A. J. Hargreaves)

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

Blackleg etiology field studies

The susceptibility of nine cultivars to blackleg was tested by inoculating seed with suspensions containing different concentrations of *Erwinia carotovora* var. *atroseptica* by vacuum infiltration soon after harvest and storing at 5°C. Plots were planted with 810 of such treated seed per cultivar and the number of diseased plants counted in August. The relative susceptibility of the cultivars to blackleg was similar to that found in previous years (Ann. Rept 1977, p.85) except that Golden Wonder was not the most resistant cultivar but with 8% plants affected it was similar to moderately susceptible cultivars such as Majestic. The most resistant cultivars were Pentland Crown and Maris Piper (3% blackleg) and the most susceptible were Bintje, and Up to Date (27% blackleg). Until the end of July, blackleg incidence was low, <1% in all cultivars except Up to Date which had 6% plants affected, and was probably associated with low rainfall and a continuously high soil water deficit (SWD) since planting time. However, 97 mm of rain then fell and the SWD was nil for 2 wk between the July and August sampling times when blackleg incidence increased substantially.

The effect of planting time on blackleg incidence was determined by planting seed of cv. Majestic inoculated with var. *atroseptica* as described above on four different dates from mid-April to the end of June. Most disease was found in the first planting (39%) and the least in the last planting (0%) when recorded in August. Blackleg was slight in all treatments in late July.

(M. C. M. Pérombelon, R. Lowe)

Growth and pathogenicity of Erwinia carotovora in mother tubers and stems

When cv. Majestic seed tubers were vacuum inoculated at planting time with *E. carotovora* var. *carotovora* and var. *atroseptica* in ratios of 1:1, 1000:1 and 1:1000, the bacteria were recovered in equal numbers

irrespective of the initial proportions in August after the tuber had rotted. A month later var. *carotovora* dominated except in mother tubers inoculated with 10^3 times more var. *atroseptica* than var. *carotovora* cells while var. *atroseptica* was always more frequently detected in progeny tubers. Contamination of progeny tubers in August was too low to allow any comparisons. When equal numbers of cells of both varieties of *E. carotovora* were stab-inoculated into stems of potted cv. Majestic plants at 15 and 30°C, only var. *carotovora* was recovered from developing lesions at 30°C while both varieties were present in approximately equal numbers at 15°C. Further experiments showed that these results may be explained by differences in the growth rates and the level of pectic enzymes produced at 15 and 30°C by the different strains.

(M. C. M. Pérombelon, R. Lowe)

Contamination of foliage by Erwinia carotovora

Experiments on survival of *E. carotovora* on leaves of plants in controlled environments at 10 and 20°C (representative of autumn and summer temperatures) and 80% RH confirmed previous results (Ann. Rept 1977, p.84). Leaves were inoculated with ca. 10^3 washed cells of var. *carotovora* and var. *atroseptica* per cm². Survival of var. *carotovora* was slightly better than that of var. *atroseptica*. The number of cells fell sharply after 72 h when they could be detected only by an enrichment technique (wetting the leaf surface with 0.1% peptone water and incubating anaerobically for 24 h). They could still be detected, however, by the tenth day. In contrast, when inoculated leaves were kept at ca. 100% RH and remained wet, bacteria were found after 10 days in numbers similar to or greater than that at zero time. More bacteria survived on senescent than on young leaves, along the mid rib and lateral veins than elsewhere, and on the lower compared with the upper leaf surface. Bacteria on leaves kept at 80% RH for 3 days and then re-wetted multiplied more rapidly during the following 24 h on senescent than on young leaves.

Washed cells of streptomycin resistant strains of var. *carotovora* and var. *atroseptica* inoculated on potato leaves in the field on a misty day in mid-August, could still be enumerated after 2 days of dry and sunny weather when the leaf surface was dry. Later, enrichment techniques were required and the bacteria could still be detected 7 wk after inoculating. They were also recovered from some progeny tubers of inoculated and neighbouring uninoculated plants.

(M. C. M. Pérombelon, R. Lowe)

Red core of strawberry

The relative susceptibility of cultivars and selections which were similar to the slightly susceptible 53Q13 when inoculated with 10^3 zoospores/ml of *Phytophthora fragariae*, was examined after inoculation with 2×10^3 , 4×10^3 , and 8×10^3 zoospores/ml. There was no linear effect of inocula and cultivar/inocula interactions were not significant.

Reference values for susceptibility obtained in experiments containing the same set of cultivars were the same as those obtained previously (Ann. Rept 1976, p.67) in experiments which comprised random collections of cultivars. A preliminary examination of replicate variability for per cent diseased root length in six slightly susceptible cultivars indicated most in Silver Jubilee (4-50%) and least in Cambridge Vigour (19-35%).

Roots of a number of cultivars which were slightly susceptible to infection as parts of whole plants were detached and inoculated at the tip with a drop of water containing 10^1 , 10^2 or 10^3 zoospores. Increasing the number of zoospores at the infection site did not increase the number of infected roots or the length of root invaded. The value of detached roots for studying cultivar response to infection was limited as the length of root invaded in susceptible and slightly susceptible cultivars was similar in contrast to the differentiation observed in whole plants. Detached leaves were inoculated and the area of lesions measured to assess differences in susceptibility between cultivars. Reproducible results were not obtained either for ranking order or significant differences and there was no relation between susceptibility of leaves and roots.

Fungal penetration of the vascular system of rhizomes was studied by dissecting and plating tissue from severely diseased plants of the cultivars Glasa, Montrose, and Cambridge Favourite. Although the red colouration of infected steles extended for several mm into rhizomes of all the cultivars, *P. fragariae* was not isolated from them.

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

Verticillium wilt of strawberry

Three cultivars and five 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. Bounty and four of the selections were susceptible and Cheam and Hatton Main's Seedling and the selection 67DB12 (Cambridge Favourite \times Glasa) were as tolerant as Redgauntlet.

(D. M. Kennedy)

Stamen blight of raspberry

A method of dispersing *Haplospheeria deformans* using spore suspensions and overhead mist-nozzles was satisfactory when evaluated by droplet collections. However, raspberry plants of four genotypes with different combinations of characters for hairy and spiny stems were not infected by this technique although they were infected when axillary buds were inoculated by hypodermic injection of a spore suspension as were the cultivars Burnetholme, Glen Isla, Malling Delight, Phyllis King, St Walfried and *Rubus laciniatus*.

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

02022 Harvest disorders of soft fruit

Buds and flowers of raspberry, from a single site, were examined twice weekly from 6 June to 7 July for superficial and latent infection by *Botrytis cinerea* as in 1977. The numbers found infected were very low until 4 July when 4 of 50 just-opened buds and 19 of 50 flowers yielded *B. cinerea* after surface sterilisation with 5% chlorox; similar proportions were also found infected in the last routine sample on 7 July. Both green and red fruit sampled on 11 July were all infected. A further sample of 100 just-opened flowers were collected on 19 July and their sepals, stamens and carpels dissected and plated separately. All the different categories of floral parts had similar proportions infected with *c.a.* 21% detected following surface sterilisation, again with 5% chlorox.

Rhizopus spp. was also frequently isolated and this rapid growing fungus tended to inhibit the establishment of colonies of *B. cinerea*. A general survey of fungi present on late-formed buds when just opened on 9 August showed 65% with latent *B. cinerea* infection. *Cladosporium herbarum* and *Alternaria* spp. were the most common co-colonizers, their numbers being similar to those of *B. cinerea*.

Overall, these results corroborate last season's conclusion that latent infected flower parts are unlikely to be responsible for fruit rots, the incidence of *B. cinerea* on flowers remaining trivial until after ripe fruit were first present.

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

02007 Biology of diseases of ornamental bulbs

Narcissus basal rot

An experiment was started in 1977 (Ann. Rept 1977, p.86) to ascertain the sources of infection of an outbreak of fusarium basal rot in a glasshouse at NOSCA. One year old bulbs (cv. *Sempre avanti*) raised for twin scales

were used as baits in fresh universal compost (UC), used UC from bulb boxes, sand and peat used in UC, and field soil from an adjacent plot in which bulbs had been grown for 3 years. Each medium was treated in four ways; sterilisation followed by inoculation with *Fusarium oxysporum* (IMI 212203), sterilisation without inoculation, inoculation but no sterilisation, no inoculation and no sterilisation. Symptoms were seen only in bulbs grown in the non-sterilised field soil where eight out of 10 bulbs in the inoculated, and seven out of 10 in the non-inoculation soil senesced early and had lesions on the basal plate. Because the isolate used for the inoculations subsequently was found to have lost its pathogenicity it seems probable that the inoculum causing the outbreak had been blown into the glasshouse on soil particles from the adjacent field plot. Replacement, at an earlier date, of glass in the greenhouse by nylon gauze lends support to this hypothesis.

(A. J. Hargreaves)

PLANT PROTECTION

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

Mycelial growth of *Leptosphaeria coniothyrium* was completely inhibited on 2% malt agar incorporating dinoseb-in-oil at 100 ppm a.i. This direct fungicidal effect may account in part for the impressive control of spreading vascular lesions attributed to *L. coniothyrium* in replacement canes on plots sprayed with dinoseb for vigour control (Ann. Rept 1977, p.87), because this fungus and other raspberry pathogens sporulate on old cane stubs and the bases of fruiting canes that inevitably would be sprayed by dinoseb.

(B. Williamson)

One pre-harvest and two post-harvest sprays of imazalil, benomyl, WL 47675 or triforine were applied to machine-harvested plots of cv. Malling Jewel for control of cane blight in 1978. The effect of treatments on the incidence and severity of vascular lesions at harvester wounds and the yield of plots will be recorded in 1979.

For the second year in succession, the level of natural infection in hand picked plots of cv. Malling Jewel was too low to evaluate the role of old cane stubs and fruiting canes as wounding agents and sources of inoculum for *L. coniothyrium*.

(B. Williamson, A. J. Hargreaves)

A qualitative assessment of the degree of penetration and cover of spray target achieved by high volume hydraulic spraying methods was made by adding a fluorescent dye to the spray liquid in the tank and sampling deposits on leaf surfaces and other targets in the crop. Flat-fan or hollow cone nozzle spray patterns were employed on tractor-mounted booms.

When the booms were adjusted to spray flowering lateral shoots (fruit botrytis programme) the flowers at terminal nodes of laterals and adaxial leaf surfaces in the cropping region of canes received moderate spray cover by either nozzle pattern, but flowers at mid-lateral nodes and abaxial leaf surfaces received only very slight spray deposits. When the booms were adjusted to spray primocanes at the beginning of June (cane midge programme) the canes and abaxial leaf surfaces were also inadequately protected. These observations suggest that the canes, foliage and flowers are screened when leaf laminae on the outside of the canopy are flattened by spray blast.

(B. Williamson, S. C. Gordon¹)

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

Chemical control

All fungicide treatments applied to cv. Cambridge Favourite planted in April, 1977, resulted in significant decreases in disease severity and significant increases in yield. The addition of a foliar spray of aluminium tris (ethyl phosphonate) in September to plants dipped in the fungicide before planting significantly improved disease control and yield. Disease severity and yield were similar in plants which had been dipped in the phosphonate before planting or which had received a soil drench of SN 66752 or dichlofluanid in September.

The efficacy of lower concentrations of aluminium tris (ethyl phosphonate) applied before planting in the spring, was evaluated by counting the number of diseased roots on plants 12 months after treatment. There was no significant decrease in disease severity following root dips in solutions containing 500, 1000 or 2000 ppm a.i.; plant immersion in those with 2000 ppm, or foliar sprays with 500 or 2000 ppm. Although plants which received fungicide sprays + Tween 80 had less disease than those sprayed with fungicide alone the difference was not significant. On the same site, post-planting low volume band-sprays of SN 66752 (7350 ppm) applied in September or November were ineffective.

In a trial planted in 1976 plants which had received annual soil drenches of sodium ethyl phosphonate or aluminium tris (ethyl phosphonate) were again

¹ Zoology Section.

the highest yielding but the difference between these and the captafol treatment was not significant in 1978 due to a substantial increase in yield, compared to that in 1977, from the captafol plots. Yields were similar from plants treated each autumn with a soil drench of etridiazole or a foliar spray of sodium ethyl phosphonate. Assessments based on the proportion of diseased roots in runners planted adjacent to yield plots in April, 1977, and lifted in April, 1978, showed that all treatments significantly decreased disease severity.

In the final fruiting year of a trial planted in 1975, plots which had received an annual autumn soil drench of prothiocarb yielded most for the third successive year despite the treatment being omitted in 1977. The results from treatments with etridiazole applied as single, double, or triple drenches were inconclusive as the increases in yield following more than one application were not significant. Etridiazole incorporated into soil before planting and pyroxychlor applied as a soil drench showed no promise as control measures.

In pot experiments, there was no significant decrease in the proportion of diseased roots following soil drenches of metalaxyl at concentrations of 200, 300, 1000, 2000, 3000 ppm a.i. or following a root dip in a solution containing 300 ppm. There was a significant decrease in the per cent diseased root length following a soil drench of 200 ppm when the number of zoospores of *Phytophthora fragariae* in the inoculum was halved and the incubation decreased from 35 to 14 days. This effect persisted for 15 days after the soil drench was applied but not after 29 days.

The effectiveness of different methods of applying aluminium tris (ethyl phosphonate) after time intervals of 1-85 days was examined in pot experiments. Plants were inoculated with a zoospore suspension after the appropriate time intervals and disease severity compared with that of untreated plants after incubation for 14 days. Significant decreases in the per cent number of diseased roots and per cent diseased root length were recorded 85 days after the soil drench and 43 days after the root dip and foliar spray. In another experiment, the same level of control was achieved after dipping roots for 10 minutes in the fungicide solution as after 300 minutes.

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

Oospores of *P. fragariae* germinated normally when extracted from diseased plants 5 days after the roots had been immersed in a solution of aluminium tris (ethyl phosphonate) for 5 h. There was no significant difference between their per cent germination and those of oospores from roots immersed in water.

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

As correct timing of fungicide applications may be critical in achieving high levels of control, field observations on infection and disease development were augmented by growth cabinet experiments. Production of sporangia and motility of zoospores were recorded at 1, 6, 10, 15, 20, 25 and 30°C. Most sporangia were formed at 10°C, fewest at 1 and 25°C and none at 30°C while the longest and shortest periods of zoospore motility occurred at 6 and 30°C respectively. Disease severity in plants inoculated and incubated at 1, 5, 10, 15 and 20°C with a day-length of 12 h and light intensity of 6456 lux was similar at 10, 15 and 20°C. A significant decrease in symptom expression occurred between 10 and 5°C and between 5 and 1°C and some plants held at 1°C though infected were without symptoms. Oospores were present in all roots infected at 15 and 20°C, in ca. 50% of those infected at 10°C and in none of those infected at 1 and 5°C. Light intensities of 5380, 10760, or 21520 lux and day-lengths of 6, 10, 18, 24 h did not affect disease severity.

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

Biological control

A method was devised to measure the rate of spread of the disease in conducive and suppressive soils and in a peat/sand mixture amended with antagonists. The rate of spread was substantially decreased by the addition of only five of many actinomycetes tested.

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

Detecting red core in planting stocks

The need for a technique to identify infected stocks of strawberry runners prior to planting is self evident. A baiting technique was developed in which the distal 20-50 mm of roots are removed from runners, mixed with universal compost (1:3 by volume), put into 150 mm diam. plastic pots and baited with runners of *F. vesca* clone VS1. In one commercial stock of cv. Cambridge Favourite runner samples were obtained by chopping the tips of every 20th bundle of plants on arrival at the farm. Using the new technique 73% of the bait plants were found to be infected indicating extensive infection in the stock although none was detected in a second commercial stock. The 5 wk duration of the test makes it difficult to check on disease between receipt and planting of runners but it should be possible to take the samples for baiting at an earlier stage of commercial production.

(J. M. Duncan)

02016 *Chemical and cultural control of potato gangrene*

The pattern of gangrene incidence in the 1977 crop following successive harvest dates and storage over winter at 3°C was similar to that of 1975, being high in the earliest harvested tubers, decreasing gradually and then

increasing sharply in tubers harvested in late October and early November. In 1976, when the final harvests were completed earlier, the pattern was similar but did not show the late increases. In 1977, the scores for gangrene rots induced by standard wounds at harvest and the scores for infection levels detected at harvest in periderm samples were closely correlated and, with the exception of the final harvest, significantly correlated also with gangrene incidence in the stored crop when scored in April. Whereas incidence in the stored crop was high following the last harvest date, the corresponding periderm and rot scores remained low. However, when the tubers were tested at the time of grading in December, instead of at harvest, the induced rot scores in the final harvested tubers markedly increased, but those for the mid-season harvest showed a relative decrease. Thus grading damage to tubers early in their storage period may accelerate gangrene development in late-harvested tubers by a greater proportion than in those harvested earlier; moreover, tubers from late harvests are more liable to grader damage being larger and, at that time, often also more susceptible being more turgid than tubers harvested earlier.

The incidence of gangrene in tubers stored in an ambient temperature bale store was again significantly lower than that of the cold-stored (3°C) tubers for all harvest dates. The greatest differences were between tubers from the early-harvested samples in which over 20% from the cold store developed lesions compared with less than 1% of the tubers from the bale store where the incidence remained less than 3% except in tubers from the final harvest where it was 7%. The results convincingly demonstrate the value of early harvesting when not only are inoculum levels usually low but the warm storage environment enhances wound healing and thus further diminishes the incidence of gangrene.

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

PHYTOPATHOLOGICAL METHODS

02020 *Development of histological and histochemical methods*

The acquisition of an Autocut Microtome completes a wide range of sectioning capability at the Institute. Resin-embedded material with block faces up to 10 mm² can now be effectively cut through a range 0.1 to 8.0 μ and stained and examined by light microscopy. The use of glycol and of butyl methacrylate methods have been adapted and further developed over the past 2 years to provide reliable and low-artifact embedding techniques well suited to studies on host-parasite interactions.

(H. M. Wilson, B. Williamson)

Previous reports have indicated difficulties encountered in raising antisera to *Phoma* spp. with adequate titres, the resultant low-titred antisera giving rise to cross-reactions because of lack of specificity. Preliminary trials using an enzyme-linked immunosorbent assay (ELISA) suggest that this technique may be used successfully with relatively low-titred antisera.

(H. M. Wilson)

VIROLOGY

B. D. HARRISON

The development of plant virus research during recent years has been greatly influenced by the introduction of new techniques. Those adopted at SHRI during the last decade include various methods of electrophoresis in gels, centrifugation and electron microscopy; serological techniques of greatly improved sensitivity; and ways of producing and infecting large numbers of mesophyll protoplasts. To this list this year we added methods of making DNA complementary in nucleotide sequence to virus RNA, of freeze-drying virus particles for electron microscopy and of examining nucleic acids in the electron microscope; all promise to make a substantial contribution to our research. The more sophisticated techniques of necessity lead to specialization by their exponents and, as happens increasingly, most of the work reported below involves a substantial measure of collaboration between people with different kinds of expertise.

Noteworthy findings in 1978 include new information on the structure of the tobacco rattle virus genome; detection of a small genome-linked protein in nepoviruses; evidence of the reliability of a method for estimating the molecular weight of virus RNA molecules of up to at least 3 million daltons; description of a new potexvirus found in tulip; data on the effects of latent viruses on the growth and cropping of raspberry; and detection of potato leafroll virus in potato leaves and tubers by electron microscope serology.

TOBRAVIRUSES

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

DNA complementary to the RNA of tobacco rattle virus (TRV)

Complementary DNA copies (cDNA) of the two separated parts of the RNA genome of two strains of TRV have been prepared, using reverse transcriptase from avian myeloblastosis virus primed with random DNA fragments. Such copies can be used in hybridization analyses to examine the relationships between virus RNA species, and have potential applications in the diagnosis of virus infections and in the solution of other research problems. Some of these possibilities are illustrated by the following preliminary results.

In reactions of an excess of RNA with its homologous cDNA, the value of $R_{0t_{1/2}}$ (initial RNA concentration \times time when 50% of the DNA has hybridized with the RNA) is a measure of the sequence complexity of the RNA. For TRV (strain CAM), both the $R_{0t_{1/2}}$ and mol. wt. of RNA-1 were four times those of RNA-2, suggesting that there are no measurable internal repetitions in either RNA. In contrast, the complexity of RNA-2 of strain ORE-Y was twice that expected from its mol. wt., implying that the isolate contains two kinds of RNA-2 molecule of similar size but completely different sequence. This interpretation is supported by the splitting of the RNA-2 band into two components of similar mobility in some experiments using polyacrylamide gel electrophoresis.

Estimates of the homology between two RNA species can be made from reactions of one RNA with the cDNA copy of the other. Such experiments showed that about 23% of the sequence of RNA-2 of strain CAM is also present in RNA-1, in agreement with results obtained by other workers using RNA-RNA hybridization. Surprisingly, no homology was detected between RNA-1 and RNA-2 of strain ORE-Y.

Hybridization with cDNA also provides a means of measuring the concentration of one RNA species in a complex mixture. Preliminary experiments with TRV (strain CAM) have shown that this method can be used, for example, to estimate the virus RNA content of infected tobacco leaf protoplasts. Work on these and other applications of RNA-DNA hybridization is continuing.

(D. J. Robinson)

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

A distinctive isolate of tobacco rattle virus (TRV) from spinach

A virus obtained in south-east England by K. W. Bailiss¹ from spinach with yellow leaf spot symptoms was transmitted from infector to bait plants grown in soil containing trichodoriid nematodes. In symptomatology it behaved more like TRV than pea-early browning virus (PEBV), but it invaded *Chenopodium amaranticolor* and *C. quinoa* systemically. Purified preparations contained straight tubular particles 22 nm wide and 190, 100, 56 and 48 nm long, with sedimentation coefficients ($s_{20,w}^0$) of 300 S, 230 S and two components of 150-160 S. Preparations of virus RNA contained four species with mol.wt., estimated by polyacrylamide gel electrophoresis in non-denaturing conditions, of 2.4, 1.4, 0.7 and 0.6 $\times 10^6$. Only one polypeptide species was obtained from virus particles; its estimated mol.wt., 25,000, was consistently larger than comparable estimates for strains CAM and PRN of TRV. The 190 and 100 nm particles both were needed to produce infections in which virus nucleoprotein particles were synthesized.

¹ Wye College, University of London, Wye, Kent.

The two shortest particles could not substitute for 100 nm particles and did not affect the symptoms produced in *Nicotiana clelandii*.

In microprecipitin, gel diffusion and electron microscope serological tests to compare the spinach virus with TRV strains CAM, ORE-Y and PRN, and with British and Dutch strains of PEBV, none of the isolates were closely related. The spinach virus and strain ORE-Y were a little more closely related to strain PRN than to the other isolates. The virus from spinach therefore is named the spinach yellow spot strain of TRV.

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

NEPOVIRUSES

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

Estimates of molecular weight of virus RNA by electrophoresis and by electron microscopy

In previous work attempts were made to obtain accurate estimates of mol.wt. of nepovirus RNA species by electrophoresis at 60°C in 2.0% polyacrylamide gels in the presence of 8 M urea. This method gave very reproducible estimates but, whereas those for RNA molecules smaller than about 1.7×10^6 daltons were probably accurate, those for larger molecules were considered, for a variety of reasons, too low. For example, estimates of only about 2.1×10^6 daltons were obtained for the RNA-1 molecules of all twelve nepoviruses examined. In further studies, in which RNA denatured in 1 M glyoxal + 50% formamide was electrophoresed in 0.75% agarose, estimates for the smaller RNA-2 molecules were similar to those found by the hot urea method but those for the larger RNA-2 molecules and for RNA-1 were much increased. Using *E. coli* ribosomal RNA and tobacco mosaic virus RNA as markers, the mol.wt. values ($\times 10^6$) for RNA-1 and RNA-2 molecules of six definitive nepoviruses were: arabis mosaic, 2.8 and 1.4; raspberry ringspot, 2.8 and 1.4; tomato black ring, 2.8 and 1.7 (satellite RNA: 0.6); myrobalan latent ringspot, 2.8 and 2.0 (satellite RNA: 0.5); cherry leaf roll, 2.8 and 2.3; tomato ringspot, 2.8 and 2.4. The estimates for the tentative nepovirus, strawberry latent ringspot, were 2.8 and 1.4. These increased values for RNA-1 were close to those expected from the properties and composition of the different kinds of nucleoprotein particles of each virus. Moreover, using the new method the estimated mol. wt. of RNA-1 and RNA-2 of the CAM strain of tobacco rattle virus were 2.4×10^6 and 0.6×10^6 , giving the ratio expected from the lengths of the long and short virus particles in which they are packaged. Estimated mol. wt. ($\times 10^6$) of the RNA molecules of some other viruses were: cowpea mosaic, 2.4 and 1.4; apple chlorotic leaf spot, 1.5; heracleum latent, 2.5; and raspberry bushy dwarf, 2.2, 0.9 and 0.4.

As a check on the reliability of estimates obtained by electrophoresis in agarose, glyoxylated RNA preparations from *E. coli*, and from tobacco mosaic, raspberry ringspot, cherry leaf roll and tobacco rattle viruses, were examined in the electron microscope using the 50% formamide spreading technique. All the molecules appeared to be free of secondary structure and very reproducible length measurements were obtained. The mol. wts. estimated by comparison with the *E. coli* and tobacco mosaic virus RNA markers, assuming that the relation between length and mol. wt. is the same for all the RNA species examined, were very similar to those obtained by electrophoresis in agarose gels. Electrophoresis of glyoxylated RNA in agarose gels evidently gives more accurate estimates of mol. wt. for plant virus RNA species (at least up to 2.8×10^6 daltons) than methods that have been popular hitherto.

(A. F. Murant, Margaret Taylor, G. H. Duncan)

Polyadenylate in nepovirus RNA

Most of the RNA extracted from particles of tobacco ringspot virus (TRSV) was bound to oligo (dT)-cellulose in buffer of high ionic strength and eluted in buffer of low ionic strength. Both genome RNA species were bound equally and very little infective RNA failed to bind. This behaviour suggests that TRSV-RNA contains polyadenylate. Experiments with ^3H -borohydride labelling showed that the 3'-terminal nucleoside in TRSV-RNA is adenosine, and suggested that the poly(A) is at the 3'-end of the RNA molecules.

RNA extracted from particles of raspberry ringspot, strawberry latent ringspot, tomato black ring and tomato ringspot viruses was also bound to oligo(dT)-cellulose. The satellite RNA of tomato black ring virus was bound less avidly and to a lesser extent than the genome RNA. Possession of 3'-terminal polyadenylate therefore seems to be a characteristic feature of nepovirus RNA.

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

A protein linked to nepovirus RNA

Evidence that a protease-sensitive structure associated with nepovirus RNA is needed for infectivity was obtained in tests in which RNA extracted by treating virus particles with phenol and sodium dodecyl sulphate was incubated with Pronase or proteinase K. The protease treatments completely inactivated the RNA of three definitive nepoviruses, tobacco ringspot (TRSV), tomato black ring and tomato ringspot viruses, and of one tentative member of the group, strawberry latent ringspot virus. This inactivation was not accompanied by any noticeable change in size distribution of TRSV-RNA molecules, judged by electrophoresis in polyacrylamide gels. Protease treatment only partially inactivated the RNA of another nepovirus, rasp-

berry ringspot virus. Tests with tomato black ring virus showed that a protease-sensitive structure is associated with both species of genome RNA but no evidence was obtained that this structure can be exchanged between RNA molecules. Indeed, with TRSV-RNA, infectivity was little affected, either by heating in formamide followed by sedimentation in sucrose density gradients containing sodium dodecyl sulphate, or by quasi-equilibrium sedimentation in caesium trichloroacetate. The protease-sensitive material therefore is covalently linked to TRSV-RNA.

Treatment with proteinase K inactivated the RNA of broad bean wilt virus, which has some affinities with nepoviruses, but did not decrease infectivity of the RNA of cowpea mosaic, tobacco rattle or tomato bushy stunt viruses.

As a first step in comparing the interaction with cells of protease-treated and untreated virus RNA, a technique was devised for infecting tobacco mesophyll protoplasts using RNA. The inoculum contained 50 μ g each of bentonite and TRSV-RNA per ml, 0.1 M phosphate buffer, pH 6.0, 0.25-1 μ g poly-L-ornithine per ml and 0.7 M mannitol; inoculation was at 0°C. Using this method, virus coat protein was detected in up to 36% of the protoplasts inoculated with control TRSV-RNA but in none of those inoculated with protease-treated RNA.

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

Chemical evidence for a protease-sensitive-structure attached to nepovirus RNA was obtained by treating RNA preparations with ¹²⁵I-labelled sodium iodide and chloramine T. The specific radioactivity of TRSV-RNA labelled in this way was 20 times that of similarly treated tobacco mosaic virus RNA. After protease treatment, 90-97% of the radioactivity of TRSV-RNA, but less than 10% of that of tobacco mosaic virus RNA, was soluble in 70% ethanol. The radioactivity per molecule was similar for the two species of TRSV-RNA. Large amounts of protease-sensitive radioactivity were also found in iodinated RNA of raspberry ringspot and tomato black ring viruses. The protease-sensitive radioactive structure in TRSV-RNA is covalently linked to the RNA; it was not dissociated from RNA either by heating in formamide followed by sedimentation in sucrose gradients containing sodium dodecyl sulphate, by sedimentation to quasi-equilibrium in caesium trichloro acetate or by heating in 8 M-urea at 60°C for 10 min. followed by electrophoresis in acrylamide gels.

After digesting ¹²⁵I-labelled TRSV-RNA with ribo nuclease, most of the radioactivity was precipitable with 90% acetone and in polyacrylamide gels this material had the mobility of a polypeptide of mol. wt. 4,000. When this material was treated with trypsin followed by two-dimensional fingerprinting of the peptides released, all the radioactivity migrated as a single spot.

The protease-sensitive structure needed for infectivity is thought to be the polypeptide detected chemically. The point at which this polypeptide is attached to the RNA molecules is not established, but as their 3'-end is polyadenylate the polypeptide may well be linked to the 5'-end. If correct this would point to a similarity in structure of nepovirus RNA and cowpea mosaic virus RNA, which is now known to possess 3'-terminal polyadenylate and a small, 5'-terminal, genome-linked protein. However, whereas the genome-linked protein of nepoviruses apparently is needed for infectivity, that of cowpea mosaic virus is not. The RNA of picornaviruses such as poliovirus and foot and mouth disease virus also has a genome-linked protein and 3'-terminal polyadenylate, but only with vesicular exanthema virus is this protein needed for infectivity. Such similarities in the organisation of the genome RNA of these viruses suggest underlying similarities in mode of replication.

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

Translation products of the RNA species of tomato black ring virus (TBRV)

In some cultures of TBRV the two RNA molecules (RNA-1, mol. wt. 2.8×10^6 and RNA-2, mol. wt. 1.7×10^6) that comprise the virus genome are accompanied by a satellite RNA (RNA-3, mol. wt. 0.6×10^6). In collaborative work with Christiane Fritsch¹ the major translation products of each RNA species were identified. Both in wheat germ extracts and in reticulocyte lysates, RNA-1 was translated into several polypeptides, the largest of mol. wt. 2.2×10^5 , and RNA-2 was translated mainly into a polypeptide of mol. wt. 1.6×10^5 . These represent about 80% and 100% respectively of the coding capacities of the RNA species. Some material translated from RNA-2 was precipitated by TBRV antiserum, suggesting that the coat protein is part of the 1.6×10^5 mol. wt. polypeptide.

Satellite RNA is translated both *in vitro* and in infected tobacco leaf protoplasts into a polypeptide of mol. wt. 4.8×10^4 . The polypeptide produced by translation of satellite RNA obtained from cultures of two serologically different strains of TBRV gave different products when digested with *Staphylococcus aureus* V8 protease or with subtilisin. The two satellite RNA species therefore have different base sequences.

(M. A. Mayo, A. F. Murant)

Inactivation and mutagenesis of TBRV by nitrous acid

Uncontaminated preparations of the middle (M) and bottom (B) nucleoprotein components of strain A of TBRV were obtained by isopycnic banding in caesium chloride followed by rate zonal sedimentation in sucrose density gradients. Infectivity of mixtures of M and B components decreased logarithmically when either component was treated with nitrous acid but B

¹ Institut de Biologie Moléculaire et Cellulaire, Strasbourg, France.

component was inactivated about twice as rapidly as M component. A slower, but still logarithmic decrease in infectivity occurred when either RNA-1 or RNA-2 was treated.

Only one mutant with altered symptoms was found among 200 single-lesion isolates obtained after nitrous acid treatment of B component. In plants kept at 28°C, it produced little or no infective nucleic acid or nucleoprotein, although wild-type virus multiplies freely at this temperature. When cultured at about 20°C the mutant has a smaller ratio of B to M component particles than the wild-type virus.

Two hundred single-lesion isolates obtained after nitrous acid treatment of either M component or RNA-2 were compared with wild-type virus. Five possible mutants were found: three had a decreased ability to invade *Chenopodium* spp. systemically, one had an altered lesion type and one failed to induce symptoms at 28°C. No antigenic variants were detected.

A problem encountered in handling most of these isolates was that when bulk cultures were made the mutants appeared to revert to the wild-type virus. However, they could be maintained by always reculturing from single lesions.

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

VIRUSES OF FLOWER BULBS

04010 Viruses infecting bulbous ornamentals

A potexvirus from tulip

A previously unreported virus was obtained from tulip plants with necrotic and chlorotic lesions in leaves in a commercial planting in Angus, Scotland. About 3% of plants in the affected stock showed symptoms and the virus, provisionally named tulip virus X (TVX), was detected only in diseased plants. TVX has filamentous particles about 500 nm × 12 nm and was readily transmitted by manual inoculation of sap to several plant species. In buffered extracts from inoculated *Chenopodium quinoa* leaves, infectivity survived dilution to 10⁻⁸, heating for 10 minutes at 60°C but not at 65°C, storage at ambient temperature for 30 days and treatment with *n*-butanol and diethyl ether. Purified preparations of the virus were strongly birefringent and contained two components which were barely resolved by rate zonal sedimentation in sucrose density gradients. The particles contained a single polypeptide species estimated by electrophoresis in 5-10% polyacrylamide gels to have a mol. wt. about 23,000. Electron microscope serological tests using antisera to TVX and other potexviruses indicated that TVX is distantly related to potato X and viola mottle viruses but no relationship was detected with bamboo mosaic virus.

(W. P. Mowat)

Virus spread in narcissus

In the third series of trials to assess reinfection rates at different places using narcissus yellow stripe as the test virus and allowing spread to occur for 1 year, plots were planted near Laurencekirk, Kincardineshire, at Kirton EHS, Lincolnshire, and at SHRI. At planting in 1977 the incidence of yellow stripe was 7% and the increases after 1 year at the three sites were 0.4%, 0.8% and 0.2% respectively. In the 3 years of these trials, the maximum increase in virus incidence in any one year was from 10% to 18%; if this low figure applies to other aphid-transmitted viruses in narcissus, it augurs well for the maintenance of a high health status when virus-tested stocks are grown in the field.

Of the seven viruses not transmissible by aphids and known to infect narcissus in Scotland, five have nematode vectors. The mode of spread of the other two viruses, narcissus tip necrosis and narcissus mosaic, is not known although their incidence is high in some narcissus cultivars. The possible transmission of narcissus tip necrosis virus by root and leaf contact, handling of leaves and flower picking was examined using boxes containing healthy and infected plants of cv. *Sempre Avanti* planted alternately in the row. However, the virus was not detected by enzyme-linked immunosorbent assay in any of the previously healthy plants in the second year after planting. In further tests, narcissus tip necrosis virus was not transmitted in pollen to the plant pollinated.

(W. P. Mowat)

04011 *Production of virus-tested bulb stocks*

Propagation of virus-tested narcissus

The third batch of virus-tested clones propagated at SHRI was released in August to ESCA and NSCA for further multiplication. The material consisted of five clones of cv. *Barrett Browning* and two of cv. *Carlton*, totalling 380 bulbs weighing 23 kg.

Further observations were made in the trial to compare the performance of twin-scales treated with benomyl (1 g/l), thiram (0.24% suspension of 80% wettable powder), captafol (1 g/l) and kinetin (1 mg/l), each alone and in all possible pairs. These treatments did not produce statistically significant differences in leaf emergence. However, the best emergence was obtained using benomyl + captafol (95% with cv. *Sempre Avanti*, 60% with cv. *Carlton*); kinetin, either alone or in combination with any of the fungicides, tended to decrease emergence in cv. *Sempre Avanti*. Benomyl, the standard treatment, gave 53% and 83% emergence respectively, in cultivars *Carlton* and *Sempre Avanti*.

In other tests of variations in the twin-scaling method, the percentage of small twin-scales (*ca.* 200 per 120 g bulb) that produced bulbils was a little greater, and the percentage producing shoots was the same, as for larger twin-scales (*ca.* 80 per bulb). When twin-scales were planted directly in soil in an unheated Tygan-covered structure, growth was slow and flowering was delayed by more than a year as compared with twin-scales planted in a frost-free glasshouse.

An alternative method of propagating narcissus involves the production of bulbils in tissue culture. The ability of bulbils, produced in this way by G. Hussey¹, to establish in potting media was tested. About 50% of the bulbils grew but they did not produce such large bulbs in the first year of growth as twin-scales. Best results were obtained using a mixture of equal parts of sand and soil-less compost.

(J. Chambers, W. P. Mowat)

RUBUS VIRUSES

04003 *Viruses infecting raspberry*

Involvement of latent viruses in bushy dwarf disease

Raspberry bushy dwarf virus (RBDV) was so named because it was commonly found in raspberry cv. Lloyd George plants with bushy dwarf disease. However, other observations have indicated that RBDV on its own is not the cause of bushy dwarf disease. A pot experiment was therefore started to compare the effects of RBDV alone and in combination with black raspberry necrosis virus (BRNV), the commonest aphid-borne virus in raspberry in Scotland, with those of BRNV alone. The effects on growth and yield were greatest in doubly infected plants, which were stunted and produced fewer and shorter canes than virus-free control plants. These effects resemble closely the symptoms of bushy dwarf disease, suggesting that this disease is caused by infection with BRNV + RBDV.

Although the mean weight of berries produced by plants infected with either or both of the viruses was on average 15% less than for virus-free controls, total fruit yield was not significantly affected although ripening was delayed on virus-infected plants, particularly the doubly infected ones. Virus infection also impaired fruit form and structure, a large proportion of fruit from BRNV-infected plants being misshapen, that from RBDV-infected plants being crumbly, and fruit from the doubly infected plants being both misshapen and crumbly.

(A. T. Jones)

¹ John Innes Institute, Norwich.

Performance of aphid-resistant genotypes

After 7 years' exposure in the field to large numbers of infective *Amphorophora idaei*, plants with genotypes giving the most resistance to this aphid were 56% infected with virus, and those with intermediate resistance to *A. idaei* were 76% infected. This compares with 75% infection after 1 year in genotypes susceptible to *A. idaei* and indicates the value of resistance to *A. idaei* in restricting the spread of viruses transmitted by this aphid.

(A. T. Jones)

Effects of four aphid-borne viruses latent in raspberry

Previous attempts to assess, under field conditions, the effects on growth and yield of the aphid-borne viruses that are latent in most red raspberry cultivars were hindered by the rapid spread of these viruses to control plants. The success of cultivars containing genes for resistance to the main vector, *Amphorophora idaei*, in restricting the spread of such viruses offers a means of overcoming this difficulty. In 1975, plants of the *A. idaei*-resistant cultivars Malling Leo, Malling Orion and selection 20/54, each derived from root cuttings of mother plants graft-inoculated with BRNV, raspberry leaf mottle (RLMV), raspberry leaf spot (RLSV) or raspberry vein chlorosis (RVCV) viruses, were planted in the field together with virus-free control plants.

Preliminary data from this experiment indicate that the effects of virus infection on vegetative growth were mostly small, although infected plants tended to produce more but shorter canes. Although total fruit yield was not greatly affected by virus infection, all virus treatments increased berry number and decreased berry weight, the greatest effect being in BRNV-infected plants. Fruit of Malling Leo plants infected with RLSV, RLMV and RVCV ripened significantly earlier than that of control plants.

(A. T. Jones)

Raspberry yellows disease

This disease has been known for many years to affect a limited number of raspberry cultivars in Britain, New Zealand and North America, but symptom expression is erratic from year to year even in recommended indicators. Recent evidence indicates that the cultivars susceptible to yellows disease are those susceptible to RBDV. In New Zealand, the symptoms appear much more regularly and are more prevalent than in Britain or North America and this may reflect the fact that Marcy, the main New Zealand raspberry cultivar, is susceptible to and frequently infected with RBDV, whereas the main cultivars grown in Britain and North America are immune to RBDV.

Field studies in Scotland with a raspberry selection (13/74) that develops yellowing symptoms more consistently than the standard indicator cultivars Lloyd George and Norfolk Giant showed that the spread of the disease is

closely associated with the spread of RBDV. However, a few yellowed plants of this selection did not yield RBDV in 1978. Also, several selections from the *Rubus* breeding programme that showed yellowing were apparently free from RBDV. Possibly the failure to recover RBDV from these plants may reflect uneven distribution of the virus in the plant but, equally, RBDV may not be the prime cause of the disease. More convincing evidence that RBDV can cause yellowing was obtained, in collaboration with G. A. Wood¹, from experiments in New Zealand in which plants of Norfolk Giant developed yellows after mechanical inoculation with RBDV. Uninoculated plants or plants that failed to become infected after inoculation with RBDV were not yellowed. Experiments are continuing in Scotland and New Zealand.

(A. T. Jones, A. F. Murant)

Raspberry vein chlorosis virus (RVCV)

Bacilliform particles 430 nm long \times 65 nm wide and rounded at both ends, and shorter particles rounded at only one end, occur in vascular parenchyma cells of raspberry plants infected with RVCV, indicating that the virus is a member of the plant rhabdovirus group. Old data on vector relations suggested that the virus is transmitted by *Aphis idaei* in a semi-persistent manner, but analogy with other rhabdoviruses suggests that it should multiply in its aphid vector. Electron microscopy of ultrathin sections of adult *A. idaei* that were raised on RVCV-infected raspberry cv. Baumforth's B revealed the presence of particles similar to those found in plant cells. Particles were found both with and without envelopes; most of the enveloped particles were rounded at one end and ca. 175 nm long and 65 nm wide but a few were rounded at both ends and ca. 350 nm long. Like the particles seen in plants, they occurred in the cytoplasm in association with the endoplasmic reticulum but not in the nuclei. The particles were found in tissue of the salivary glands and central ganglion, and in the region of the sucking pump and oesophagus. The particles were not seen in non-viruliferous aphids. These results therefore suggest that RVCV multiplies in its vector.

(A. F. Murant, I. M. Roberts)

VIRUSES OF UMBELLIFEROUS PLANTS

04007 *Viruses affecting umbelliferous crop plants*

Carrot mottle virus

In continuing studies on the purification of particles of carrot mottle virus, the distribution of the infective particles was examined after sedimentation in gradients of sucrose, caesium chloride, potassium tartrate and Percoll,

¹ Plant Diseases Division, DSIR, New Zealand.

and after chromatography on columns of Sepharose 2B and controlled pore glass beads. Work is now in progress to combine some of these procedures into a purification scheme.

Treatment of partially purified preparations of carrot mottle virus with phenol yielded extracts with little or no infectivity, but most RNA preparations made directly from infected *Nicotiana clevelandii* leaves using phenol were very infective. The infectivity in such extracts behaved as a single-stranded RNA of apparent mol. wt. about $1.5-1.6 \times 10^6$ in agarose-polyacrylamide gels, and with a sedimentation coefficient of about 28-30 S in linear-log sucrose density gradients. No peak of u.v.-absorbing material was detected in the parts of the gels or gradients containing the infective RNA, which was therefore estimated to comprise less than 1% of the total RNA in the extracts. Leaf extracts containing 1 $\mu\text{g/ml}$ RNA were infective and the virus RNA is therefore infective at less than 0.01 $\mu\text{g/ml}$. Chromatography on oligo(dT)-cellulose showed that the infective RNA does not contain any considerable polyadenylate sequence. Infectivity was not impaired by treatment with Pronase, showing that the infective RNA does not require an associated protein for infectivity. The apparent mol. wt. of carrot mottle virus RNA is much less than that of togaviruses, to which the virus has superficial similarities.

(E. L. Halk, D. J. Robinson, A. F. Murant, J. H. Raschke)

Carrot red leaf virus

Symptom type, vector relations and distribution in host tissues suggest that carrot red leaf virus is a member of the luteovirus group, and experiments were begun to purify the virus using methods that have been successful with other members of the group. Extracts of chervil leaves were incubated with an enzyme preparation containing cellulase and pectinase, clarified using a butanol/chloroform mixture, and the virus concentrated by differential centrifugation. The preparations contained isometric particles *ca.* 30 nm in diameter which resemble those seen by electron microscopy in phloem tissue of infected chervil plants.

(P. Waterhouse, A. F. Murant)

VIRUSES OF AGRICULTURAL CROPS

04001 *Potato viruses, especially soil-borne viruses*

Detection of potato leaf roll virus (PLRV) by electron microscope serology

In further attempts to detect PLRV in plant extracts by sensitive serological tests, electron microscope grids were coated with PLRV antiserum (kindly supplied by P. Gugerli¹) and then exposed to extracts of leaf veins and mid-

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ribs. Using samples from infected potato cv. Maris Piper, all leaves except the youngest tested (leaflet 2 cm long) yielded large numbers of PLRV particles; most virus was obtained from the oldest leaves (leaflet 12-14 cm long). Infected *Physalis floridana* leaves yielded less virus than those of potato. The method of staining the electron microscope grids was critical for good results, and the procedure finally adopted was to wash the virus-bearing grids with water followed by uranyl formate/sodium hydroxide at pH 4.8.

PLRV could be detected easily in leaf extracts stored at 4°C for 10-12 days, and also in extracts of infected potato tubers or of virus-carrying *Myzus persicae*.

These results illustrate the general usefulness of electron microscope serology in work with PLRV and show that the Scottish isolates tested are closely related serologically to the Swiss isolate used to prepare the antiserum.

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

Insecticidal control of spread of PLRV

In a field experiment begun in 1977, two granular systemic insecticides, with or without systemic insecticidal sprays, were compared for their effect on PLRV spread. Granules of thiofanox (0.73 kg a.i./ha) and disulfoton (1.1 kg a.i./ha) were applied in the furrow at planting in April, and sprays of demeton-S-methyl (0.24 l a.i./ha) were applied five times at fortnightly intervals beginning on 23 June. Each granular insecticide gave a good control of *Myzus persicae* for much of the growing season (Ann. Rept 1977, p.116) and the sprays gave no further improvement.

The incidence of PLRV in the progeny of plants adjacent to infectors was decreased from 9% in control plots to 2-3% in plots treated with the granules; a similar decrease in PLRV incidence was found among plants distant from infectors. There was little difference in the control given by thiofanox and disulfoton. The sprays did not give additional virus control.

Application of granular insecticides at planting has therefore substantially decreased PLRV spread both in 1976, an abnormally hot summer, and in 1977. In 1977 most of the PLRV spread in control plots could probably be attributed to incoming aphids carrying virus from nearby infected crops. This suggests that the granular insecticides not only prevented aphid colonization for long periods but also interfered with inoculation of virus by incoming infective aphids. Thus despite the risk of selecting insecticide-resistant aphids, the use of granular systemic aphicides should prove a worthwhile insurance for growers of VTSC seed potatoes in eastern Scotland.

(B. D. Harrison, J. A. T. Woodford¹, C. S. Aveyard¹)

¹ Zoology Section.

Stability of particles of phleum mottle virus (PMV)

Particles of PMV isolates from cocksfoot and timothy were stable at pH 6.0 in buffer containing 1 M KCl or 0.01 M ethylene diamine tetraacetate (EDTA) but when the pH was increased above 7.0 a precipitate formed and the particles were disrupted. However, the particles were stable and apparently were not swollen at pH 7.2 in 0.1 M buffer lacking EDTA; in these conditions they were disrupted by 0.5% but not by 0.05% sodium dodecyl sulphate (SDS).

These results emphasize the difference in behaviour of PMV and southern bean mosaic virus (SBMV), which has particles that swell at high pH in low molarity buffer containing EDTA and are disrupted at high pH only in the presence of both EDTA and 1 M NaCl, or of EDTA together with at least 1% SDS. Although particles of PMV and SBMV have some similarities in structure and composition, and seem to be stabilized by several kinds of bond, the relative importance of these types of bond differs between the two viruses.

Cocksfoot streak virus

To characterize this virus more completely, tests were made on purified preparations of virus particles. Such preparations contained infective flexuous filaments with a modal length of about 750 nm and many shorter particles. The infective particles had a sedimentation coefficient of 139 S at infinite dilution, and contained a single polypeptide species (mol. wt. 31,000) and a single RNA species (mol. wt. 2.6×10^6 , estimated by electrophoresis in aqueous polyacrylamide gels). Cocksfoot streak virus therefore behaves as a typical potyvirus.

(Lesley Torrance, B. D. Harrison)

OTHER VIRUSES

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

Electron microscopy of ilarvirus particles

Particles of elm mottle, prune dwarf, prunus necrotic ringspot and tobacco streak viruses were examined and compared using electron microscopy. Purified virus preparations (examined using negative stains or shadowing) consisted predominantly of spherical or quasi-spherical particles with diameters in the range 22-34 nm for each virus. In addition, preparations of each virus contained a small proportion of bacilliform particles with an average diameter of 22 nm and length ranging from 34 nm for tobacco

streak virus to 75 nm for prunus necrotic ringspot virus. Some bacilliform particles showed indications of a periodic structure in negative stains. Careful examination of specimens that were fixed, shadowed or freeze-dehydrated (see under Techniques) suggested that the bacilliform particles are not deformed spherical particles.

(I. M. Roberts, E. Halk)

TECHNIQUES

04021 *Techniques for electron microscopy*

Freeze-drying of virus particles

A simple freeze-drying block measuring 80 mm × 50 mm was constructed to allow further studies on the size and structure of virus particles. The block was machined from brass and is in two parts, a top which is filled with lead shot and fitted with a lifting hook, and a base into which the top fits. The base is thermally insulated from the top by a thin polythene ring, and has four 1 mm-deep, 12 mm diam, machined recesses.

In use, the block is immersed in liquid nitrogen and the top and base separated. Grids with specimens to be freeze-dried are immersed in liquid nitrogen and transferred to the recesses. The block is reassembled under liquid nitrogen and transferred to a vacuum plant where it is kept for ca. 3 h at 10^{-2} Pa. The top is then raised and the grids allowed to return to room temperature. The design of the block allows several grids from each of four different samples to be freeze-dried at the same time; moreover negatively stained and shadowed samples can be processed at the same time. Preliminary tests indicate that particles of several viruses are better preserved by this technique than by the routine method and that new structural features can be seen in some instances.

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

Freeze-dehydration of virus particles

In an attempt to prevent the particles of some viruses from collapsing during preparation for electron microscopy, specimens were dehydrated below 0°C. Stained or unstained specimens were placed on grids provided with carbon-backed pyroxylin films. Most of the liquid was then removed and, without drying, the grids were immersed in liquid nitrogen. They were then transferred quickly to a slush of solid/liquid acetone in a separate container in the liquid nitrogen bath. The solid acetone, containing the grids, was then removed from the nitrogen and allowed to return to room temperature, when the grids were removed, drained, dried and examined in the electron

microscope. The technique is simple and takes only 30 min. Some negatively stained and some shadowed specimens (e.g. particles of ilarviruses) were preserved much better by this method than by conventional techniques.

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

Electron microscopy of virus nucleic acid

A kit was constructed for preparing samples of nucleic acid for electron microscopy by the Kleinschmidt method, using a formamide-containing hyperphase and hypophase. Troughs (85 mm × 35 mm × 10 mm) for holding the samples, and bars (60 mm × 10 mm × 5 mm) for sweeping the liquid surface, were machined from a solid block of teflon, which is hydrophobic, acid-resistant and durable, and proved superior to other materials tested. Twice glass-distilled water was used for preparing solutions. The high-vacuum evaporation apparatus was modified for low-angle rotary shadowing (120 rev./min.) of specimens with platinum from a thick tungsten filament. The platinum was evaporated slowly for 4-5 min. without excessive alloying with the filament.

In the electron microscope, single- and double-stranded nucleic acid molecules were easily distinguished. Moreover, using tracings or projected enlargements of molecules of glyoxylated single-stranded RNA, very reproducible estimates of molecular weight were obtained (see p.99).

(G. H. Duncan)

ZOOLOGY

D. L. TRUDGILL

Potato cyst nematodes are the most serious nematode pests in Britain. On infested land serious yield losses can be avoided only by using long rotations or nematicides or resistant cultivars. All these methods have disadvantages. Another option, which we are starting to explore with the backing of a research grant from the Potato Marketing Board, is the growing of cultivars which are less susceptible (tolerant) to damage by potato cyst nematodes.

In Scotland we have increasing evidence that the root-lesion nematode *Pratylenchus penetrans*, can be a damaging pest where raspberries are being re-planted. We also suspect that the virus-vector nematode, *Longidorus elongatus*, causes direct damage to several crops. In our research on these, and other nematodes we aim to gain a further insight into their ecology and behaviour, and particularly how the damage they do can best be prevented; to this end we are testing new application equipment, which has become available in Scotland, for applying the liquid fumigants metham-sodium and dichloropropene (Telone II).

Effective control of potato leaf roll virus and of potato aphids for up to 3 months has been obtained in field trials over the last 3 years using granular insecticides applied at planting. However, with a return to colder winters the widespread, routine use of insecticides to protect seed potato crops is now unnecessary and may hasten the selection of insecticide-resistant aphid strains. The evidence accumulated over the last 4 years suggests that except for VTSC crops insecticides should be reserved for years when heavy, early aphid infestations are forecast. Alternatively, to ensure that there is no repetition of the situation in the early to mid 1970s when the incidence of potato leaf roll virus was added to year by year, insecticides could be applied in the year following such an infestation.

NEMATOLOGY

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

Rotylenchus robustus damage to carrots

The effects of aldicarb (3.36 kg/ha), dichloropropene (Telone II, 2251/ha) and four levels of fertiliser (0, 35, 70 and 140 units of N) on the yield of

carrot cv. Cluseed New Stump Rooted were investigated at a site with 232 *R. robustus* and 23 trichodorid spp. per 200 g soil. Aldicarb and dichloropropane decreased the numbers of *R. robustus* by 51.5% and 99%, and of trichodorid spp. by 93% and 96% respectively. Carrot yields, meaned over all nitrogen levels, were increased by 18% and 47% by aldicarb and dichloropropene respectively, whilst the increase from the highest rate of N, meaned over the nematicide treatments, was 48%. The response to the nematicides was additive to that of the fertiliser.

(B. Boag)

Hoplolaimidae of the British Isles

Three genera, *Rotylenchus*, *Helicotylenchus* and *Scutellonema* have been found in a survey of the British Isles. Five species of *Rotylenchus* were identified and their distributions mapped. *R. fallorobustus* and *R. goodeyi* were the most widespread species, occurring throughout the British Isles. *R. fallorobustus* was frequently found in damp peaty soils, whereas *R. goodeyi* was confined to the drier mineral soils, especially in central and eastern Scotland. *R. buxophilus* and *R. pumilus* were confined to southern Britain, *R. pumilus* being recorded from Wales and south west England where *R. buxophilus* was confined to central and south eastern England. *R. robustus* was found at scattered sites throughout Britain.

During the survey a new undescribed species of *Scutellonema* was found in the Channel Islands.

The mapping of the numbers of the genus *Helicotylenchus* has proved more of a problem because of the greater difficulties in identifying the different species.

(B. Boag)

Ecology of Rotylenchus robustus

The life cycle of this nematode may take up to 18 months. Adults added to Sitka spruce seedling in January, 1977, did not produce larvae until July, 1977, and new adult nematodes were not recovered until the following July. When adult nematodes were added in May the life cycle took 14 months to complete. Adult *R. robustus* added to Sitka spruce seedling in August, 1977, produced few larvae in 1977, but large numbers in the following August. None of these larvae had become adult by December, 1978.

(B. Boag)

Survey of nematodes in vegetables

The nematodes associated with peas in Scotland were surveyed. Samples were taken from 238 fields on 165 farms, all in the east, extending from

Angus in the north to Berwick in the south. Seventy-nine per cent of the samples contained hoplolaimid nematodes, 53% contained longidorid and 53% contained stunt nematodes. Trichodorid nematodes were recovered from 15% of the samples, but no outbreaks of pea early browning disease were detected. The cyst nematode *Heterodera goettingiana* was not found.

The results of this survey indicate that plant parasitic nematodes are not, at present, causing any serious harm to the pea crop in Scotland.

(B. Boag)

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

Spraing disease of potatoes

The efficacy of a fumigant nematicide, a granular systemic nematicide and a liquid systemic nematicide in controlling spraing in potatoes caused by tobacco rattle virus (TRV) was tested in a field trial. The site had a light sandy soil infested with the trichodorid nematode vectors of TRV. Dichloropropene, as Telone II, was applied at 225 l/ha by a knife-injector in replicated plots and the soil sealed by a light rolling. Four weeks after fumigation further plots were treated with aldicarb (1.8 kg a.i./ha) applied in-furrow and a spraing susceptible potato cv. Pentland Hawk planted. Six weeks after planting when the newly forming tubers are most vulnerable to infection with TRV, aldicarb (1.8 kg a.i./ha) was side placed into drills of established potato plants in previously untreated plots. At this time further plots were sprayed with a 0.31% solution of oxamyl in water at a rate equivalent to 5.56 kg a.i./ha. At harvest potato tubers selected at random from each treatment were examined for spraing symptoms. All treatments significantly decreased the incidence of tubers with spraing from 76% in the untreated control to 9% (aldicarb at planting), 16% (aldicarb at 6 wk), 32% (dichloropropene), and 36% (oxamyl). Yield was not significantly affected.

(T. J. W. Alpey with P. Osborne¹)

Effect of soil sealing after fumigation

Different methods of sealing the soil surface after fumigation with dichloropropene were compared. Pots, lined with polythene, were filled with 2.5 l of soil infested with three trichodorid spp. and *R. robustus*. Dichloropropene (0.13 ml/pot) was injected into the centre of each pot at equivalent to half the recommended field rate. The soil surface was sealed by compaction, by covering with polythene or by spraying with a water based synthetic resin dispersion (Vinamul 3270). All pots were left fallow, but watered as necessary to prevent drying. After 4 wk the dichloropropene had significantly decreased the numbers of nematodes in all the treated pots.

¹ ESCA

Greatest control (98% kill) was obtained where the soil had been sealed with polythene. The degree of control obtained in pots sealed with Vinamul 3270 resin (88%) did not differ significantly from that in pots where the surface had been sealed by compaction alone (89%).

The effect of soil sealing was also tested in replicated plots in two field trials. The recommended rate of dichloropropene (220 l/ha), sealed by rolling, was compared to dichloropropene applied at 110 l/ha, sealed by rolling followed by a spray of a resin. Two resins were tested, Vinamul 3270 as a 10% or 20% solution in water (applied at 1680 l/ha) and Concure 75-430 (2500 l/ha). Other treatments included dichloropropene (110 l/ha) with dazomet (50 kg/ha) raked into the soil surface before rolling, aldicarb (3.36 kg a.i./ha) applied broadcast, resin sprays alone and untreated soil. Soil samples collected 5wk after treatment showed that the Vinamul 3270 and the aldicarb treatments had not decreased numbers of migratory plant parasitic nematodes. The most effective treatments were dichloropropene (220 l/ha) sealed by rolling and dichloropropene (110 l/ha) with dazomet. Control by dichloropropene (110 l/ha) was not improved when the soil surface was sealed with Vinamul or Concure.

(T. J. W. Alpey)

Toxicity of chemicals with nematicidal action

Differences in the susceptibility of several species of plant parasitic nematodes to six chemicals were examined. The chemicals were incorporated into pots (1.3 l of soil) containing one of four soils, each infested predominantly with a single genus of plant parasitic nematode. All the soils were kept moist but left fallow. Four weeks after treatment, only the fumigant nematicides dazomet (Basamid, 214 mg/pot) and dichloropropene (Telone II, 0.14 ml/pot) had decreased the number of nematodes to less than 5% of the numbers in the untreated control. Dazomet was equally effective against *Xiphinema diversicaudatum*, *Longidorus elongatus*, *Pratylenchus penetrans*, *R. robustus* and the trichodorid species present. However, dichloropropene failed to control the *X. diversicaudatum* in a heavy, clay soil. Oxamyl (Vydate, 31 mg/pot), aldicarb (Temik, 19 mg/pot), quintozene (Botrilex, 252 mg/pot) and thiabendazole (25 mg/pot) were largely ineffective over the 4 wk period.

(T. J. W. Alpey)

In four field trials using swede, aldicarb (Temik) applied at rates varying from 28 to 77 g/100 m row, did not affect the numbers of nematodes recovered 6 wk after treatment. However, 28 wk after treatment the higher rate of aldicarb had significantly decreased numbers of plant parasitic nematodes in three of the trials.

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

Aphelenchoides fragariae on strawberries

Strawberry plants with small, distorted leaves were found at several sites in the spring of 1977. *A. fragariae* was readily recovered from many of these plants and the damage was typical of that caused by this species. Later in the summer the symptoms and the *A. fragariae* had largely disappeared, but re-appeared in the following spring.

In a pot test aldicarb (0.125 mg a.i. in 1.5 l soil) applied in the spring and autumn failed to control *A. fragariae*. However, in the field 0.15 g a.i./plant applied as a spot treatment apparently controlled the nematode.

(B. Boag)

05007 Ecology of Longidorus and Xiphinema spp. in relation to their role as plant pathogens

Effect of temperature on the feeding of Xiphinema diversicaudatum

The effect of temperature on the rate of feeding of *X. diversicaudatum* on the roots of S24 perennial ryegrass (*Lolium perenne*) growing in 7% agar was observed. At 5°C the frequency of oesophageal bulb pumping was about 27 contractions per min, at 10°C this increased to 50 contractions per min, whilst at 20°C the rate of pumping was about 114 contractions per min. Above 25°C the frequency of pumping did not increase further. With *Rotyleachus robustus*, the rate of bulb pumping approximately doubled with each 10°C rise in temperature between 0°C and 30°C. At 1°C there was a pronounced pause between each contraction. At the higher temperatures pumping continued apparently with no pause.

(B. Boag)

Spatial distribution of Longidorus elongatus in permanent pasture

The distribution of *L. elongatus* was studied in a field of permanent pasture. Three sizes of plot, 45 m square, 4.5 m square and 50 cm square were intensively sampled. One hundred pairs of soil samples were taken on a 10 x 10 grid from within each plot.

To test if the nematodes were aggregated within each of these plots, the logarithm of the variance was plotted against the logarithm of the mean. This test showed that the *L. elongatus* tended to be regularly distributed in the smallest plot, but was aggregated in the two larger plots.

The relationship between number of samples per plot and the mean population was also investigated. From the largest plot it was calculated that for a site with a mean of 17 *L. elongatus* per 200 g soil, nine separate samples would give an estimated mean within 10% of the true mean with 95% probability. Similar analyses were made from the same samples on

the distribution of *L. goodeyi* and *Rotylenchus goodeyi*. To accurately estimate the mean population, the number of samples required increased as the amount of aggregation increased or as the mean population decreased.

(B. Boag, L. Jones¹)

Mapping of nematodes in Spain

In co-operative work with A. Bello² maps were prepared of the distribution of some plant parasitic nematodes in Spain. Computer files listing grid references for the distribution of six *Longidorus* spp., 12 *Xiphinema* spp. and 41 criconematids were created. A file containing data to produce a base map of the Iberian peninsula was also prepared. The files were used as input to the CAMGRID program of ERCC to produce single species distribution maps. An alternative mapping programme GIMMS was also tested. A study to characterise and classify the geographic distributions of the Spanish nematode populations using CLUSTAN and GENSTAT computer programs was initiated.

(T. J. W. Alphey, P. Topham³)

Taxonomy of Xiphinema spp.

The effect was examined of combinations of three methods of killing, seven of fixing and three of mounting on the morphometrics of a population of *X. diversicaudatum*. For each of 28 treatment combinations 10 females and five males were measured, taking those measurements most often used in descriptions of species. The measurements obtained were also compared with those from live nematodes measured in 0.75% water agar.

All treatments changed some of the values obtained. A few treatments caused measurement changes in excess of 20%, body width being most commonly affected. Those least affected were odontostyle, odontophore and total stylet length. Total body length and body width at the anus were also relatively stable, differing by less than 10% from the mean values obtained from live nematodes for all treatments.

(D. J. F. Brown)

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

The dorsal salivary gland cell in *Xiphinema index* was examined immediately post-feeding. In thin section numerous electron-dense granules were closely associated with dictyosomes (Golgi bodies) aggregated near the gland ducts. The granules are probably secretory, but no similar electron-

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³ Crops Research Section

dense material was found in the lumen of the ducts except at the apices of the folds in the duct lining. However, a small, amorphous, electron-dense plug was observed where the fan-shaped main duct opens into the food canal.

The main duct opening is a longitudinal slit in the cuticular wall of the oesophageal lumen just anterior to the pump chamber. Attached to the sides of the slit are four, radial, dilator muscles which extend, subdorsally to the periphery of the basal bulb. To balance the pull of these dilator muscles three other groups of radial muscles are attached to the ventral and lateral sides of the food canal. Observations with the light microscope on nematodes which were feeding suggested that the part of the main duct near the food canal, which is lined with a thin layer of cuticle, may act as a one-way valve whilst the slit is dilated.

(W. M. Robertson)

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

Feeding behaviour of Longidorus elongatus and Xiphinema diversicaudatum

L. elongatus and *X. diversicaudatum* differed in their feeding behaviour on ryegrass growing in agar and although both species induce root-tip galls, only *L. elongatus* fed exclusively at the root-tip. The long stylet of *L. elongatus* penetrated deep within the root prior to feeding, and was not moved once feeding had started, with the tip often remaining in the same cell for several hours. From measurements of the numbers of oesophageal bulb pulsations, the volume of the oesophageal bulb and the average size of the cells in the root-tip, it seems likely that *L. elongatus* feeding in this way ingests contents greatly in excess of the volume of the cell on which it is apparently feeding. It is not known how it is able to do this.

The feeding behaviour of *X. diversicaudatum* is much more variable than that of *L. elongatus*. *X. diversicaudatum* feeds on the root hair and older parts of the root in addition to the root-tip and root-tip galls. At each of these sites several cells may be fed upon using its long stylet to feed progressively deeper within the root. Depending on the nature of the cells at each of these sites, feeding behaviour varies. When feeding on ungalled root-tips, on cortical or on epidermal cells *X. diversicaudatum* tends to feed for only a few minutes within each cell. Short periods of ingestion of up to 20 seconds are separated by short pauses, lasting at the most a few seconds, for salivation. The rate of oesophageal bulb pulsation decreases towards the end of each period of ingestion until the nematode again salivates. As feeding within a cell progresses, the overall rate of oesophageal bulb pulsation gradually declines and the frequency of saliva-

tion increases until feeding within that cell ceases and the next, deeper, cell is penetrated.

When feeding deep within galls some cells are fed upon for long periods of time, a pattern of behaviour consistent with the nematodes feeding upon large cells containing greater amounts of food than are found in cells within the ungalled root-tips. In these cells the individual periods of ingestion are longer, often lasting several minutes, and more numerous than in cells within ungalled root-tips.

When feeding deep within the root hair region, the feeding behaviour is characterised by long periods, often hours, of continuous ingestion at a constant rate of oesophageal bulb pulsation without pauses for salivation. This pattern of behaviour is consistent with feeding in a vessel, probably a phloem vessel, containing unrestricted amounts of food.

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

Feeding on leaves

During studies on *X. diversicaudatum* feeding on roots of *Gomphrena globosa* and *Fragaria vesca* growing in agar, groups of nematodes were observed feeding on leaves which had contact with the agar. Feeding continued for several days until the leaves were destroyed.

(S. Kurppa¹, W. M. Robertson)

Cell response to feeding by X. diversicaudatum and L. elongatus

Cell changes in the root-tip galls of three hosts for *X. diversicaudatum* were compared in sections cut on a cryostat microtome. In ryegrass, which is a moderate host for *X. diversicaudatum*, feeding in the provascular region induced swelling of the cortical and epidermal cells immediately posterior to the feeding site without inducing obvious changes in their nuclei or cytoplasm. When nematodes fed upon regions of high mitotic activity close to the vascular stele (i.e. lateral primordia but not the main root meristem) they induced some cells to become enlarged, multinucleate or with enlarged, amoeboid nuclei and with dense cytoplasm.

In rose, which is an excellent host for *X. diversicaudatum*, the root-tip galls contained an increased number of cells many of which were enlarged, cytoplasm enriched and multinucleate. Similar changes have also been observed in root-tip galls induced by *X. diversicaudatum* in *Gomphrena globosa*.

Ryegrass is an excellent host for *L. elongatus* which feeds only at the root-tip. Here galls are formed which initially contain cells with enlarged, amoeboid nuclei. In older galls, stained using the Feulgen reaction, only the

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epidermal cells contained nuclei. Nuclei were apparently absent in the deep cells, but whether they had been ingested or lost in some other way is uncertain

S. Kurppa¹, W. M. Robertson)

Transmission of viruses

In recent years we have developed a system, using small numbers of hand-picked nematodes, for assessing the efficiency with which nematodes transmit viruses. In this system feeding on virus source and bait plants is assessed from the numbers of root-tip galls induced. Access to virus in the source plants is assessed from slash-testing nematodes, and acquisition and retention are assessed from thin sections of their feeding apparatus.

Applying this system to the nematode vectors occurring in Britain and the viruses they transmit, we have found *X. diversicaudatum* and *L. attenuatus* to be relatively efficient vectors and *L. elongatus* and *L. macrosoma* to be relatively inefficient vectors.

In co-operation with J. Klingler² and F. Roca³ tests have been undertaken to establish the efficiency with which certain viruses from woody plants are transmitted. The viruses tested were grapevine fanleaf (GFLV) and grapevine chrome mosaic (GCMV) from Switzerland and isolates of strawberry latent ringspot virus (SLRV) from olive, peach and raspberry in Italy. Firstly, herbaceous plants were tested for their suitability as virus source and bait plants. *Chenopodium quinoa* and *Gomphrena globosa* were found to be satisfactory test plants for GFLV and GCMV with *Xiphinema index*. The nematodes fed and induced root-tip galls readily and virus, manually inoculated into the leaves, spread systemically into the roots. *C. quinoa* was also a satisfactory test host with *X. diversicaudatum* and the isolates of SLRV from Italy, but *G. globosa* was less satisfactory as a source plant because the Italian isolates of SLRV spread only occasionally from the inoculated leaves to the roots. *X. vuittenezi*, included in these tests because it was suspected as being a vector of GFLV in Switzerland, produced few root-tip galls on any of the plants tested (*Cucumis sativus*, *Lycopersicon esculentum*, *Tetragonia expansa*, *C. quinoa* and *G. globosa*).

In spite of using suitable herbaceous test hosts, none of these viruses was transmitted in preliminary tests. With *G. globosa* as both source and bait plant GFLV was apparently not transmitted by *X. index*. Similarly with *G. globosa* and *C. quinoa* none of the Italian isolates of SLRV were transmitted by a population of *X. diversicaudatum* from Scotland.

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

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² Swiss Federal Research Station for Fruit Growing, Viticulture and Horticulture, Wädenswil, Switzerland.

³ Laboratorio di Nematologia Agraria applicata ai Vegetali, Bari, Italy.

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

Tolerance to damage by potato cyst nematode

Considerable differences in the tolerance of potato cultivars to damage by potato cyst nematode (*Globodera rostochiensis*) were found in a small plot trial at SHRI. The nematode resistant cv. Maris Piper yielded almost as much in soil heavily infested with potato cyst nematode as it did in soil treated with aldicarb (Temik). In contrast the yield of the non-resistant cv. Pentland Dell was almost halved in heavily infested soil. The early cultivar Maris Peer was even less tolerant, plants in infested plots yielding only 40% of those in aldicarb treated plots.

(D. L. Trudgill)

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

Two raspberry field trials, started in 1976 and 1977 to test the effect of controlling *Pratylenchus penetrans* (see Ann. Rept 1977, p. 112), were continued.

In the second year of the first trial yield and cane growth of cv. Glen Clova were increased by 45% in plots where aldicarb (Temik, 3.3 kg a.i./ha) had been applied at planting. Compared with plots where the aldicarb had been re-applied in the spring of the second year yield was more than doubled and cane growth increased by 61% while yield and growth were more than doubled in plots treated with dazomet (Basamid 220 kg/ha).

At the second site the yield in the second year of cv. Malling Jewel was increased by 67% in plots treated with aldicarb (6.6 kg a.i./ha) but cane growth was increased by only 35% compared with that in untreated plots. Plots treated with dazomet (240 kg/ha) prior to planting yielded 90% more and contained 70% more cane at the end of the second year than untreated plots. However, a higher rate of dazomet (340 kg/ha) more than doubled yield and cane growth.

Five further trials, at sites provided by the East of Scotland College of Agriculture, were started in 1977. Dazomet (340 kg/ha) was applied to strips containing between four and 24 *P. penetrans* per 200 g soil. Treatments were not replicated but at all sites cane growth in the first year was increased compared with that in adjacent untreated areas. At most sites a strip of aldicarb was also applied but again the response to aldicarb was less than that to dazomet.

The difference in effectiveness of dazomet and aldicarb is probably related to their different modes of action. Aldicarb is water soluble, relatively immobile and mainly controls nematodes. In contrast dazomet reacts with

soil moisture to produce a fumigant gas which in cold soils ($<7^{\circ}\text{C}$) tends to move down the soil profile. Sampling at depth has confirmed that dazomet, applied in the autumn, controls *P. penetrans* better than aldicarb. Dazomet also has a partial, soil-sterilising action which produces a number of beneficial side effects. In addition to killing nematodes, some soil-dwelling fungi are controlled. The value of this effect is unknown, but evidence that control of fungi can be beneficial was obtained in a pot experiment. In soil from a raspberry plantation which had already been treated with aldicarb to control *P. penetrans*, the fungicide quintozone (Botrilex) further improved the growth of newly replanted raspberries. Deep freezing the soil prior to planting raspberries also improve their growth more than aldicarb, again possibly because some fungi were controlled. Another 'side effect' following treatment with dazomet is that the availability of soil nitrogen is increased. However, in a field trial using three rates of nitrogen, dazomet (340 kg/ha) without nitrogen improved raspberry growth in the first year more than aldicarb with 90 kg/ha of nitrogen applied.

(D. L. Trudgill)

Two less costly alternatives to dazomet, metham-sodium (Campbell's metham sodium, Sistan, Vond Metam) and dichloropropene (Telone II), were tested in 1978. Both are liquids and for best effect have to be applied by specially designed machines such as the Rumpstadt 'Combiject' which has recently become available for contract work in Scotland. Preliminary results indicate that both chemicals can effectively control *P. penetrans* and other plant parasitic nematodes but their effect on the growth of subsequent crops has yet to be determined.

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

ENTOMOLOGY

05001 *Ecology and control of horticultural and agricultural pests,
particularly raspberry cane midge and mite*

Raspberry cane midge *Resseliella theobaldi*

Biology

The decrease in midge numbers observed in 1977 continued in 1978. As in 1977 when adult midges emerged at SHRI in late May the primocanes contained very few natural splits, suitable for egg-laying. In young primocanes of the cultivars Malling Jewel and Glen Clova, in which the epidermis had been split artificially, egg-laying reached a peak at SHRI in the first week of June. However, at a plantation of Glen Clova 12.5 km east of SHRI the midges emerged and laid their eggs about a week earlier. The

first eggs of second generation midges were found on 26 July at both sites but maximum numbers of eggs were found 9 days earlier at SHRI than at the other site. Differences in temperature between the two sites may account for the observed differences in egg-laying. The eastern site, being closer to the coast, was probably slightly warmer early in the season but cooler later. Larvae were found at both sites up to early October, when observations ceased.

Chemical control

The effectiveness of chlorpyrifos granules or spray, applied to the soil on 4 May before adult midges emerged, was tested in a 3 year old plantation of Glen Clova. The granules (5%) were raked into a 1 m band centred on the raspberry row at a rate equivalent to 1 kg a.i./ha. Chlorpyrifos (48% e.c.) was sprayed on separate plots at a rate of 0.96 l a.i./1000 l water/ha. However, when these treatments were assessed on 1 June, neither had decreased the numbers of eggs and larvae in artificial slits made in primocanes compared with the number in untreated plots.

A second trial compared chlorpyrifos and fenitrothion sprays applied on 6 and 19 June at 0.96 l a.i. and 0.5 l a.i./1000 l/ha respectively with a single spray of chlorpyrifos 0.96 l a.i. applied on 19 June. Both chlorpyrifos and fenitrothion had almost completely controlled larvae in artificial slits 3 days after the first spray, but the single spray of chlorpyrifos on 19 June was equally effective when the number of surviving first generation larvae was assessed on 29 June.

In a glasshouse test five insecticides were applied to infested raspberry canes using a cabinet precision pot sprayer. Fenitrothion (50% e.c.) 0.06% a.i., chlorpyrifos (48% e.c.) 0.1% a.i., permethrin (25% e.c.) 0.01% a.i., DDT (20% e.c.) 0.25% a.i., HCH (20% e.c.) 0.1% a.i. and water (control) were applied at a volume equivalent to 1123 l/ha. The canes were stored at room temperature for 7 days before the bark was removed to assess the number of living and dead midge larvae. A significantly greater proportion of dead larvae ($P < 0.05$) was found in all canes treated with insecticides, and canes treated with fenitrothion or chlorpyrifos contained a greater proportion of dead larvae than canes treated with the other insecticides tested ($P < 0.05$).

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

05008 *The ecology of aphids infesting potato, raspberry and ornamentals*

Potato

The pattern of development of aphid populations on potato in 1978 was very different from that observed in the previous 2 years. Large numbers of winged *Macrosiphum euphorbiae* migrated to potato crops at SHRI in

late May and early June, producing widespread colonies. Populations of *M. euphorbiae* reached a peak on potatoes (cv. Maris Piper) in the third week of July. This peak was 3 weeks earlier and the numbers were 50% greater than in 1977. Alatae migrated from potato during the last half of July and the first half of August. Fungal diseases killed most of the remaining aphids and few *M. euphorbiae* were found after mid August.

In contrast, *Myzus persicae* was very scarce in 1978. As in 1977, a few winged aphids colonised potato crops at SHRI in early June but unlike the previous 2 years there was no large increase in the population in June or July.

Similar patterns of potato aphid development were recorded in a late-planted (11 May) crop of Maris Piper in a trial at St Fort, near Wormit, Fife. *M. euphorbiae* colonised the emerging plants in mid June and the population increased until the first week of August. *M. persicae* was not found until August and the population remained very small.

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

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

Potato

The spread of leaf roll virus (PLRV) in 1977 in potato plots protected by insecticides is reported on p.108. In a different field experiment in 1977 untreated cv. Maris Piper plants in large pots were grown next to plants infected with PLRV. The pots were lifted on three dates: 13 July when the initial period of colonisation by winged aphids from overwintering sites was complete, 27 July before the dispersal of winged aphids from potato crops, and 6 September. The lifted plants were sprayed with an insecticide and grown on in an aphid-proof glasshouse until September when the tubers were harvested. An assessment of PLRV in these tubers showed that the virus had spread most among plants exposed to infection until 6 September with 12% of the progeny tubers being infected. Tubers lifted on 27 July or 13 July were 2.8% and 1.2% infected, respectively, indicating that in 1977 most PLRV spread after July. This corresponds to the period when most aphids were found on potato in 1977 but contrasts with results obtained in 1976 which indicated that the main period of spread in that year was before mid July.

The effectiveness of disulfoton (1.1 kg a.i./ha) or thiofanox (0.70 kg a.i./ha), applied at planting, to limit the spread of PLRV was tested in a further trial on Maris Piper in 1978. *M. persicae* were scarce on all plots, but slightly more numerous on plots treated with disulfoton than on the control plots. Thiofanox and disulfoton prevented *M. euphorbiae* reproducing

during June and delayed increase until mid July, after which numbers increased slightly. In two other treatments four sprays of pirimicarb (140 g a.i./ha) or demephion (250 g a.i./ha) were applied at fortnightly intervals from 6 July to plots in which no granular aphicide had been used. Both chemicals gave excellent control, plots receiving the first spray containing fewer aphids after treatment than those treated with granules.

To assess the effectiveness of early haulm destruction as a method of limiting tuber infection by PLRV, the haulm of plants growing in part of each plot were destroyed on 23 August, when the maximum number of seed-sized tubers had been produced. Seed tubers were collected from these and from the remaining plants the haulms of which were destroyed 2 weeks later.

The effectiveness with which PLRV-infected aphids transmit virus to insecticide-treated crops is unknown. This was tested in a glasshouse experiment where *M. persicae* which had been reared on potato infested with PLRV were caged on virus-free potato plants cv. Maris Piper. Some of these plants had been treated with disulfoton or thiofanox incorporated into the soil at planting 7 weeks earlier, at the rate of 30 mg a.i. in 4.5 l soil corresponding to normal commercial rates of field application. After 4 days 94% of the aphids on the untreated plants were still alive, 47% survived on disulfoton-treated plants, but only 2% survived on thiofanox-treated plants. The plants were then sprayed regularly with insecticide, and progeny tubers were harvested 7 weeks later. When grown on it was found that treatment with disulfoton had not decreased the proportion of mother plants infected with PLRV but had slightly decreased the number of infected progeny tubers. Compared with the control, thiofanox decreased the proportion of infected mother plants from 52% to 22% and the proportion of infected tubers from 38% to 10%.

Weekly bioassays in 1978 of leaves excised from plants treated in the field with disulfoton or thiofanox showed that treated plants were most toxic to *M. persicae* at emergence (late May). The toxicity of both insecticides decreased at similar rates until, in mid July, 13 weeks after planting, there was little difference in the survival of *M. persicae* on treated or untreated leaves.

Aphid bioassays were also used to test the toxicity of an experimental 5% granular formulation of pirimicarb (JF6582) applied to potato drills at planting at rates of 71 g/100 m, 112 g/100 m and 142 g/100 m. JF6582 was relatively less persistent than 5% granular thiofanox (112 g/100 m) and was effective against aphids for about 11 weeks after treatment, compared with about 13 weeks for thiofanox.

In glasshouse experiments, a laboratory clone of *Aulacorthum solani* transmitted PLRV, though less efficiently than *M. persicae*, but a clone of *M. euphorbiae* was a very inefficient vector. In subsequent tests, however,

M. euphorbiae, collected from leaf roll-infected potato plants in the field, were able to transmit PLRV in a small proportion (3%) of tests. The role of *M. euphorbiae* as a vector of PLRV requires further elucidation in view of the large populations of this species on potato in Scotland.

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

Field experiments were started in 1978 with entomologists from the Scottish Colleges of Agriculture to determine the need in different areas for granular insecticides to prevent the spread of PLRV. Plots of potato (0.1 ha), treated at planting with either disulfoton (1.1 kg a.i./ha) or thiofanox (5.6 g a.i./100 m) or left untreated, were grown at Portknockie, Banffshire, Dunfermline, Fife, and Auchincruive, Ayrshire. A similar trial was also established at Earith in Cambridgeshire. Foundation stock seed (FS1) from a farm in Easter Ross was planted at each site. Fifteen tubers of cv. Up to Date, infected with PLRV, were planted at regular spacings in the centre of each plot. Aphids were sampled at 2 week intervals from 30 May until 21 August. *M. persicae* were abundant only at Auchincruive and, briefly at Earith. No *M. persicae* were found on potato throughout the season at Portknockie and *M. euphorbiae* were also scarce, the population not reaching a maximum until mid August when it was still relatively small (21 *M. euphorbiae* per plant). More surprisingly, *M. euphorbiae* was also scarce at Earith, where a small population in July was rapidly decreased by fungus disease. At Auchincruive, a very large population of *M. euphorbiae* developed in mid July and a similarly large population developed on the experiment at Dunfermline, reaching a peak on the crop, which was planted on 8 May, in August.

Haulms were destroyed in the third week of August (first week of September at Dunfermline) and 'infector unit' and 'bulk' samples of tubers were harvested during the first half of September. Infector unit samples consisted of five tubers from three hills to either side of each infector. Bulk samples of 100 tubers were taken from two drills in each plot. All samples will be indexed for PLRV in 1979.

(J. A. T. Woodford, C. S. Aveyard with M. W. Shaw¹,
R. G. McKinlay², P. Osborne³ and G. N. Foster³)

Raspberry Beetle

Permethrin (ICI Ambush 25% e.c.), a synthetic pyrethroid insecticide, was compared with fenitrothion (0.05% a.i.) for controlling raspberry beetle (*Byturus tomentosus*). The insecticides were applied to raspberry cv. Mall-

¹ NSCA

² ESCA

³ WSAC

ing Jewel heavily infested with eggs and larvae, on 10 July at rates equivalent to 1000 l/ha. One hundred berries were sampled from each plot on four occasions (19, 21, 26 and 31 July) and the number damaged assessed. Fenitrothion and the 0.01% a.i. permethrin treated plots had consistently fewer damaged fruit than those treated with 0.005% a.i. permethrin which in turn had significantly less damage than the untreated control plots.

(S. C. Gordon)

ESTATE

W. I. A. JACK

Sowing and planting were completed several weeks later than usual following the most prolonged wet weather experienced during the winter and spring period for several years; these difficult conditions were followed by a cool, dull and wet summer, and harvesting operations were beset by rain, particularly during August. However, improved weather conditions during October and November allowed land work to proceed until 28 November when it was brought to an end by one of the wettest Decembers since meteorological recording began at the Institute in 1954.

Farm and experimental crops

Farm crops included 34.0 ha barley, 8.1 ha winter wheat, 7.6 ha hay, 4.1 ha grass, 1.0 ha potatoes, 5.5 ha other crops, 1.8 ha fallow; this is an increase of 2.6 ha from the previous year as more land was released from field experiments and used for cereals.

Barley sowing was completed by 26 April, 17 days later than 1977. The crop did not establish well in the wet conditions and although growth improved slightly during a short spell of fine weather in late May and early June the crop always appeared to be struggling to make growth; in fact, in some of the fields the straw length was no greater than 20 cm. Outbreaks of mildew (*Erysiphe graminis*) also occurred in some fields. Combining started on 23 August but was frequently interrupted by rain, being completed under difficult conditions on 18 September. The yield of 5.4 t/ha was down 0.9 t/ha on the previous year. Despite the poor growing and harvesting season, grain samples in general were fair; with again moisture content (m.c) of 17.6% and nitrogen content of 1.4% all was sold for malting.

Winter wheat, gave an excellent yield of milling quality grain despite being sown in difficult conditions, surviving a cold wet winter and spring, and being harvested in wet conditions. The yield of 7.7 t/ha at 20% m.c. was the highest average yield recorded for this crop at SHRI; all was sold for milling.

The weather broke almost as soon as hay cutting was completed on 20 June and highlighted the problem of field haymaking in a wet season; baling was completed by 7 July. Quality was poor and the yield of 8.0 t/ha was 1.6 t/ha less than in 1977.

Seed for the Institute's 1979 potato experiments grew well and protective spraying against pests and diseases was applied throughout the growing season; haulm was flailed off early in September as an added precaution against pests and diseases. Lifting under difficult conditions was completed early in October and gave a good clean sample. A yield of 34.6 t/ha was an increase of 4.5 t/ha on 1977.

Field experiments included 12.0 ha raspberries, 5.7 ha black currants, 2.3 ha strawberries, 1.7 ha blackberries and hybrid berries, 0.1 ha blueberries, 4.5 ha vegetables, 3.3 ha potatoes, 0.5 ha field beans, 0.5 ha ornamental bulbs, 1.2 ha nursery stock and 1.2 ha other crops; this represents a decrease of 2.3 ha on the previous year. Fruit picking started with strawberries on 19 June, followed by loganberries 10 July, raspberries 13 July, black currants 16 July, Tayberries 2 August, loganberries 10 August, blackberries 28 August, blueberries 1 September and finally cranberries 19 October. Fruit picking was made difficult by frequent showers and low numbers of pickers, with the result that a proportion of the soft fruit crop had to be abandoned. Fruit was small in size at the start of the season but size and quality improved as the season progressed. Because of the problems encountered, there was a higher incidence of grey mould disease; however, reductions in yield were balanced by higher produce prices.

The fruit crop sold included 44.75 t raspberries, 15.13 t strawberries, 4.18 t black currants, 0.95 t blackberries, 0.34 t blueberries, 0.09 t loganberries, 0.03 t cranberries, 0.01 t red currants and 0.1 t Tayberries. This totalled 9.42 t less than 1977.

Marketable produce from the vegetable trials totalled 6.5 t and included Brussels sprouts, beetroot, cabbages, calabrese, carrots, courgettes, French beans, lettuce, leeks, onions and swedes.

During periods when land work was at a standstill, useful improvements were made to the estate and included the erection of a car port adjacent to the staff houses on Errol Road, the preparation of a maximum yield area for the Crops Research section, the renewal of 130 m of fencing in School field and, where necessary, the resurfacing of farm roads with chippy dust. Soil from the new crop handling building site and glasshouse frame area was transported to Haugh field to help raise the field above the burn level in an attempt to overcome waterlogging which renders parts of the field unusable following heavy rainfalls.

New farm equipment acquired during the year included three balances, a semi-automatic potato planter, vegetable and strawberry planter, and a 20 m³ cold room for fruit storage.

Glasshouses

The production and maintenance of plant material for use by the scientific sections increased this year. Plant production at 146,734 units was up by 22,127 on the previous year and included the propagation of 7,200 rasp-

berry pot plants from 59 cultivars, produced from root cuttings for Institute use; 1,800 black currant plants were raised from single bud cuttings for a plant breeding project; 6,000 strawberry runners from six cultivars were rooted for a mechanical harvesting trial in 1979, and several successive sowings of brassicas produced plants for field trials. The annual propagation of raspberry pot plants for SNSA was discontinued as this is now undertaken by ESCA at Liberton from roots of virus-tested mother plants maintained at the Institute.

Other projects included the preparation of fruiting plants of the four new strawberry cultivars to illustrate plant breeding techniques for the ARC display at Chelsea Flower Show at the end of May. A collection of new SHRI Liliium cultivars were manipulated to flower out of season in August for an exhibit at the Ayr Flower Show.

Whitefly (*Trialeurodes vaporarium*) has been a recurring problem, but was held in check by regular routine spraying and fumigation programmes. No other particular pest problems were encountered. The principal disease under glass has been powdery mildew, and trials were started during the year using triadimefon (Baylton) and (Ridomil 25).

Labour resources were directed towards several maintenance undertakings; useful improvements were carried out to improve the north entrances to the Pratten houses by replacing awkward steps with ramps; three Dutch light houses had concrete floors laid to improve general hygiene; two large frame beds were built to raise large sowings of brassica plants; and after several years of service the compost mixer was completely overhauled.

INFORMATION SERVICES

R. J. A. EXLEY

1978 was the busiest year yet experienced for the Institute in public relations activities.

Together with other Institutes of the ARS, and under the auspices of the ARC, manned exhibits were provided at the British Growers Look Ahead exhibition and at the Chelsea Show; in August the Institute continued its now traditional policy of being represented at Ayr Flower Show, the premier event of its kind in Scotland.

To celebrate the Institute's Silver Jubilee, the Institute held a public Open Day in July. This provided the opportunity to expose the very wide spectrum of work done at the SHRI, by means of manned static exhibits and guided tours of some of the field experiments. There was a larger attendance than at the Institute's first Open Day in 1974, which was all the more gratifying because the event coincided with the commencement of Dundee Festival week, when many rival attractions were on offer. Indeed the Institute also provided a display of its work at the Festival Science Fair, which was part of the Civic programme.

Visual Aids

The trend of increases in the turnover of visual aids was again evident in 1978. In particular, there was a considerable increase in the amount of monochrome materials used due to the production of three theses during the year.

| | Jobs | Colour | Photography Monochrome | Diazo | E.M./Prints | Graphic Jobs |
|------|------|--------|---------------------------|-------|-------------|-----------------|
| 1977 | 1454 | 4373 | 3275 | 440 | 1922 | 115 |
| 1978 | 1438 | 4065 | 5550 | 483 | 2541 | 86 |

Time-lapse cinemicrography and cinematography were undertaken to assess the amount of feeding time required for nematodes to induce galling in root tips, and preliminary observations on stem extension and leaf development in field bean, respectively; encouraging results were achieved on both projects and much further use of this recording technique is envisaged.

Electronic pulse equipment necessary for time-lapse sequences to be accurately recorded was built by the Maintenance Section.

Early in May production began on the 'Silver Jubilee' Open Days. Nineteen exhibits comprising over 80 display boards, 200 colour prints, 35 graphics and almost one kilometer of captions and titling were produced, together with a 20 minute 'dissolve' slide presentation with taped commentary entitled 'SHRI—the organisation and the work'.

Aerial photography of raspberry plantations in Perthshire and Angus, and field bean plots at Mylnfield was undertaken in August and September.

T. G. Geoghegan, S. F. Malecki and M. I. McMaster attended the third ARC Photographers Conference at the Rowett Research Institute, 12-13 April.

(T. G. Geoghegan)

LIBRARY

Library finances were sufficiently sound to allow an increase in the purchase of new books, and a total of 95 books were added to the holdings. Two new journal subscriptions were also taken out.

After only 3 years in the new building, available shelf space has been rapidly filled, and the acquisition of new shelving will have to be considered in the very near future. During the year, a marked increase was apparent in inter-library loans and internal borrowing.

The librarian attended the ARC Librarians' meeting held at ARC headquarters, London, in July.

Margaret Mitchell

Committee

| | | | |
|-----------------|----------------|-----------------|-----------------|
| <i>Chairman</i> | A Logan | P. G. Mitchell | P. C. Stewart |
| | C. A. Acheson | D. Morrison | T. M. Thomson |
| | G. Bruce | J. G. Porter | J. S. Whitehead |
| | G. M. Hodge | J. R. Robertson | |
| | C. C. McIntyre | R. J. Smith | |

Events

The 10th Annual General Meeting was held on 24 May, and after the business of the meeting a paper was read by Mr R. Thompson of the Institute staff on conditioning of seed potatoes in relation to subsequent yield. Afterwards, members were given the opportunity to visit the new crop handling building.

The routine of the annual summer visit to the field experiments was changed because of the Institute's Silver Jubilee Open Day arrangements. Members were invited to inspect and discuss with staff the many exhibits demonstrating the Institute's varied work, which was on display to mark the occasion. However, as usual during the afternoon there was the opportunity to view the raspberry and strawberry National Fruit Trials.

Two winter meetings were organised. On 16 February the subject was 'Producing healthy seed potatoes' and on 9 November the subject was 'Soil sterilisation and control of nematodes in soft fruit and potato land'. For both these subjects it was appropriate to invite speakers from outside the Institute, and the good attendance at the meetings suggests that the programmes were considered by the membership to be both interesting and timely.

METEOROLOGICAL RECORDS 1978

01046 *Agrometeorological recording*

Mylnefield

The year began with cold, wet and dull weather and, apart from a brief spell of warm bright weather at the end of May, continued into a dull damp summer.

Wind

Windspeed for the year as a whole was only slightly below the 15-year mean; however, with the exception of March the first 8 months of the year had below average windspeed with February being the calmest month since our records began in 1959. Windspeeds from September to December were 128% of average.

Temperature

The winter of 1977-78 was, as in 1976-77, a cold one confirming that the recent series of mild winters should not be taken as an established pattern. Mean minimum temperatures in February were the lowest since 1963 and the actual minimum air and grass temperatures were the lowest since 1956.

Early summer began well in a warm spell of 5 days at the end of May with maximum temperatures above 20°C and the highest maximum of 23.7°C on 29 May. Unfortunately this weather was not repeated at any time in the rest of the summer.

Rainfall

The winter and spring of 1977-78 were wet, with precipitation over the period January to April being 71% up on the average. Thereafter, in summer and autumn, rainfall was close to average with the exception of August which was wet and October which was dry. December rainfall was extreme, making this by far the wettest month since our rainfall records began in 1954. (The previous wettest month was October, 1959, with 156.5 mm.)

The estimated* soil moisture deficit during the growing season reached a maximum of 86 mm in mid-July, making this summer the least dry since 1971.

* 'Potential Transpiration'—Technical Bulletin No. 16 MAFF (1957).

Sunshine and Solar Radiation

The total of hours of sunshine for the year was slightly down on average while December's total sunshine was the lowest recorded at Mylnefield for any month.

Average sunshine over May and June was 0.9 h per day above the long term average whereas over July and August it was 0.9 h below.

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

METEOROLOGICAL RECORDS 1978

AUCHINCUIVE

Temperature

There were heavy snowfalls and exceptionally hard frosts in January and February, and even in April there were twice as many ground frosts as in the same month in 1977. Supplementary glasshouse heating was therefore required and extra ventilation in the polythene tunnels to minimize frost damage to emerging strawberry flowers. Relatively minor frost damage occurred in the field probably because of the late break in dormancy. Fruiting, however, started about the normal time probably because March and May were warmer than usual. Above average temperatures in late autumn swelled but failed to adequately ripen a potentially large crop.

Rainfall

Although total rainfall for the year was only marginally higher than average, precipitation occurred at the wrong time for the strawberry crop. The very cold start to the year combined with a wet March delayed planting until May; then drought necessitated the almost constant use of irrigation essential to wash in pre-emergent herbicides, and keep new plantations alive. This dry weather reduced strawberry yields to the lowest for many years. During August and September, when autumn cropping selections should have been at their best, there were only 9 days without rain, resulting in high fruit losses from botrytis.

Sunshine

After 2 exceptional years for bright sunshine hours, 1978 was a complete contrast with 122 hours less than average. August and September were particularly overcast and mainly contributed to the deficit.

Total solar radiation levels were well below 1977.

(R. J. McNicol)

Temperature

| Month | Daily Air Maxima | | Daily Air Minima | | 0.1m Soil | | 0.3m Earth | | Accumulated Day Degrees | | Days Ground Frost | Potential Evaporation mm | Rainfall | | Bright Sunshine hours | | Mean daily Solar Radiation | | Windspeed km/h | |
|-----------|------------------|------|------------------|------|-----------|------|------------|------|-------------------------|-----------|-------------------|--------------------------|----------|--------|-----------------------|-------|----------------------------|------|----------------|---|
| | Mean °C | DFA* | Mean °C | DFA* | Mean °C | DFA* | Mean °C | DFA* | Above 6°C | Below 6°C | | | Total mm | DFA* | Total | DFA* | mWh cm ⁻² | Mean | DFA† | |
| January | 4.6 | -0.9 | -0.9 | -0.9 | 0.8 | -0.6 | 2.9 | +0.6 | 7 | 140 | 28 | 0.0 | 109.9 | +49.5 | 64.0 | +11.8 | 52 | 11.3 | -1.2 | |
| February | 3.4 | -2.3 | -2.9 | -3.0 | 0.6 | -0.9 | 1.9 | -0.6 | 3 | 165 | 23 | 1.5 | 75.3 | +31.9 | 68.6 | -8.2 | 113 | 7.0 | -5.6 | |
| March | 8.7 | +0.7 | 2.8 | +1.2 | 3.9 | +0.7 | 5.1 | +1.0 | 30 | 47 | 18 | 34.3 | 59.0 | +15.9 | 110.2 | +5.2 | 199 | 15.5 | +0.8 | |
| April | 8.5 | -2.7 | 3.1 | 0.0 | 5.5 | -0.8 | 6.8 | -0.1 | 28 | 42 | 12 | 46.8 | 78.2 | +36.5 | 116.0 | -45.8 | 292 | 12.2 | -2.7 | |
| May | 14.7 | +0.9 | 6.9 | +1.1 | 11.1 | +1.0 | 10.9 | +0.8 | 151 | 5 | 2 | 91.4 | 47.2 | -11.5 | 217.3 | +36.9 | 515 | 9.3 | -3.9 | |
| June | 16.5 | -0.4 | 8.7 | +0.2 | 14.5 | +0.7 | 14.3 | +0.8 | 195 | 2 | 2 | 94.9 | 45.5 | -5.7 | 200.1 | +19.6 | 538 | 11.7 | -0.2 | |
| July | 17.2 | -1.1 | 9.9 | 0.0 | 14.3 | +0.7 | 14.3 | -0.7 | 230 | 1 | 0 | 83.8 | 60.2 | -6.3 | 146.6 | -26.3 | 413 | 10.6 | -0.4 | |
| August | 18.3 | +0.4 | 11.0 | +1.2 | 14.5 | +0.5 | 15.3 | +0.7 | 261 | 0 | 0 | 63.4 | 95.9 | +22.3 | 120.0 | -28.9 | 327 | 7.1 | -2.8 | |
| September | 15.9 | 0 | 9.6 | +0.9 | 11.5 | -0.1 | 12.7 | +0.1 | 198 | 0 | 0 | 51.8 | 50.9 | -5.3 | 98.9 | -22.6 | 239 | 16.1 | +6.0 | |
| October | 13.8 | +1.1 | 7.9 | +1.8 | 9.2 | +1.0 | 10.7 | +1.0 | 148 | 1 | 4 | 25.4 | 12.4 | -42.4 | 90.4 | -1.4 | 144 | 12.6 | +1.7 | |
| November | 10.1 | +1.9 | 4.4 | +2.4 | 5.8 | +1.8 | 8.0 | +2.5 | 76 | 42 | 12 | 5.1 | 47.1 | -11.6 | 56.9 | -8.3 | 65 | 15.8 | +3.8 | |
| December | 5.2 | -1.1 | 1.8 | +1.0 | 2.7 | +0.4 | 4.3 | +0.8 | 6 | 94 | 17 | 9.2 | 215.6 | +151.2 | 14.4 | -29.9 | 22 | 16.5 | +4.2 | |
| TOTALS | — | — | — | — | — | — | — | — | 1333 | 539 | 118 | — | 897.2 | +224.5 | 1303.4 | -97.9 | — | — | — | — |

DFA — Deviation from average 1954-1974

† — Deviation from average 1959-1974

Temperature

| Month | Daily Air maxima | | Daily Air minima | | 0-1m Soil | | 0-3m Earth | | Accumulated Day Degrees | | Rainfall | | Bright Sunshine Hours | | Mean daily Solar Radiation | | Windspeed | |
|-----------|------------------|------|------------------|------|-----------|------|------------|------|-------------------------|-----------|----------|-------|-----------------------|--------|----------------------------|-----------|-----------|--|
| | Mean °C | DFA* | Mean °C | DFA* | Mean °C | DFA* | Mean °C | DFA* | Above 6°C | Below 6°C | Total mm | DFA* | Total | DFA* | mWh cm ² | Mean km/h | | |
| January | 5.8 | -0.9 | 0.6 | -0.9 | 2.0 | 4.3 | -0.6 | 9 | 88 | 21 | 79.8 | -10.5 | 59.0 | +16.3 | 49.7 | 12.9 | | |
| February | 5.2 | -1.1 | -0.3 | -1.2 | 0.7 | 2.7 | -0.9 | 10 | 101 | 19 | 41.3 | -26.2 | 85.0 | +11.1 | 112.9 | 9.2 | | |
| March | 9.0 | +1.4 | 3.5 | +1.7 | 4.5 | 5.5 | +0.3 | 45 | 18 | 12 | 125.8 | +86.0 | 82.8 | -22.2 | 185.4 | 15.6 | | |
| April | 9.8 | -1.3 | 3.0 | -0.2 | 5.7 | 7.0 | -0.3 | 53 | 32 | 16 | 20.3 | -17.9 | 128.1 | -39.9 | 307.5 | 10.9 | | |
| May | 16.2 | +2.1 | 6.7 | +0.2 | 11.5 | 10.2 | 0.0 | 184 | 5 | 9 | 7.2 | -49.5 | 211.2 | +37.3 | 473.3 | 8.4 | | |
| June | 16.6 | -0.5 | 8.9 | +0.4 | 14.3 | 13.4 | +0.4 | 216 | 0 | 3 | 41.2 | -10.6 | 182.4 | -23.9 | 511.5 | 12.9 | | |
| July | 17.0 | -0.6 | 9.9 | -0.7 | 14.4 | 13.7 | -0.8 | 244 | 0 | 0 | 47.3 | -22.6 | 180.0 | +8.4 | 466.4 | 12.2 | | |
| August | 16.5 | -1.3 | 11.1 | +0.3 | 14.1 | 14.5 | -0.1 | 257 | 0 | 0 | 93.6 | +26.0 | 97.3 | -55.7 | 296.8 | 9.0 | | |
| September | 15.4 | -0.3 | 10.3 | +1.5 | 12.1 | 13.3 | +0.2 | 218 | 0 | 0 | 149.3 | +79.9 | 84.8 | -40.9 | 203.9 | 14.2 | | |
| October | 14.0 | +1.0 | 9.4 | +2.9 | 10.6 | 11.7 | +1.2 | 187 | 1 | 2 | 66.5 | -4.3 | 88.3 | -11.4 | 137.0 | 12.8 | | |
| November | 10.6 | +2.1 | 5.6 | +2.7 | 7.5 | 9.5 | +1.9 | 107 | 31 | 7 | 127.1 | +28.2 | 51.8 | -3.8 | 61.4 | 15.6 | | |
| December | 5.7 | -2.1 | 1.1 | -1.9 | 2.8 | 5.0 | -1.1 | 14 | 85 | 22 | 67.4 | -16.5 | 40.9 | +2.6 | 38.2 | 13.6 | | |
| TOTALS | — | — | — | — | — | — | — | 1544 | 361 | 111 | 866.8 | +61.9 | 1291.6 | -122.1 | — | — | | |

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

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INSTITUTES FOR AGRICULTURAL RESEARCH IN GREAT BRITAIN

The research programmes of all the research Institutes supported from public funds are co-ordinated by the Agricultural Research Council. The following is a list of Institutes. Most of them publish reports annually and details can be obtained from the Secretaries of the Institutes concerned.

ARC Institutes

| | |
|---|--|
| Animal Breeding Research Organisation | King's Buildings, West Mains Road, Edinburgh, EH9 3JQ |
| Food Research Institute | Colney Lane, Norwich, NR4 7UA |
| Institute of Animal Physiology | Babraham, Cambridge, CB2 4AT |
| Institute for Research on Animal Diseases | Compton, Newbury, Berks., RG16 0NN |
| Letcombe Laboratory | Letcombe Regis, Wantage, Berks., OX12 9JT. |
| Meat Research Institute | Langford, Bristol, BS18 7DY |
| Poultry Research Centre | King's Buildings, West Mains Road, Edinburgh, EH9 3JS |
| Weed Research Organisation | Begbroke Hill, Sandy Lane, Yarnton, Oxford, OX5 1PF |

State-aided Institutes in England and Wales

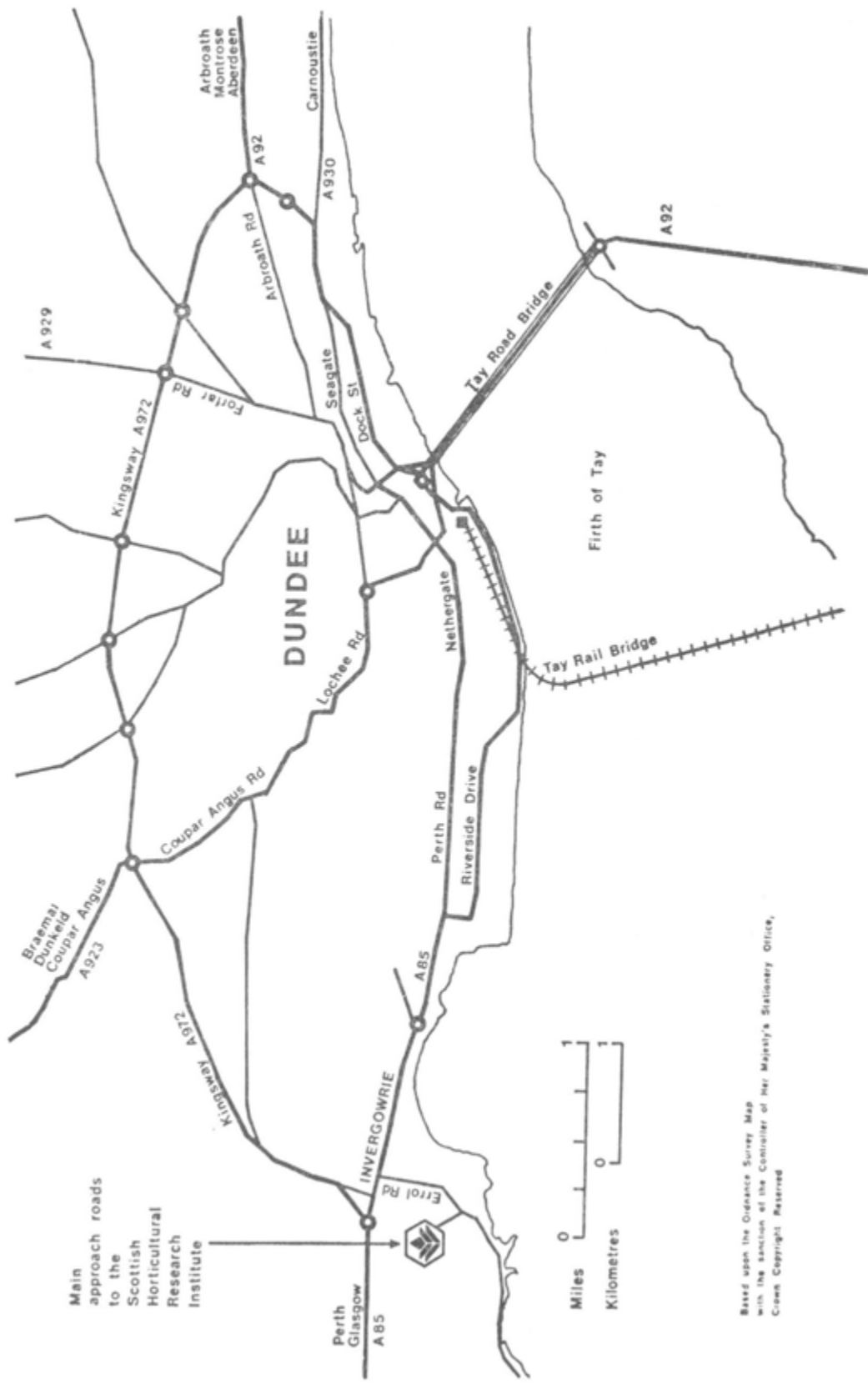
| | |
|--|---|
| Animal Virus Research Institute | Pirbright, Woking, Surrey |
| East Malling Research Station | East Malling, Maidstone, Kent, ME19 6BJ |
| Glasshouse Crops Research Institute | Worthing Road, Rustington, Little- hampton, Sussex, BN16 3PU |
| Grassland Research Institute | Hurley, Maidenhead, Berks., SL6 5LR |
| Houghton Poultry Research Station | Houghton, Huntingdon, PE17 2DA |
| John Innes Institute | Colney Lane, Norwich, NR4 7UH |
| Long Ashton Research Station | Long Ashton, Bristol, BS18 9AF |
| National Institute of Agricultural Engineering | Wrest Park, Silsoe, Bedford, MK45 4HS |
| National Institute for Research in Dairying | Shinfield, Reading, RG2 9AT |
| National Vegetable Research Station | Wellesbourne, Warwick, CV35 9EF |
| Plant Breeding Institute | Maris Lane, Trumpington, Cambridge, CB2 2LQ |
| Rothamsted Experimental Station | Harpenden, Herts., AL5 2JQ |
| Welsh Plant Breeding Station | Plas Gogerddan, Aberystwyth, Cardiganshire, SY23 3EB |
| Wye College, Department of Hop Research | Ashford, Kent, TN25 5AH |

State-aided Institutes in Scotland

| | |
|--|--|
| Animal Diseases Research Association | Moreduin Institute, 408 Gilmerton Road, Edinburgh, EH17 7JH |
| Hannah Dairy Research Institute | Ayr, Scotland, KA6 5HL |
| Hill Farming Research Organisation | Bush Estate, Penicuik Midlothian, EH26 0PH |
| Macaulay Institute for Soil Research | Craigiebuckler, Aberdeen, AB9 2QJ |
| Rowett Research Institute | Bucksburn, Aberdeen, AB2 9SB |
| Scottish Horticultural Research Institute | Invergowrie, Dundee, DD2 5DA |
| Scottish Institute of Agricultural Engineering | Bush Estate, Penicuik, Midlothian, EH26 0PH |
| Scottish Plant Breeding Station | Pentlandsfield, Roslin, Midlothian, EH25 9RF |

ABBREVIATIONS

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| AAB | Association of Applied Biologists |
| ACAS | Agricultural Chemicals Approval Scheme |
| ADAS | Agricultural Development and Advisory Service |
| ARC | Agricultural Research Council |
| BA | British Association for the Advancement of Science |
| BBC | British Broadcasting Corporation |
| BMS | British Mycological Society |
| DAFS | Department of Agriculture and Fisheries for Scotland |
| EEC | European Economic Community |
| ESCA | East of Scotland College of Agriculture |
| ERCC | Edinburgh Regional Computing Centre |
| EHS | Experimental Horticultural Station |
| FBPP | Federation of British Plant Pathologists |
| HEA | Horticultural Education Association |
| JCO | Joint Consultative Organisation |
| NFT | National Fruit Trial |
| NIAB | National Institute of Agricultural Botany |
| NSDO | National Seed Development Organisation |
| NSCA | North of Scotland College of Agriculture |
| SNSA | Scottish Nuclear Stock Association |
| USDA | United States Department of Agriculture |
| VTSC | Virus tested stem cutting |
| WSAC | West of Scotland Agricultural College |



Main approach roads to the Scottish Horticultural Research Institute



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