

21

ANNUAL

THE SCOTTISH HORTICULTURAL  
RESEARCH INSTITUTE

1974



SCOTTISH HORTICULTURAL  
MYLNEFIELD  
INVERGOWRIE  
DUNDEE  
RESEARCH INSTITUTE

The Scottish Horticultural Research Institute

21st Annual Report for the year 1974

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## Governing Body

- Chairman* Professor N. F. Robertson, B.Sc., Ph.D., M.A., Dip.Agric.Sc.
- John Arbuckle, Esq., O.B.E.
- George Bruce, Esq.
- David W. H. Cargill, Esq.
- T. Martin Clucas, Esq.
- Professor W. W. Fletcher, B.Sc., Ph.D., F.L.S., F.I.Biol., F.R.S.E.
- M. Douglas Henderson, Esq.
- Professor D. L. Lee, B.Sc., Ph.D.
- Ian D. Lowe, Esq., M.A., Dip.Agric.(Cantab), M.B.A.
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- A. Gordon Porter, Esq.
- John R. Robertson, Esq.
- Ronald Smith, Esq.
- Professor W. D. P. Stewart, B.Sc., Ph.D., F.R.S.E.
- Professor P. E. W. Weatherley, M.A., D.Phil., F.R.S.E., F.R.S., F.I.Biol.
- Professor M. B. Wilkins, Ph.D., D.Sc.

## Staff

- Director* C. E. Taylor\*†, B.Sc., Ph.D., F.I.Biol.
- Deputy Director* C. North\*, B.Sc.Hort., M.Sc., Ph.D., N.D.H.
- ### Crops Research
- Head of Section* P. D. Waister\*, B.Sc., Ph.D.
- R. J. Clark  
M. R. Cormack, N.D.H.  
J. B. Cowan, B.Sc.  
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.  
Sheila M. Royle, B.Sc.  
H. Taylor, N.D.H.  
R. Thompson, B.Sc., M.Sc.  
Pauline B. Topham, M.A., B.Sc., Ph.D.  
J. S. Wiseman, S.D.H.
- Assistants* D. G. Cathro  
D. Crabb  
Elizabeth Lowe  
Katherine R. Myles  
G. C. Nicol  
Heather A. Ross  
Mrs Janet Sharp  
Jeanette McD. Shepherd  
R. N. Wilson
- ### Plant Breeding
- Head of Section* C. North\*, B.Sc.Hort., M.Sc., Ph.D., N.D.H.  
M. M. Anderson, N.D.H., S.D.H., D.H.E.  
A. Dale, B.Sc., Ph.D.  
Eleanor Carmichael  
J. R. T. Hodgkin, B.Sc.  
D. L. Jennings, B.Sc., Ph.D.  
A. J. Redfern, B.Tech., L.I.Biol.  
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* Joyce E. T. Fyffe  
G. Steele  
W. B. Taylor  
Jane A. Woodsford
- ### West of Scotland Unit (Auchincruive)
- Officer-in-Charge* H. J. Gooding, B.Sc., Ph.D., F.L.S.  
K. C. McConnell, S.D.H.  
R. J. McNicol, B.Sc.
- Assistant* Mrs Marjorie Morrison  
*Attendant* Mrs Sarah Borland  
*Secretary* Janet B. Henry

## Mycology

- Head of Section* 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  
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
- Assistants* Evelyn M. Ballantine  
Mrs Alison M. Campbell  
Mrs Norma M. Colliar  
Frances Devaney  
Mrs Caroline M. Gill  
Mrs Moira E. Mackenzie  
Mrs Sheena Strachan
- Attendant* Norah E. Cotogno

## Virology

- Head of Section* B. D. Harrison\*, B.SC., PH.D.  
H. Barker, B.SC.  
J. Chambers, B.SC.  
R. A. Goold  
Mrs Aileen M. Hutcheson  
A. T. Jones, B.SC., PH.D.  
M. A. Mayo, B.SC., PH.D.  
W. P. Mowat, B.SC., DIP.AGR.SCI.  
A. F. Murant, B.SC., PH.D.  
I. M. Roberts, DIP.RMS.  
D. J. Robinson, M.A., PH.D.
- Assistants* Margot E. Anderson  
Erica M. Bell  
Mrs Agnes Donald  
Mrs Morag P. Gordon  
Eleanor M. W. Innes  
J. H. Raschké
- Attendant* 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.  
S. C. Gordon  
W. M. Robertson  
J. A. T. Woodford, B.A., M.A., PH.D.

## Zoology—continued

- Assistants* Sandra A. Birrell  
D. J. F. Brown  
Sylvia Hebbourn  
Sheena M. Morton  
Mrs Irene Raschké
- Estate*
- Manager* W. I. A. Jack  
*Foreman* R. W. Reid
- Glasshouses*
- Manager* J. Cantwell, C.D.H.  
*Foreman* R. D. Taylor
- Farm Workshop*  
W. R. S. Batchelor  
G. W. Pollock
- Maintenance*
- Head of Section* J. H. Couttie  
J. R. Caithness  
A. Low  
R. MacDonald  
G. Merchant  
D. J. G. Redford  
A. Ryce  
L. A. Swan
- Information Services*
- Information Officer* R. J. A. Exley, C.D.H.  
*Photography* J. I. Campbell, A.L.I.P.  
S. F. Malecki  
*Graphics* Maureen I. McMaster, D.A.  
*Library* Mrs Margaret Mitchell
- Administration*
- Secretary* N. D. Anderson  
*Assistant Secretary* A. P. Thomson  
D. L. McIntosh  
I. A. McLeish  
*Director's Secretary* Ruby B. L. McGill  
Margaret Campbell  
Mrs Jean Findlay  
Mrs Margaret Mauchland  
Helen Moncrieff  
*Stores* Mrs Anne Bertie  
J. F. McLean

\*Honorary Lecturer in the University of Dundee.

†Honorary Senior Lecturer in the University of St. Andrews.

## General Report

C. E. TAYLOR

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A New Laboratory building was opened by the Minister of State for Scotland, Lord Hughes of Hawkhill, on 12 July. The Minister, accompanied by Lady Hughes, and guests were welcomed by the Chairman of the Governing Body, Professor N. F. Robertson. After his address, Lord Hughes appropriately used a pair of garden shears to cut a ribbon at the main entrance to the building and unveiled a plaque which records the event. Various aspects of the Institute's programme of research were the subjects for exhibits presented in the new laboratories which were then open for viewing. On the following day the Institute held an Open Day to give the general public the opportunity to see the research facilities within the building and exhibits of work.

The New Laboratory building occupies the site of the old farm steading. It is 2,600 sq m in area and provides office and laboratory accommodation for the Crops Research, Mycology and Plant Breeding Sections, a Visual Aids suite and a Staff restaurant. The architects were W. M. Wilson & Partners, Dundee, and the main contractor was J. B. Hay Ltd., Dundee.

In his address Lord Hughes referred to the harmful effect of cuts in expenditure on research which is for the benefit of the community and expressed the hope that Research Institutes could be insulated as far as possible from this. Also in the Government White Paper on 'Food from our own Resources' (Cmnd. 6020, published April 1975) reference is made to the need for a continuing investment in the scientific improvement of agricultural technology and the dependence on research to achieve potentially higher output. These are heartening words which we hope will be matched by appropriate financial support to sustain the research effort that is directed towards overcoming problems impeding crop production and for the innovation and development of ideas which can increase productivity. The effects of the financial constraints presently imposed on agricultural research will be manifest for several years after support is fully restored, mainly because of the time lag between research findings and their development to commercial application. At a time when financial cuts must be expected in all sectors of Government expenditure there is nevertheless a strong case for sustained and fully effective support for agricultural research to ensure that the call for more home produced food can be met.

This report gives details of research work undertaken at the Institute during the 1974 and commissioned by the Department of Agriculture for Scotland. Each project has a number which identifies it within the Agricul-

tural Research Council Planning Unit System of Project Classification and Costing.

#### *Governing Body*

It is with regret that we report the death of Mr James Gilchrist who was a member of the Governing Body from 1953 to 1968.

The Secretary of State for Scotland re-appointed nine members of the Governing Body to serve for a further period of 3 years, from 1974 to 1977. As previously reported, three members of the Governing Body retired and in addition to their replacements a further three members were appointed to provide a complement of 16. New members are Professor W. W. Fletcher, University of Strathclyde; Professor D. L. Lee, University of Leeds; Professor M. B. Wilkins, University of Glasgow; Mr T. Martin Clucas, Asmer Seeds Ltd., Leicester; Mr J. R. Robertson, Esk Foods (Angus) Ltd., Montrose; and Mr R. J. Smith, Springhill Nurseries, Aberdeen.

#### *Appointments*

Dr A. Dale was appointed as HSO in the Plant Breeding Section in September to undertake research on *Rubus* breeding. In December Dr B. Boag was appointed as HSO in the Zoology Section to undertake research on parasitic nematodes associated with vegetable crops; previously he had been employed at the Institute on nematodes associated with trees financed by a grant from NERC and in association with the Institute of Tree Biology, Edinburgh. In July Mr R. J. McNicol was appointed as SO at the West of Scotland Unit, Auchincruive, Ayr.

During the year the following Assistant Scientific Officers were appointed:—

Frances Devaney	Mycology Section
W. B. Taylor	Plant Breeding Section
Jane A. Woodsford	Plant Breeding Section
Mrs I. Raschké	Zoology Section

Mrs Rena Reid was appointed as Laboratory Attendant in the Virology Section in November.

Miss Sheena Y. Thomson was appointed to a new shorthand/typist post in August.

Dr W. R. Jarvis resigned in August to take up an appointment as Head of the Plant Pathology Section of the Research Branch, Canada Department of Agriculture at Harrow, Ontario; he came to the Institute in December 1953 and during his period of 21 years has been particularly concerned with research on *Botrytis* infection of raspberry and strawberry.

Mr K. C. McConnell (HSO) resigned in December after serving for 22 years at the West of Scotland Unit, and Mr R. A. Gould (HSO) also resigned in December after 12 years in the Virology Section. Miss Sheena Fyfe resigned in October from her SO post in the Plant Breeding Section. Mrs K. J. Harrison also resigned in October from her post as Librarian.

Mrs Georgina A. Laing and Mr J. Wardlaw resigned their appointments as Assistant Scientific Officers and Mrs Eileen Harrison and Miss Norah E. Cotogno resigned from their appointments as Laboratory Attendants.

#### *Visiting Workers*

Mr K. Hanada (University of Kyushu, Japan), holder of a scholarship from the Japanese Ministry of Education, arrived in September to spend a year working on nepoviruses (Virology Section).

Dr S. Kubo (Japan Tobacco and Salt Public Corporation, Yokohama) arrived in April to spend a year on the staff studying the behaviour of tobacco rattle virus in leaf mesophyll protoplasts (Virology Section).

Dr F. D. McElroy, a nematologist from the Canada Department of Agriculture, Research Branch, Vancouver, will spend a sabbatical year until June 1975 in the Zoology Section working on the specificity of the relationship between plant viruses and their nematode vectors (Zoology Section).

Dr J. W. Randles (Waite Agricultural Research Institute, S. Australia) arrived in September to spend a sabbatical year studying the properties of seed- and soil-borne viruses (Virology Section).

Dr F. Roca from the Agricultural Nematology Laboratory, Bari, Italy, visited the Institute from 25 November to 6 December to learn fixation and sectioning techniques for studying virus vector nematodes (Zoology Section).

Ir G. M. Tichelar, Netherlands Institute of Phytopathological Research worked in the Mycology Section for 2 weeks in September to familiarise himself with current work on potato gangrene on which the Netherlands now has a research programme (Mycology Section).

#### *Research Students*

Mr A. T. Dickson continued his DAFS-sponsored post-graduate studentship working on the population dynamics of aphids infesting raspberries (Zoology Section).

Mr S. El Nagar completed his studies on the transmission by aphids of viruses of umbelliferous plants (Virology Section).

Ing. L. Salazar of the International Potato Center, Peru, began studies in September on the properties and relationships of viruses from Peruvian potatoes (Virology Section).

In October Mr Charles Wright, a graduate of the University of Bath, was appointed to an ARC Studentship. He will investigate the nature and effects of the competition which exists within the raspberry plant between its vegetative cane and its fruiting cane (Crops Research Section).

#### *Sandwich Course Students*

Kathleen Bell from Dundee Technical College, assisted in the work on pests of calabrese and *Aphis fabae* on beans from April to September (Zoology Section).



Mr J. Kelly from Dundee Technical College, assisted with work on meristem-tip culture of narcissus from April to August (Virology Section).

*Courses attended*

T. J. W. Alphey, D. J. F. Brown and B. Boag attended the Edinburgh Regional Computing Centre for a course on the use of the 'Statistical Package for the Social Sciences.'

N. D. Anderson attended a Job Appraisal Review Training Course at ARC Headquarters.

B. Boag, A. T. Dickson and Sheila Royle attended an Occasional Speakers Course at NIAE, Bush Estate, Penicuik, Midlothian.

J. B. Cowan, R. J. Clark and Pauline B. Topham attended a Genstat course and J. B. Cowan an IMP course at the Edinburgh Regional Computing Centre.

J. M. Duncan, P. A. Gill, D. K. L. MacKerron, B. Williamson and H. M. Wilson attended courses held at Long Ashton Research Station on Stereoscan Electron Microscopy.

S. C. Gordon attended an Association of Applied Biologists Workshop Meeting on Phytophagous Mites.

Aileen M. Hutcheson attended a Hitachi-Perkin Elmer course on electron optics and electron microscopy at University of Edinburgh.

I. M. Roberts attended a Royal Microscopical Society course in advanced techniques in electron microscopy for biologists, University of Glasgow.

Sheila Royle, B. Williamson and J. A. T. Woodford attended an ARC Induction Course.

P. Smith and J. A. T. Woodford attended an 'Introduction to Genstat' course, Edinburgh Regional Computing Centre, Edinburgh.

*Conferences at which papers were given*

4 January Association of Applied Biologists/Society of Experimental Biologists joint meeting on nematode physiology, Leeds University.

W. M. Robertson Nervous organisation of the oesophagus of *Longidorus leptcephalus*.

15 January Weed control in the northern environment. BCPC Symposium, Edinburgh.

H. M. Lawson Patterns of emergence of several important arable weed species.

6 February ADAS Plant Pathologists Open Conference, Northampton.

J. M. Duncan Methods of detecting red core.

7 March	British Growers Look Ahead Conference, Harrogate.	
	C. E. Taylor	Mechanical harvesting and new soft fruit cultivars.
	P. D. Waister	Mechanical harvesting and cultural developments in soft fruit.
14 March	ADAS Growers and Advisers Bulb Meeting, Kirton EHS.	
	W. P. Mowat	Production of virus-tested clones of narcissus.
19-23 March	Pathology Section, European Association for Potato Research, Dundee.	
	T. J. W. Alphey	Chemical control of <i>Trichodorus</i> spp. and transmission of tobacco rattle virus to potatoes.
	B. D. Harrison	Studies on the nature of the resistance of potato cultivars to tobacco rattle virus.
	B. D. Harrison	Experiments on the control of potato mop-top virus.
	M. C. M. Pérombelon	Effect of soil temperature and seed origin on geographical distribution and level of occurrence blackleg.
	D. L. Trudgill	Changes in the growth, salt uptake and water relations of potatoes infested with potato cyst nematode and the influence of fumigation.
	H. M. Wilson	Histology of potato gangrene ( <i>Phoma exigua</i> var <i>foveata</i> ).
1-5 April	ISHS Second International Symposium on Flower Bulbs, Littlehampton.	
	C. North	Embryo culture as an aid to breeding <i>Lilium</i> .
	W. P. Mowat	Results and applications of a survey of virus infection in narcissus stocks in Scotland.
3 April	ARC Conference on electron microscopy, Wellesbourne.	
	I. M. Roberts	The poor man's diamond knife.
8 April	Society for General Microbiology Virus Group, London.	
	A. F. Murant	Two protein and two RNA species in strawberry latent ringspot virus.

8 April	D. J. Robinson	Early events in infection with temperature-sensitive mutants of tobacco rattle virus.
9 April	The Campden Food Preservation Research Association 1974 Agricultural Symposium, Stratford-on-Avon. P. D. Waister	Recent advances in harvesting soft fruit and their implications for processing.
19 May-6 June	NATO Advanced Study Institute on nematode vectors of plant viruses, Taranto, Italy. T. J. W. Alphey	A preliminary note on the geographical distribution of Trichodorids in the British Isles.
	T. J. W. Alphey	Chemical control of Trichodorids and of transmission of tobacco rattle virus.
	B. Boag	A preliminary study of the factors influencing the distribution of Trichodorid species in the British Isles.
	D. J. F. Brown	An interim report on the distribution survey of the Longidoridae within the British Isles.
	D. J. F. Brown	The use of modern data processing techniques and equipment in the organising of the British Longidoridae survey and their application to a European Longidoridae survey.
	W. M. Robertson	The structure and function of the feeding apparatus in <i>Longidorus</i> and <i>Xiphinema</i> .
	W. M. Robertson	Ultrastructure of the feeding apparatus in <i>Trichodorus</i> .
	C. E. Taylor	Acquisition, retention and transmission of viruses by nematodes.
1-7 September	Society of European Nematologists XII International Symposium of Nematology, Granada, Spain. D. L. Trudgill	Changes in the growth, salt uptake and water retention of potatoes infested with potato cyst nematode and the influence of soil fumigation.

1-7 September	D. L. Trudgill	Feeding of <i>Longidorus</i> spp. in relation to acquisition and transmission of plant viruses.
	C. E. Taylor	Specific retention and transmission of viruses by nematodes.
	C. E. Taylor	Ultrastructure of the musculature of the feeding apparatus in <i>Longidorus</i> and <i>Xiphinema</i> with reference to species differences in <i>Longidorus</i> .
2-6 September	1st International Congress of IAMS, Tokyo. B. D. Harrison	Potato mop-top virus and its vector, <i>Spongospora subterranea</i> .
10 September	University of Kyushu, Fukuoka. B. D. Harrison	Recent research on tobacco rattle virus.
19 September	Australian National University Workshop on viruses with divided genomes, Canberra. B. D. Harrison	Plant virus systems.
23-27 September	Eucarpia Meeting on Cruciferae, SHRI. J. R. T. Hodgkin	Genetic control of self compatibility levels in Brussels sprout.
	A. B. Wills	Practical application of seed isoenzyme analyses.
24 October	Meeting, Federation of British Plant Pathologists, London. M. C. M. Pérombelon	Contamination of potato seed stocks of stem cutting origin by <i>Erwinia carotovora</i> .
2 November	Scottish Electron Microscopists Symposium, Edinburgh. I. M. Roberts I. M. Roberts	The poor man's diamond knife. Handling and staining epoxy resin sections for light microscopy.

#### Visits abroad

B. D. Harrison visited universities and research institutes in Japan after the Intersectional Congress of IAMS in September, to discuss research on plant viruses. He then went by invitation to Australia to take part in a workshop at the Australian National University, Canberra, and to visit the Waite Institute, Adelaide.

B. D. Harrison visited Kenya in November as ODM consultant to the project on virus diseases of food crops, centred at the East African Agriculture and Forestry Research Organization, Muguga.

A. T. Jones visited research institutions in France in May to discuss research on plant viruses and see virus problems in raspberry crops.

On 24–29 June C. North attended VII Congress of Eucarpia, Budapest and chaired Meeting of Horticultural Sections.

D. A. Perry attended the 17th International Seed Testing Congress, Warsaw, Poland, on 14–22 June.

C. E. Taylor attended meetings of the Consiglio Scientifico del Laboratorio di Nematologia, Bari, Italy, in May and December.

#### *Radio and Television*

Dr C. E. Taylor discussed soft fruit research on the BBC Scottish Region Farming Journal programme on 12 July, and on 15 July was interviewed on Grampian TV on the opening of the New Laboratory building.

#### *Editorial duties*

C. E. Taylor	Associate Editor of <i>Journal of Horticultural Science</i> . Member of the Board of Editors of <i>Nematologia Mediterranea</i> . Member of the Board of Editors of <i>Horticultural Research</i> .
B. D. Harrison	Editor of <i>Journal of General Virology</i> . Editor of <i>Commonwealth Mycological Institute/Association of Applied Biologists Descriptions of Plant Viruses</i> . Member of Editorial Board of <i>Intervirology</i> .
A. F. Murant	Editor of <i>Commonwealth Mycological Institute/Association of Applied Biologists Descriptions of Plant Viruses</i> . Member of Editorial Board of <i>Annals of Applied Biology</i> . Member of Editorial Board of <i>Journal of General Virology</i> .
Pauline B. Topham	Editor of <i>Horticultural Research</i> .
P. D. Waister	Associate Editor of <i>Journal of Horticultural Science</i> .

#### *Awards*

S. El Nagar—Ph.D. of the University of Dundee.

#### *Staff overseas*

M. A. Mayo was given leave of absence for a year as from March 1974 to work on plant viruses at the Institut de Biologie Moleculaire et Cellulaire, Strasbourg, France.

A. F. Murant was seconded for a year as from July 1974 to the Canada Agriculture Research Station, Vancouver, to study viruses of *Rubus* and umbellifers.

#### *Conferences organised*

R. A. Fox, Head of Mycology Section, organised a residential meeting in the University of Dundee from 19–23 March 1974 of the Pathology Section of the European Association for Potato Research of which he is Chairman. The theme of the meeting, at which there were 90 registrants, was 'Methods for testing for disease resistance and methods of assessing disease.' Twenty-nine papers were read in four formal sessions; Pathogen and Pest Control; Host and Pathogen Interaction; Diseases mainly associated with Damage; and Diseases not mainly associated with Damage. There were, in addition, two discussion groups, and technical visits to see potato handling, grading and fumigation.

C. E. Taylor, with Professor F. Lamberti of Bari, Italy, and Dr J. W. Seinhorst, Wageningen, The Netherlands, organised a NATO Advanced Study Institute on Nematode Vectors of Plant Viruses, which was held at Riva dei Tessali, Taranto, Italy, from 19 May to 6 June, 1974. The Institute provided a forum for a critical appraisal and discussion of all aspects of the biology of virus vector nematodes and the occasion brought together most of the nematologists and several of the virologists who are working in this particular field. The Proceedings of the Institute will be published (June 1975) by Plenum Press.

#### *Service on committees*

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. ARC Management Advisory Committee. ARS Whitley Council. Joint ARC/IPCS Working Party on Promotion Procedure. NFT Advisory Committee. NFU Soft Fruit Working Group Committee. SNSA—Adviser to Committee. SADC Crops Committee. NSDO Advisory Committee. Member of Scientific Council of the Laboratorio di nematologia agraria, University of Bari, Italy.
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C. North  
 M. M. Anderson  
 B. Boag  
 J. I. Campbell  
 R. A. Fox  
 H. J. Gooding  
 B. D. Harrison  
 D. L. Jennings  
 A. T. Jones  
 H. M. Lawson

ACAS Advisory Committee.  
 HEA Scottish Branch.  
 East of Scotland Bulb Growers' Consultative Committee.  
 Eucarpia Member of Board of Directors.  
 Eucarpia Chairman Vegetable Section.  
 Dundee University Botanic Garden Committee.  
 NFT Black currant Sub-Committee.  
 ADAS Migratory Nematodes Working Party.  
 City and Guilds of London Institute  
 744/745-1-01 Objective Examination Item Writing and Editing.  
 745-1-03 Examiner. 745-1-04 Assessor.  
 Chairman, Pathology Section, European Association for Potato Research.  
 SHRI/Scottish Colleges Liaison Group.  
 NFT Strawberry Sub-Committee.  
 NFU Soft Fruit Working Group.  
 NFT ad hoc Committee on soft fruit breeding.  
 City and Guilds of London Institute Advisory Panel on Tropical Agriculture.  
 International Society for Plant Pathology Member of Council.  
 British National Committee for Biology Member of Microbiology Sub-Committee.  
 Society of General Microbiology Member of Virus Group Committee.  
 JCO, Member of Plant Science Committee.  
 Joint Vice-Chairman, Third International Congress for Virology Programme Committee.  
 NFT Raspberry Sub-Committee.  
 NFT Scottish Trials Committee.  
 SNSA—Adviser to Committee.  
 Association of Applied Biologists Member of Council.  
 ISHS Working Group on Weed Control in Vegetables.  
 British Crop Protection Council Sub-committees—weed control meetings and publications.  
 JCO, Technical Secretary of Field Vegetables Committee.

K. C. McConnell  
 W. P. Mowat  
 A. F. Murant  
 D. A. Perry  
 R. Thompson  
 Pauline B. Topham  
 D. L. Trudgill  
 P. D. Waister

HEA Scottish Branch.  
 East of Scotland Bulb Growers' Consultative Committee.  
 International Organisation of Citrus Virologists Liaison Committee on Citrus and other fruit plant virus diseases.  
 Chairman, Vigour Test Committee, International Seed Testing Association.  
 NIAB Vegetable Trials Advisory Committee.  
 NIAB VTAC Cauliflower Panel.  
 JCO, Working Group on Crop Improvement (Field Vegetables Committee).  
 SHRI/Scottish Colleges Liaison Group.  
 ERCC Research Councils Users Committee.  
 Nematology Group, Association of Applied Biologists.  
 JCO, Member of Fruit Committee.  
 Scottish Council/DAFS Joint Committee on Food Processing.

*Address given by Lord Hughes of Hawkhill  
 12 July 1974*

I am concerned as a Minister to see that Scotland's horticulture is on a sound footing but I am also deeply interested in this particular part of Scotland. I have therefore watched with close attention the expanding influence of the Institute during its relatively short history. It has contributed much to the horticultural industry in Scotland, and elsewhere, and I am sure it will continue to make its authority known and recognised.

Horticultural research embraces many crops, but here at Mylnefield the raspberry crop must surely have a special place. Some 85% of the UK raspberry crop—or 15,000 tons for those who prefer the figures and can imagine what 15,000 tons look like—is grown each year in Scotland; mostly in eastern Scotland. This crop has a value of nearly £2 million and is therefore of considerable economic importance to the Scottish horticultural industry. The Scottish climate is ideal for producing raspberries. Like all crops, however, it has its problems, and it is in this sphere that SHRI has done so much to help the raspberry industry. It has poured forth a wealth of ideas which have led to increased productivity. Plant breeders have contributed by breeding new varieties suited to the processing market to which the bulk of the Scottish crop goes. The new variety—Glen Clova—has an appropriately east coast name. It was made available to growers in 1971 and has shown itself to be highly productive and of excellent quality. Increases in yields can bring their own problems. These include aggravating the shortage

of casual labour to harvest the crops. I recognise, however, that it is one form of industry which it is not easy to mechanise. Research on mechanical harvesting has been going on at Mylnfield since 1968 in conjunction with the Scottish Station of the National Institute of Agricultural Engineering at Bush Estate, near Edinburgh. Work is still in the experimental stage but it looks as if a suitable machine can be produced for the harvesting of the raspberry crop even if it may still be a few years away. There will also be raspberry varieties more suited to mechanical harvesting than at present. The Institute has, I know, released this year a new variety bred specifically for machine harvesting; and improved varieties will undoubtedly follow. The SHRI-bred strawberry Redgauntlet has contributed much to the spectacular increases in yields since its introduction in the mid-50s. Yields of 6-10 tons an acre are common now compared to some 36 hundredweights an acre in those earlier years. I gather the Institute is also carrying out interesting work in the production of late fruiting varieties which could open up useful markets for the industry.

The Institute work on vegetables has profound importance for the processed vegetable market in Scotland. The need is for timely production and uniformity of produce coupled with large scale growing operations. These are being met by new research. Research has shown how plants can be manipulated to produce the required end product, such as the size of Brussels sprouts for freeze packets. A high level of research is aimed at producing what might be called a blueprint for each crop so that it can be grown with the precision required for present-day economic production. Work on calabrese—a green sprouting form of broccoli—in conjunction with the East College, is an example of this approach, where the input of ideas and information over the past few years has led to an increase in acreage from less than 30 acres to over 600 acres at present. Research work on potato blackleg and gangrene is of great importance to the potato crop in Scotland and the Institute's standing in this area is shown by the decision of the Plant Pathology Section of the European Association for Potato Research to meet here last March.

Let me now mention the research that is going on into ornamental bulb crops such as narcissus and tulips. This research shows that quality stocks for dry bulb production can be maintained here in Scotland. Work in conjunction with the North and East Colleges and with growers is planned to produce virus-tested stocks of the commercially grown *Narcissus* varieties. Research on tulips shows there is a potential advantage in the Scottish climate for dry bulb production of tulips. This could well lead to import saving—a modest but helpful contribution to our balance of payments. Even more, think of the possibilities that open up in tourist terms. I can see the call now: 'Visit the Bulb Fields of Eastern Scotland!' It would quite literally add colour to our lives and provide further evidence that our climate works to our benefit much if not all of the time. It is at any rate about time someone spoke up for our climate!

We need to spend money on research if we are to continue to progress. The question we have to resolve is contained in the old formula: how much? This is difficult to decide at the best of times. In periods of financial stringency, such as at present, it is still more important to satisfy ourselves that the expenditure is being put to its best use. This brings problems to sponsors and contractors alike and calls for sympathetic understanding on both sides. Research institutes can certainly be assured that everything possible will be done to minimise the effects that any enforced cuts in Government expenditure may have on research programmes.

I am delighted to open the new building and look forward to hearing more about the research work from the scientists themselves.

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## Crops Research

P. D. WAISTER

Field beans have a history of variable yield in England, and it has been said that in Scotland there is no cultivar which is reliable. For the past 3 years the crop has been examined at the Institute in a series of experiments designed to establish the nature of the limiting factors and their effects on yield components. During this time yields have been consistently high and the results provide a base-line for yield components against which any future crop failures may be measured.

Previous reports have referred to the competition which exists between the vegetative and fruiting phases in the raspberry. There have been indications that this could be altered in cv. Norfolk Giant in a way that could have practical significance, but this has not proved possible with Malling Jewel. The SHRI bred cultivar Glen Clova now occupies one-eighth of the raspberry acreage, so the very marked yield benefits obtained with this cultivar this year by removing early competition from young cane are particularly significant. The mechanism of intra-plant competition is being investigated in greater depth.

### CROP ENVIRONMENT

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

##### *Crop response to shelter*

The effects of wind on growth of Cambridge Favourite strawberry are being investigated in an experiment planted this year. In the first season, sheltered plants grew more vigorously and produced two more leaves per plant (a 10% increase) and a 14% increase in leaf size, compared with the exposed control plots. By early July the protected and exposed plants had produced 4.6 stolons and 3.6 stolons per plant respectively.

Measurements with an infra-red thermometer showed little difference in leaf temperature between sheltered and exposed plants. The main factor influencing leaf temperature was incident radiation, and the temperatures of sunlit and shaded leaves differed by up to 3°C whether sheltered or not. This effect was even more marked on berry temperatures, with differences of 6.5–10.5°C between sunlit and shaded berries.

The effect of a windbreak were measured in spawn beds of four raspberry cultivars. All cultivars gave significant increases in cane height and Malling Admiral showed a 30% increase in cane numbers.

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

#### *Irrigation and water use*

Yields of raspberry were unaffected by irrigation whether applied frequently to maintain high soil water potential or when restricted to a single application at pink fruit stage, despite an apparent alleviation of stress as indicated by an increase in leaf water potential of up to 6 bars in the irrigated plots compared with the non-irrigated controls.

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

#### *Low temperature injury*

Each week throughout the winter a separate sample of canes of raspberry cv. Glen Isla was subjected to a frost cycle simulating a natural fall to an air minimum plateau temperature of  $-10^{\circ}\text{C}$ , using a portable frost chamber in the field. Bud and pith tissue temperatures were monitored by hypodermic thermistor probes, and showed mean minima between  $-7.4^{\circ}$  and  $-8.4^{\circ}\text{C}$  for the 4 h period of lowest temperature. Damage was subsequently measured in the developing buds, laterals and fruits. Cooling treatments applied prior to mid-March, the time of onset of bud-swelling, had no measurable effect on yield. After this time, frosting damaged primary laterals resulting in increased development of secondary and tertiary laterals and subsequently decreased yield.

Cane and bud death in this cultivar during winter has in the past been tentatively attributed to frost injury. This view is not supported by these results, though the possibility of damage in seasons which produce cane which is physiologically less frost-tolerant is not ruled out.

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

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

##### *Wind*

Attempts to measure wind effects on the growth of carrot were thwarted at two sites on sandy soil when a sand blow inundated the screened plots. At a third site, plant population was reduced by 30% by mid-June in exposed plots, compared with sheltered plots. The effects of these population differences on subsequent growth obscured the effects of wind on plant growth.

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

##### *Low temperature*

In Scotland, autumn-sown field bean, oilseed rape and onion are potentially more successful than spring-sown, provided they do not suffer winter injury.

The relative frost tolerance of different cultivars of each of these crop species is being assessed at intervals throughout the winter by applications of frost cycles using the portable frost chamber described in the report for 1973.

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

#### 01003 *Effects of weather conditions on growth and yield of flower bulb crops*

##### *Flower blindness in narcissus cv. Double-White*

Flower production has been recorded for three seasons from plots of Double White narcissus planted at three depths, 75 mm (shallow), 150 mm (normal) and 225 mm (deep). Though there have been large differences between treatments in the total numbers of flowers produced, blindness has been at a relatively low level and has not been affected in a consistent way by depth of planting. Shallow planting resulted in 8% more flowers and deep planting 27% less flowers in total over 3 years compared with the normal treatment. Stem length and flower diameter were inversely related to flower number.

Mean temperatures were similar in the different treatments but the temperature range differed. Maximum temperatures were up to  $2.3^{\circ}\text{C}$  lower during May and June at bulb level in the deep planting compared with shallow planting and in September and October  $2.5^{\circ}\text{C}$  higher.

The experiment was terminated this year and the bulbs were lifted and graded. Shallow planting gave an increase of 30% in weight of bulbs over the deep planting though mean bulb size was smaller.

Taking into account both the number and quality of flowers produced there seems no reason to treat this cultivar differently from others with regard to planting depth.

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

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

##### *Continuous sowing experiment*

Calabrese, carrot, onion and red beet were sown at weekly intervals for 13 weeks commencing on 2 April. All stocks were of high vigour, field conditions were generally good over the whole period and the proportions of viable seeds which produced seedlings dropped below 0.8 on two occasions only with beet and calabrese, and at no sowing were they as low as 0.8 with carrot and onion. Minimum emergence figures were obtained from 4 June and 18 June sowings, and in both cases were associated with deterioration of soil structure, confirming the importance attributed to this factor in previous years. An  $F_1$  hybrid onion cultivar was used for the first time this year and the mean emergence level (86%) contrasted strikingly with the results obtained in 1972 and 1973 with non-hybrid onion (58% and 54%).

(T. W. Hegarty)



*Effects of moisture and fluctuating temperature on seedling emergence*

In a laboratory experiment, seeds of calabrese and carrot were sown in soils at a range of water potentials, and similar samples of seeds were placed in polyethylene glycol (PEG) solutions of equivalent potentials. Constant or diurnally fluctuating temperature regimes were superimposed.

In soil at low and moderate moisture stress, seedlings of both species emerged faster in the fluctuating temperature environment than at constant temperature. At high moisture stress, emergence occurred only in the fluctuating temperature environment.

In osmotic solutions, calabrese germinated faster in the changing temperature environment but germination of carrot seeds was unaffected by the temperature treatments. It seems that apart from any effect that fluctuating temperatures may have on the germination process itself, there is an additional effect perhaps on the availability of moisture in the soil. Such an effect could be brought about by temperature-induced gradients of soil moisture in the fluctuating temperature environment.

(T. W. Hegarty)

*Pre-sowing seed treatment with polyethylene glycol 20M*

Seeds of carrot, chicory, leek and red beet were soaked in a PEG solution with a water potential of -15 bars, at 10° or 20°C for varying periods of time before being washed, dried back, and sown in the field. Though all the treated seeds emerged earlier, there was no subsequent effect on final emergence level, crop yield or on uniformity.

(T. W. Hegarty)

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

*Field bean*

A range of topping treatments applied to cultivars Herz Freya and Ostlers at stages from 5 weeks after emergence to the time of pod swelling did not significantly increase either yield or seed size. For the second year in succession the harvested seeds were smaller than those that were sown, but yields were again high at about 5.7 t/ha.

(T. W. Hegarty)

*Seed vigour in brassica*

The inbred parents of the Institute's F<sub>1</sub> cabbage Celtic Cross show a difference in time of seed ripening of about 10 days. No differences were found between hybrid seed produced by these two lines in terms of percentage establishment or speed of emergence when each was harvested at its optimum date.

Randomly outcrossed seed was investigated from a selection of the selfed progeny and F<sub>1</sub> hybrids obtained by intercrossing three different lines

of Brussels sprout with four lines from different crop types of *Brassica oleracea*. The seed was sown on 25 April and intermediate and final emergence percentages were recorded. Final emergence levels of the inbred parents ranged from 38% to 94% and of the outcrossed progeny from 86% to 97%. The difference between the selfs and crosses was significant at the 0.1% level. Vigour as assessed by the rate of seedling emergence did not differ between selfs and crosses but did differ significantly ( $P < 0.01$ ) within selfs. The results show that the vigour (seedling emergence in the field) of outcrossed seeds of F<sub>1</sub> hybrids is significantly higher than that of the outcrossed seed of their inbred parents. This suggests that one aspect of inbreeding depression can be transmitted to the F<sub>1</sub> hybrid progeny.

(T. W. Hegarty, T. Hodgkin<sup>1</sup>)

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

*Seedling establishment and soil treatment*

Soil crusting was artificially induced by overhead application of 5 mm water immediately after sowing in plots of calabrese sown on five occasions between 10 April and 20 June. Emergence was reduced by this treatment on only one occasion, 20 June, when the seed was sown into moist soil and there was no rain between sowing and emergence; a 20% reduction in emergence was recorded. No such reduction occurred in plots in which seeds were covered by vermiculite, instead of soil, before watering.

(S. M. Royle, T. W. Hegarty)

*Weathering effects on the susceptibility of seedbeds to crusting*

There is some evidence that crusting is less liable to occur on a seedbed subjected to a period of natural weathering before it receives heavy rain. The emergence of calabrese seed sown into moist soil on 23 May was compared with similar sowings to which 5 mm of water were applied, either on the day of sowing, 1 day after sowing or 3 days after sowing. There was no interference from rain before emergence and the emergence levels recorded were 84, 61, 74 and 86% respectively. Penetrometer values were inversely related to these figures. Comparison of the morphology of seedlings from the control plots and those watered on the day of sowing, showed that the latter had longer and more twisted underground portions of the hypocotyl. This suggests that the decreased emergence may have been a consequence of soil factors acting on seedling growth rather than on seed germination.

(S. M. Royle, T. W. Hegarty)

<sup>1</sup>Plant Breeding Section.

01021-01024 Weed ecology and control in soft fruit, flower bulbs and vegetables*Weed competition*

Competition from spring-germinating weeds reduced yield of bulbs of narcissus cv. Carlton by 17% compared with a weed-free control. Reductions of between 5% and 35% have been recorded in this type of experiment at SHRI over a number of years, the size of the effect being determined largely by the intensity of weed growth during the month of June.

Tulips cv. Apeldoorn were exposed to competition from light infestations of either over-wintered weeds or spring-germinating weeds in spring and summer 1974. The total weight of bulbs lifted was not significantly reduced but whereas bulbs of circumference greater than 13 cm comprised 37% of the total weight on weed-free plots, this size accounted for only 19% and 25% respectively of the yield on plots with winter or spring weeds present.

In the absence of any weed control after transplanting, 18 inch square planted Brussels sprout cv. Topscore suffered no significant yield reduction compared with plants kept weed-free. At a 24 inch square spacing competition from weeds resulted in longer stems, a reduced leaf area and a yield decrease of 17%.

The presence of untreated weeds at harvest reduced yields of pea cv. Sprite by 28% and 56% in two experiments in 1974. This was considerably higher than the average loss experienced in previous years and was attributed to low plant populations combined with a dense population of chickweed (*Stellaria media*).

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

*Herbicide evaluation*

The current series of experiments on herbicide programmes for peas was concluded in 1974. Of the range of residual herbicides used, cyanazine consistently provided the most effective weed control, while bentazone/MCPB at 3.0 lb a.i./ac was superior to dinoseb-amine as a post-emergence treatment. Neither treatment had any adverse effect on crop yield.

In leek cv. Malabar, excellent early weed control was achieved by pre-emergence treatment with propachlor plus paraquat. Late-germinating fat hen (*Chenopodium album*), however, had become a major problem and was flowering by the time the crop had reached the 3-leaf stage. Ioxynil and bentazone gave acceptable control of this size of fat hen but caused moderate to severe crop injury. Aziprotryne, methazole and particularly cyanazine were less effective by themselves but a later treatment with ioxynil rendered these plots practically weed-free without further scorch. Plots originally treated with ioxynil required further treatment with methazole to control knotgrass (*Polygonum aviculare*).

Narcissus cv. Carlton was treated during flowering with a range of herbicides prior to the germination of the spring weed flora. Metoxuron, cyanazine and especially methazole discoloured crop foliage and reduced bulb yield. Chlorbufam/pyrazone and bentazone had no adverse effect on the crop. The latter offers a useful alternative to chlorbufam/pyrazone where residual pre-emergence herbicide treatment fails to prevent the emergence of spring weeds such as mayweed (*Matricaria* spp) and fumitory (*Fumaria officinalis*). Unfortunately, knotgrass is completely resistant.

Propyzamide has proved to be a useful herbicide for the control of perennial grasses in top and bush fruit. Its use in strawberry has been restricted to certain soil types and to the period between October and December because of crop injury.

Single applications of propyzamide at 1.25 lb a.i./ac to strawberry cv. Cambridge Favourite at monthly intervals between October and May in two experiments and over 2 years had no adverse effect on crop growth or fruit yield. These results indicated that greater flexibility of timing could be considered on sandy clay loam soils in eastern Scotland. Joint field screening experiments on strawberry with the Weed Research Organization have been continued and a range of new herbicide treatments was evaluated for crop safety after application in late March.

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

01029 Weed control in crop rotations

A raspberry experiment which compared 7 years of managerial treatments involving either regular soil cultivation or annual applications of simazine for weed control in the alleys was terminated in 1973. The area was test-cropped with barley in 1974. There was no visible evidence in the barley crop of residues of simazine sufficient to affect crop growth, maturity or yield. Weed numbers recorded in the barley crop in plots originally cultivated were nearly double those present on plots previously treated with simazine, due principally to larger numbers of annual nettle (*Urtica urens*). This species had been the major constituent of the weed flora which infested these plots between the final cultivation before fruit harvest and the recommencement of cultivation in late winter.

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

## VEGETABLE CROPS AND FLOWER BULBS

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

In the population range 0.35-12 plants/ft<sup>2</sup> (3.8-129.2 plants/m<sup>2</sup>) there was little yield difference between square arrangement and 24 inch rows for the cultivars Rex and Corvet. Rex, the genetically larger cultivar, again showed

maximum yield at a lower population than Corvet (0.7 and 1.3 plants/ft<sup>2</sup>). These optima for yield are considerably lower than those reported last year, probably because rainfall was only 70% of the 15 year average for the critical months of July and August.

Manipulation of population gave spear size ranges from 4 in to 2 in for both cultivars, but spears of similar diameter, 3.3 in for Rex and 3.5 in for Corvet, were obtained from densities (0.7 and 1.3 plants/ft<sup>2</sup>) giving the maximum yield for each cultivar of 4 and 6 ton/ac respectively.

Of 33 cultivars examined, Gem, F<sub>1</sub> 73378, Extra Early No. 12, Premium Crop and Duchess gave the best combination of yield, uniformity and quality.

Times to 50% maturity for sowing dates between 1 April and 20 June were in close agreement between 1973 and 1974 for the cultivar Corvet. Values declined almost linearly between 1 April and mid-May from 110 days to 88 days. Between mid-May and end of June time from sowing to maturity was constant at 85 days. Over most of the sowings Rex and Harvester were 5 days later and 12 days earlier respectively than Corvet.

Mechanical harvesting of crops of Corvet and Gem organised jointly by SHRI, East of Scotland College of Agriculture and National Institute of Agricultural Engineering (SS) were carried out at East Hillhead Farm, Monikie, with a machine built by the National Vegetable Research Station for harvesting mini-cauliflowers. Potential yield determined by hand harvesting was 2.85 ton/ac and machine harvesting recovered 2.5 ton/ac. The production of 1 cwt of trimmed spears by machine cutting, and with some loose leaf removed by aspiration, took 96 man min. This compares with between 80 and 120 man min/cwt for commercially hand harvested crops. The main benefit offered by the machine this year was the ability to harvest crops in wet weather when hand harvesting was difficult.

#### Pea

The yield/density relationship of a leafless mutant obtained from the John Innes Institute was compared with that of the widely-grown cv. Green Shaft. The yield of Green Shaft reached a plateau at a higher density than that of the mutant (7.7 and 2.5 plants/ft<sup>2</sup>). However, over the range of populations examined (1–10 plants/ft<sup>2</sup>), the yields of the mutant were lower than those of Green Shaft, and the respective plateau levels were 4.6 ton/ac and 6.0 ton/ac at T120. The mutant's potential is as parental material rather than as a commercial cultivar, and it remains to be seen whether its yield stability over a wide range of plant densities is an attribute that can be incorporated in higher-yielding types.

(R. Thompson, H. Taylor)

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

##### Field bean

Time of sowing was the most significant factor affecting yield of field bean in this year's programme of experiments. Averaged over populations from 1–7 plants/ft<sup>2</sup>, yields of the cultivars Herz Freya and Ostlers fell from a common value of 2.5 ton/ac to 1.5 and 1.1 ton/ac respectively for sowings made on 28 February and 18 April. At the early sowing populations varying from 3 to 7 plants/ft<sup>2</sup> gave similar yields, the means for the two cultivars differing by only 6% (2.8 and 2.6 ton/ac for Herz Freya and Ostlers respectively). Differences in yield between sowing dates were accounted for largely by differences in average bean weight of 20% between extreme sowing dates together with a corresponding 23% reduction in the number of pods per plant. This reduction in pod number was due solely to a reduction in the proportion of pod-bearing nodes per plant. The 41% greater seed weight of Ostlers was balanced by Herz Freya producing 27% more beans/pod and 28% more pods/plant.

(R. Thompson, H. Taylor)

#### 01037 Control of growth, yield and quality of flower bulb crops by cultural methods

##### Tulip

An earlier experiment showed the potential value of biennial as opposed to annual lifting of tulip, but was not sufficiently comprehensive to establish optimum rates and bulb sizes. These aspects were examined this year, using five sizes of mother bulb of the cultivars Merry Widow and Apeldoorn, each grade planted at three densities. From the results the optimum population for the biennial system for any size grade may be determined.

Assuming the target is economically to maximise yields of bulbs of 10 cm and over, a number of potentially useful combinations of bulb size and planting rate were found. For example, for Apeldoorn a 4–5 cm mother bulb combined with a planting rate of about 600,000 per acre (1.7 ton/ac) gave 170,000 bulbs per acre over 10 cm in size. A similar yield was obtained from an alternative combination of a 7–8 cm mother bulb at 222,000 per acre (1.2 ton/ac). Yields of Merry Widow of about 160,000 bulbs per acre over 10 cm in size were obtained from planting 6–7 cm sized bulbs at 222,000 per acre (0.92 ton/ac) and lifting 2 years later. These figures may be compared with those predicted for conventional planting systems after 1 year. The cultivars Merry Widow and Apeldoorn, planted as 9–10 cm mother bulbs at 130,000 per acre would have given about 130,000 and 105,000 bulbs of 10 cm and over, respectively.

(R. Thompson, H. Taylor)

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

*National Fruit Trial 1971*

There were some very pronounced changes in yield ranking of the 19 cultivars and seedlings this year. The two top yielding cultivars in 1973 were Malling Orion and Glen Isla (M14) but their yields were halved in 1974 and they fell to 15th and 17th positions respectively. Examination of yield component shows that both cultivars suffered similar drops in cane numbers (mean 27% and in yield per cane (mean 40%), while the control cultivar M. Jewel showed negligible differences in these components between the 2 years. Damage to young cane caused by high winds and by pickers in July 1973 may have been a contributory cause but, if so, it is not yet clear whether the yield decrease is a direct effect of physical damage or an indirect one *via* a pathogen or pathogens.

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

*Propagation of virus-tested stocks*

The Institute releases virus-tested material to the Scottish Nuclear Stock Association as pot plants which have been derived from root cuttings under glass. A series of experiments on establishment of spawn beds directly from roots have not yet given evidence that this is a feasible alternative system to pot plant production. However, in the course of this work it has been found that pot plants produced in October from cold-stored roots offer as good or better prospects of field establishment than those from the conventional spring production system.

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

*Raspberry management*

Discing along the side of cane rows up to three times between late winter and the onset of fruit picking had no adverse effect on cane or fruit production in cv. Glen Clova. This agreed with results of a previous experiment on cv. Malling Jewel.

Discing once to a depth of 5-7 in along rows of Malling Jewel in early spring 1974 substantially reduced translocation to crop rows of aminotriazole and glyphosate applied to suckers growing in the alleys. Control of suckers with a range of herbicides with contact action was disappointing.

Primocane growth in the final year of a plantation competes with fruiting cane, obstructs picking and adds to the problem of ploughing-in the plantation. Attempts to remove young primocane of M. Jewel by single application of paraquat or dinoseb-in-oil applied at different stages of cane development were only partially successful; many of the primocanes recovered from the initial check, and the yield from fruiting canes was not significantly increased.

The vigour of newer cultivars presents management problems. Removal of primocane early in the season may be one method of reducing competition between fruiting and young canes in the main fruiting years of a plantation, provided sufficient cane emerges subsequently to produce adequate numbers, size and quality of fruiting wood for the following season. Young canes were removed (by cutting) from an established plantation of Glen Clova when they reached 4, 8, 12, 18 and 24 in high respectively. Subsequent cane growth was left untouched. Treated plots yielded up to 60% more fruit than the control, as a result of increases both in berry size and number. Differences in overall yield between the various cutting systems were not significant but later dates of cane removal produced earlier ripening of fruit. Cane produced after the various cutting treatments will be retained for fruiting in 1975 for assessment of quality and health status.

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

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

*Raspberry*

In 1973 yields of hand harvested plots of four cultivars were compared with those from plots harvested by six passes of the machine. The mechanically harvested plots were noticeably poorer in leafing-out in the spring of 1974, so the whole experiment was hand harvested to give a measure of the damage caused to the young cane in the previous year. Yields from the machine harvested plots of the four cultivars were one-third less than from hand harvested, the depression being attributable to a combination of reduction in number of live canes/plant, number of cropping nodes/cane, and berry size. In one cultivar there appeared to have been an additional depression in mean numbers of berries/node.

Berries which fall to the ground between the catching plates of the machine represent a considerable loss in yield. Attempts to reduce this by changes in training methods were unsuccessful, but a treatment in which canes of the new cultivar Glen Isla were bowed-over and tied (instead of being tipped) produced a 39% increase in yield over the conventional training system. The crop from this treatment was also earlier.

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

Raspberry fruits increase in size as they ripen but these increases are not maintained throughout the life of the berry. Fruit of Malling Jewel tagged when it had just turned from green to orange started to lose weight 4 days later but the fruit of Glen Isla did not start to shrink until 10 days after tagging. Nevertheless, these changes in berry weight with ripening were insufficient to explain why machine harvested plots yielded less fruit than hand picked plots even when losses caused by removal of green berries and by fruit falling on the ground were taken into account.

Nine raspberry seedlings have been screened for fruit retention strength (FRS) in relation to stage of ripeness, and some have shown marked superiority to M. Jewel in their ease of detachment from their receptacles. The FRS is measured by a Correx tension gauge which does not simulate the action of the harvesting machine. Its value as a predictive tool will be assessed in 1975 when the seedlings will be large enough to be harvested by machine.

(D. T. Mason)

The effect of harvesting method, harvest timing and cultivar, on the total yield and the ripeness composition of the harvested fruit is being studied by statistical modelling techniques. Factors considered so far include the distribution of crop ripening over the season, losses due to ageing of unpicked fruit, losses of particular ripeness classes depending on the method of harvest (machine versus hand pick) and the harvest interval. The model is being used to see whether the reduction in yield on machine harvesting can be explained by existing information and whether it can be minimised by changing the harvesting technique.

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

#### 01040 Post-harvest handling of soft fruit

Several years' work have confirmed the feasibility of transporting small consignments of raspberries to the south of England using refrigerated transport. A local firm has this year successfully used liquid nitrogen cooled vehicles throughout the season and this project will therefore be held in abeyance unless problems arise because of new cultivars or physiological factors.

(D. T. Mason)

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

The final crop from the 1971 National Fruit Trial confirmed the strong interaction between cultivar and defoliation treatment reported last year. The Dutch cultivar, Tamella, gave very high yields, its main drawback being the rather tender fruit skin which may limit its use for some market outlets. None of the other seedlings in trial looked promising.

Yields from autumn-fruiting seedlings produced at the Institute were of the same order as those of the remontant cultivar Ostara. Mulching with transparent polythene sheet only marginally improved cropping.

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

#### 01012 Ecology of new fruit crops for Scotland

##### *Blackberry*

In the USA, the biennial cropping system, in which young cane is removed in alternate years, has given promising results on blackberries. Its merits

under Scottish conditions are being assessed for the cultivar Ashton Cross, and the first cane removal treatment was applied this year.

Some marked differences in ease of striking were found when a number of blackberry and loganberry cultivars were propagated from root cuttings. The erect N. American cultivar Darrow produces shoots readily, in contrast to Bedford Giant which establishes very poorly.

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

##### *Vaccinium species*

The percentage fruit set in highbush blueberry was poor this season, and so too was the amount of vegetative growth. This may reflect the low rainfall in the April-August period, which was 30% lower than the 15 year average, but in the case of fruit set there is also doubt as to whether the population of pollinating insects was adequate. The cultivar Ivanhoe gave the highest yield in the co-operative experiment organised by the International Society for Horticultural Science.

The first crop was harvested from the 1971 cultivar trial of cranberry, and the two best cultivars yielded at the rate of 3.5 ton/ac. Applications of peat have stimulated growth and yield in a soil amelioration experiment, but the effect is apparently not solely that of pH as its adjustment with sulphur has not produced the same increase in yield over control.

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

#### STATISTICS AND COMPUTING

#### 01042 Statistical studies in plant variation

Variation in components of yield in the strawberry was examined in order to identify sources of bias in sampling. Discrepancies between yields estimated from yield components and those actually obtained were mostly associated with a particular yield component, and a less subjective sampling technique was suggested. The bias was only revealed because all yield components were assessed, illustrating the importance of keeping sampling methods under review and avoiding derivation of the final yield component.

(P. B. Topham, M. R. Cormack)

Principal component analysis was used to investigate relationships among plant characters in a pea experiment involving three cultivars and four population densities. The vectors obtained could be divided into those which mainly reflected differences between cultivars and were not related to any measure of yield, showing little response to plant densities, and others, connected with yield, which were very responsive to plant density and which showed differences among the cultivars in this response.

(P. B. Topham, R. Thompson)

01043 *Computer applications to genetics and plant breeding*

A GENSTAT macro was written to estimate dominance and heterosis from generation means.

Planning is in progress for the construction of an empirical selection index for a cyclic single cross selection program in Brussels sprouts. Over 25 characters will be recorded, including dichotomous, qualitative and quantitative variables. It is desirable that some at least of the utility functions used should be non-linear and, because many of these must be based on subjective value judgments, it is important to alter them readily and to omit or include variables at will, in order to study the effect of such changes on the ratings obtained from known material.

(P. B. Topham)

01044 *Design and analyses of experiments (service)*

Advice or assistance was given to 38 members of staff. The topics covered included cluster analysis, growth curves, principal component analyses of yield components, the power law transformation applied to insect counts, the use of yield density relationships to calibrate the yield of barley and, for agronomic studies of yield in other crops, most probable number estimation of infective fungal spores, calibration of a neutron probe and probit analysis of bacterial decay and insect metamorphosis.

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

01045 *Use of computing facilities*

A system was developed in 1973 for editing jobs on Edinburgh Multiple Access System (EMAS) and submitting them to the IBM 370/158. The system has been rewritten in the IMP language, saving 50% of the time and cost and 85% of the paper output of the previous EMAS command language version. A facility has been developed for urgent GENSTAT jobs whereby the output from the IBM 370/158 is routed back to an EMAS file for fault checking. In conjunction with the syntax checker this should allow several turn rounds a day.

Results from raspberry machine harvesting experiments were analysed on the day that they were obtained, using the EMAS link and EDEX program; results were plotted on the Wang Programmable Desk calculator. The exercise made heavy demands on facilities but was worthwhile in an area with such a short experimental season.

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

Data collected by members of the Zoology section concerning the distribution of nematode species within the British Isles continues to be reduced into a form suitable for mapping at the Monkswood Biological Records Centre, and versions of the mapping program have been produced to deal with individual species, whole genera and site information.

The *Botrytis* bibliography has been enlarged and used to retrieve information on specific topics.

(P. B. Topham)

Members of staff registered as users of the ERCC now total 23. The number of computing jobs was 835, 4% less than in 1973, and of variates from designed experiments 9,006, 6% less; the proportion of jobs originating in different sections shows very minor changes.

Section	1973		1974	
	Jobs	%	Jobs	%
Crops Research	469	53.7	517	61.9
Plant Breeding	146	16.7	140	16.8
Mycology	93	10.7	86	10.3
Zoology	134	15.3	70	8.4
Virology	31	3.6	22	2.6

The number of GENSTAT jobs increased by 40% to 369. A welcome stabilization in the volume of data analysed will make the planning of future computing requirements much easier. Twelve programs were written for the Wang programmable desk calculator including five for general statistical use; whilst most users are content to use the programs provided, three members of staff write their own.

(P. B. Topham)

## Plant Breeding

C. NORTH

Two new projects have been added to the Section's programme, namely the breeding of calabrese and *Narcissus*. The breeding system of calabrese including the behaviour and distribution of S-alleles, will be studied as preliminary for the examination of various breeding methods. With *Narcissus* the first objective is to produce fertile artificial tetraploids from the sterile hybrids between the 7- and 10-chromosome types.

Work on both of these new projects will be done without additional staff that on calabrese, largely by phasing out the *Phaseolus* bean work, and on *Narcissus* by a reorientation of the *Rubus* programme now that Dr Dale has been appointed to work on that crop.

### 03001 *Strawberry: breeding and associated genetic studies*

Screening for resistance to *Phytophthora cactorum* by inoculating pot-grown plants in spring gave more clearly defined cultivar differences than when plants were inoculated in autumn or winter. These results correlated with the time of appearance of the disease in the field. The cultivars Crusader Marmion and Redgauntlet were highly susceptible but cv. Cambridge Favourite and two seedling selections from cv. Pocahontas and cv. Steelmaster showed some resistance.

Some early fruiting selections were compared when grown in a traditional method and in a maiden cropping system at high density on a ridge. This reduced the time from planting to fruiting from 16 to 11 months. One selection (66W23) reached 50% harvest 14 and 5 days earlier than Cambridge Favourite for the traditional and the maiden cropping systems respectively. It has a high resistance to red core, bright glossy fruit with red flesh and is similar to Cambridge Prizewinner in yield and time of maturity. The selection will be tested further before deciding whether to send it to the National Fruit Trials (NFT).

Five new selections were sent for inclusion in the NFT trials at Brogdale including one early maturing selection derived from cv. Glasa. Five selections, but not all of the above, have been included in a trial at Luddington Experimental Horticultural Station for evaluation of their suitability for machine harvesting. One (68AN78) has strong erect pedicels which tend to support the fruit clear of the ground and trials in 1974 confirmed that this feature should aid efficient machine harvesting.

A trial was carried out at SHRI Auchincruive to find whether it might be advantageous to hand-pick a crop before once-over mechanical harvesting. The results suggested that this procedure might well be advantageous especially if on a 'pick-your-own' basis. One of the seedlings included in this trial gave very promising results in jamming tests; it is earlier than Cambridge Favourite, red fleshed, and its fruits remain whole after boiling.

(H. J. Gooding, K. C. McConnell, R. J. McNicol)

Two autumn fruiting selections made at SHRI Mylnefield gave promising results there and at Brogdale, but were poor at Auchincruive probably because of their susceptibility to red core. One (7020/131) will be further tested together with 67NP137, a red core resistant selection from Auchincruive.

(H. J. Gooding, D. L. Jennings, R. J. McNicol)

### 03003 *Strawberry: breeding systems at different ploidy levels*

#### *Reciprocal recurrent selection programme*

Five selections from the 65G family were crossed with five selections from the 66AQ family. An analysis of the progenies has shown that 65G parents gave higher values for yield components, and one of the 65G individuals was an outstanding parent in this respect. The implication for practical plant breeding is that the large differences shown by individuals emphasise the need for carefully choosing individual combinations of parents, even from among closely related material.

(H. J. Gooding, Marjorie M. Morrison)

### 03006 *Raspberry: breeding and associated genetic studies*

#### *Breeding disease resistant raspberries*

One of the main objectives of the 1974 crossing programme was to combine the degree of fruit firmness considered essential for machine harvesting with improved fruit colour and fruit size. Derivatives of the Canadian cultivar Carnival were used as sources of good colour and derivatives of M31 as sources of large size. Another objective was to improve plant habit by using parents whose growth is very erect and only moderately vigorous. Improvement in this respect is important, because recent selections with excessive cane growth have been difficult to pick and have suffered unacceptable losses of canes during picking operations or through high winds.

Five new selections were submitted to the National Fruit Trials for inclusion in new trials at Brogdale and SHRI. Of these, two gave promising yields of good quality fruits in a SHRI trial harvested entirely by the Agricultural Sciences harvester, and a third gave a high yield but with an unacceptable content of green fruits; the other two were not tested.

In the study of fruit resistance to *Botrytis cinerea* a high correlation was found between fruit firmness and resistance, and thus good resistance was

obtained from parents selected for their exceptional fruit firmness. General combining ability accounted for nearly all the variation in resistance. Because the improvement of fruit firmness is an important breeding objective it is doubtful whether attention to *Botrytis* resistance *per se* will be necessary in future.

Preliminary screenings were made for resistance to *Fusarium avenaceum* among a large number of raspberry cultivars and selections. The presence or absence of necrotic lesions will be recorded early in 1975 on canes inoculated in July 1974.

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

#### *Genetic factors affecting yield in raspberries*

The study of the inheritance of 'multilaterals,' *i.e.* the capacity to develop more than one lateral per node, gave different results from those reported for 1973. The development of laterals was not affected by frost in 1974 and the incidence of multilaterals was consequently lower than in 1973. Although segregation occurred for individuals with high numbers of multilaterals, the differences between families in mean multilateral production were small and not significant, and there was no correlation between multilateral development and cane diameter. Because some of the progenies were hybrids of cv. Glen Clova, which has strong multilateral development, the result suggests that capacity to produce multilaterals tends to be recessive in inheritance.

A study was begun on fruiting-lateral variation in respect of the numbers of flowers and fruits present and their distribution along the lateral. Large differences, associated with particular parents, occurred in the capacity to develop more than one flower or fruit at a lateral node and strong development in this respect tended to be associated with the presence of a high number of flowering nodes.

In another investigation the changes in concentration of food reserves in canes and roots were studied for the period 11 September 1973 to 4 March 1974. There appeared to be a movement of food reserves from canes to roots in late November but the movement was not associated with dormancy changes and may have been induced by weather changes. A genotype with delayed dormancy and prolonged leaf retention had a relatively high December concentration of starch in the roots, but this was not associated with advantageous differences later. This study was interesting because it helps to explain the success of procedures being used to propagate raspberries from roots.

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

#### 03008 *Other berries*

##### *Breeding early, erect blackberries*

A further 29 progenies were raised to combine early ripening and improved growth habit. These included five progenies in which early ripening is being

transferred from tetraploid raspberries to tetraploid blackberries. Observations on parental material showed that there are two aspects to the problem of earliness: for example, the indigenous cv. Ashton Cross flowered late on 10 July and required only 48 days to ripen its fruits, whereas the American cultivar Darrow flowered early on 18 June and required 68 days. Early material is therefore being sought by combining the early flowering of types like Darrow with the rapid ripening of types like Ashton Cross. However, considerable emphasis is being placed on breeding for thorn-free cultivars, and it is unfortunate that the best source of this character has hitherto been cv. Thornfree, which is both late to flower and slow to ripen. It will therefore require several generations of breeding to combine all the characters being sought. New sources of germplasm are also being assessed, in particular the new thornfree American cultivars Dirksen's Thornless and Black Satin, which are earlier to ripen than Thornfree in the USA.

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

#### 03009 *Breeding black currant for northern regions of the UK*

The two selections 93/16 and 93/20 have now been granted Plant Breeders' Rights and named Ben Lomond and Ben Nevis respectively. Propagation is proceeding well and it is expected that 50,000 plants of the two cultivars will be available for distribution in autumn 1975.

The selection programme received a setback when many of the seedlings were inadvertently damaged by simazine residual in the soil. Some entire families were killed including interesting accessions of *Ribes hudsonianum* forms, but about 25 per cent of the material was salvaged and replanted. Furthermore, other material was affected by hormone spray drift; the flowers were damaged so that it was impossible to assess fruit quality.

New crosses were made to combine upright plant habit with good fruit quality using selections derived from *R. dikuscha*, *R. bracteosum*, *R. ussuriense*, *R. nigrum sibiricum*, *R. nigrum* x *R. grossularia* and a selection (N43/6) derived from *R. nigrum*, *R. dikuscha*, and *R. hudsonianum* which suffers little from fruit-drop. Some 20,000 seedlings from these crosses were planted in closely spaced nursery rows.

A late fruiting selection 7/189 sent to Brogdale in 1968 has performed well there though it has not been outstanding at SHRI. It flowers late, about 5 days later than cv. Malling Jet, but ripens 15 days before that cultivar. The fruit is large, of good quality and preliminary tests suggest that it is acceptable for processing. The bushes are productive but growth is rather vigorous for mechanical harvesting. However, this characteristic may be overcome by close spacing and could be useful on lower fertility soils. This selection is being propagated, and a decision on its release will be made within the next year.

(M. M. Anderson, J. Wardlaw)



03010 *Brassicac: genetics of S-allele incompatibility system in Brassica oleracea*

*Partial self-compatibility in B. oleracea*

Correlations between numbers of seeds per flower in bagged (selfed) and unbagged (open pollinated) inflorescences in two experiments were reported in the 1973 Annual Report. The results showed that differences in fertility between lines had obscured differences due to variation in self-incompatibility. Further analysis has shown that there was also a correlation between bagged and unbagged inflorescences in the number of seeds per fertile siliqua although there was none for the proportion of fertile siliqua per flower. The level of incompatibility of plants flowered in the field in these experiments is therefore probably best reflected by the proportion of fertile siliqua per flower.

To obtain data from a wider range of Brussels sprout material progenies from three experiments designed to study inheritance of partial self-compatibility were flowered in the field. Although originally designed as diallels, shortage of seed resulted in the experiments being grown as half diallels. Date of flowering and numbers of flowering sites, fertile and infertile siliquae and total seeds were recorded for self- and open-pollinated inflorescences. The results are now being analysed.

The amount of seed set on selfing open flowers is determined not only by the strength of the pollen/stigma incompatibility reaction but also by fertility factors affecting development of the gametophytes and the zygotes. Therefore, while incompatibility can be measured by pollen tube counts on selfing, this does not give a direct estimate of the likely proportion of selfed seed set on any plant which is open-pollinated in the field. To examine the ways in which these factors interact to affect inheritance studies, counts were made of pollen tubes and seed set on selfing and of seed set on outcrossing in  $F_1$ ,  $F_2$  and backcross progenies from three inbred lines. These were homozygous for S-allele  $S_{45}$  but differed in self-compatibility and fertility levels. Analysis of the data is in progress.

(J. R. T. Hodgkin)

*Analysis of incompatibility variation in S-allele homozygotes*

Plants differing in pedigree, but all homozygous for the recessive incompatibility allele  $S_5$ , were intercrossed in all combinations and the numbers of pollen tubes penetrating the stigmas counted. The source of pollen to stigma in any pollination explained from 40 to 60 per cent of the total variation observed; a further 10 to 30 per cent being interaction and the remainder between flower variation. The numbers of pollen tubes penetrating stigmas in any one plant was not correlated with tube numbers produced by that same plant as a pollen source. Pollen source was always more important than stigma source as a component of observed variation, indeed in one set of tests all the between plant variation could be accounted for as pollinator differences. Self pollinations were not significantly different from outcross

pollinations. Thus it appears that the ability of pollen from a particular plant to penetrate stigmas of other  $S_5S_5$  plants is independent of the capacity of that plant to permit stigma penetration by  $S_5$  pollen. Because earlier reports (Rept. Scottish Hort. Res. Inst. 1970; van Hal, unpublished) failed to reveal the relative importance of pollen source in determining strength of incompatibility, further investigations will be made. (J. R. T. Hodgkin)

03011 *Brussels sprout: breeding hybrid cultivars*

Nine experimental glossy  $F_1$  lines—two double glossy and seven single glossy hybrids—are being compared with three commercial  $F_1$  cultivars at the SHRI and the National Vegetable Research Station. Most of the experimental hybrids are at least as vigorous as the commercial cultivars and the sprout quality and yield of some of them is good. These trials have been demonstrated to members of the seed trade and it is hoped that the belief will have been dispelled that glossy hybrids are invariably weaker, less hardy and of poorer quality than 'non-glossy' hybrids. When harvesting is complete, it will be decided whether to demonstrate some of the glossy hybrids on a larger scale on commercial holdings.

Additional glossy parent lines are being developed to increase the range of S-alleles and agronomic qualities available. This is being done by a cyclic single cross selection system allowing for the maximum rate of inbreeding within the lines, together with selection based almost entirely on the characteristics of hybrid progenies.

(A. J. Redfern, C. North)

03012 *Cabbage: breeding hybrid cultivars*

To assist the National Seed Development Organisation to build up seed stocks, 1 acre of cv. Celtic Cross was grown for seed near the Institute. Much effort was expended in providing vermin protection, supporting the fruit plants and drying the crop under cover. Despite these efforts the seed yield was poor compared with that of a seed crop grown in 1973, largely due to inadequate insect pollination. Eight hives were placed in the crop at flowering time but the bees foraged elsewhere.

Seed production of the parents of cv. Celtic Cross by hand pollination gave a much larger yield of seed for the labour involved than in 1973. An experiment to compare seed yields under different treatments showed that the increase was due mainly to the plants being kept in a heated glasshouse at flowering time. Other treatments, including date of lifting, amount of trimming and fertilizer levels, had relatively little effect on seed yield.

Work was continued on the development of  $F_1$  cultivars similar to Celtic Cross using the parent lines in other crosses. Fifty inbred and hybrid lines were grown in the field and assessed for S-allele status and a similar number of new lines were produced for testing in 1975.

(A. J. Redfern, C. North)

03013 *Brassicac: isoenzyme analysis in Brassica oleracea*

*Electrophoretic techniques for detection of 'sibs' in Brassicac*

The application of polyacrylamide gel electrophoresis was extended to the separation of soluble proteins of seeds, cotyledons and first leaves.

Staining by Coomassie Blue G250 in methanol, water and acetic acid in the ratio 5:4:1, followed by electrophoretic de-staining, was found to give the most favourable resolution of soluble proteins from dry seed samples. Celtic Cross cabbage and its parent lines were used throughout the experiments. Distinct differences in the banding pattern could be detected between one parent line and the hybrid, whereas only differences in staining intensities distinguished the other parent from the hybrid. Seventeen different protein bands were identified.

Protein extracts were obtained from cotyledons and first leaves by grinding or crushing procedures followed by centrifugation to remove particulate matter. It was difficult to analyse the results because of the inadequate reproducibility of the banding pattern. It is recognised that the number of distinct bands seen in the gels is small in relation to the potential number of soluble proteins in the tissues. Various agents have been incorporated in the gel buffers to release components from protein complexes and to eliminate aggregation, but it is too early to make predictions about the usefulness of such treatments.

(Eveline M. Wiseman, Sheena K. Fyfe, A. B. Wills)

03014 *Brussels sprout: breeding hybrids from seed exchanged between SHRI and National Vegetable Research Station*

Seed stocks of one 'good combining' SHRI parent have been built up. This parent can now be used in combination with the best NVRS lines to assess the feasibility of hybrid production and to continue yield trials.

(J. R. T. Hodgkin)

03015 *Brassicac: genetics and cytology of Brassica oleracea*

*Major genes and linkage relationships*

Emphasis was again placed on work with genes expressed during seedling development, including the search for possible linkages among them, 14 genes being tested in 29 combinations. Polycotyledony occurred in a number of families, apparent monogenic segregations were observed in some, digenic in others, while in yet others the mode of inheritance was obscure. Linkage was detected between polycotyledony (po) and leaf excrescence (le) with a recombination of  $14.56 \pm 0.05\%$ . Further tests will be made to confirm these results. Preliminary results in an  $F_2$  suggest linkage between a glossy gene (gl-3) and an unidentified pale green gene (pg) with recombination of  $37.38 \pm 0.31\%$ . Confirmation of this result would extend linkage group VI

(c-2-Fn-gl-3). Linkage between pg-2 and hairy (Hr-1), previously reported by Sampson, was confirmed (recombination  $18.86 \pm 4.73\%$ ). No other linkages were apparent.

Association between pollen abortion and the S-locus in Brussels sprout material was reported from Unilever, Duiven. Seeds were kindly supplied to us and pollen fertilities and S-allele constitutions were determined in two segregating families. Appropriate backcrosses were made to further investigate the linkage.

Results from scoring families in the field for mature plant characters during 1974 are still undergoing analysis.

(A. B. Wills, P. Smith)

*Quantitative genetics*

A preliminary experiment showed heritable genetic variation in two seedling characters in an incomplete diallel cross of calabrese. Considerable inbreeding depression was measured in the first selfed generation. Problems encountered, especially in seed production, simultaneous character measurement and obtaining a uniform seedling environment, have been taken into account in designing the next experiment in which seedling and flowering characters will be measured.

(P. Smith, A. B. Wills)

03018 *Bulbs: breeding disease-resistant lily cultivars*

Five new cultivars named Adonis (232/1), Ariadne (230/13), Minos (102/1), Odysseus (83/1) and Orestos (142/1) are now being propagated under licence and may be commercially available in the autumn of 1976. Ariadne received a Royal Horticultural Society (RHS) Preliminary Commendation. Adonis received an RHS Award of Merit and was the subject of the award of the Reginald Cory Memorial Cup. Another cultivar Orpheus was also granted the Award of Merit, but insufficient material was available for commercial propagation.

Six other clones have been multiplied with a view to release as new cultivars in 1976. Two of them are derived from crossing plants of the 230 family *L. lankongense* x *dauidii* with 'Asiatic hybrid' cultivars. They are similar in coloration and scent to the first *L. lankongense* hybrids but the flowers are considerably larger. Some 350 other seedlings of crosses of this type are expected to flower for the first time in 1975.

(C. North, Barbara M. M. Tulloch)

03020 *Bulbs: breeding basic material of Narcissus for further selection*

The primary objective of this new project is to produce fertile allotetraploid forms from cultivars of the 'Poetaz' section *N. poeticus* (n=7) x *N. tazetta* (n=10). The two parent species combine resistance to several important viruses and differ in their chilling requirements, but hybrids between them are



- Habit:* Moderately vigorous, forming medium-sized bushes at maturity. Branches fairly upright but tending to spread outwards with the weight of the fruit.
- Fruit:* Berries of both cultivars are large with fairly thick tough skin and ripen uniformly on the strig. Both are suitable for jam production and present indications are that Ben Lomond and possibly Ben Nevis are acceptable for juice processing.
- Season:* Both cultivars commence flowering and ripen their fruit a few days before Baldwin.
- Productivity:* Generally more productive than Baldwin.
- Disease:* Both cultivars are moderately resistant to American Gooseberry mildew but not to leaf spot, gall mite or reversal disease.

## Mycology

R. A. FOX

Of particular interest during the year were observations by J. M. Duncan on the germination of oospores of the strawberry red core fungus *Phytophthora fragariae*. This is only the second occasion since the fungus was first described that germination has been seen, the previous observations also being by a member of the Section, Isabel G. Montgomerie. A defined synthetic medium has been developed on which this pathogen will grow to sexual maturity.

Another useful technical advance is the production of a semi-selective medium which allows enumeration of the potato gangrene pathogen *Phoma exigua* var *foveata* within 6-7 days of plating soil samples. The use of this medium during the last growing season enabled us to confirm previous predictions that inoculum in the soil increases through the growing season and, in particular, that it increases subsequent to haulm destruction.

An exciting technical development has resulted from co-operation between B. Williamson with I. M. Roberts of the Virology Section which should allow integrated observations and complementary studies on the same material using both histo- and cyto-chemical techniques of light microscopy with those of electron microscopy.

### SOIL MICROBIOLOGY AND ROOT DISEASE

#### 02017 *Biology of potato gangrene*

At weekly intervals, from late July until mid-October, stems were taken from plants of cv. Pentland Crown grown in the field from seed tubers artificially infected with *Phoma exigua* var *foveata*. The results of isolations made from tissues of surface disinfected stems, sampled both above and below ground level, showed that they were unlikely to be a common source of infection to tubers that were harvested at intervals during the growing season. In contrast, many of the seed tubers had only partly rotted, perhaps because of dry soil conditions, and most had extensive gangrene lesions with pycnidia in and on them.

Continuing histological studies have still failed to show how the fungus moves from infected seed tubers into stems. In both normal sprouts, and in those kept in the dark and devoid of chlorophyll, vertical spread of the fungus

into the stem has not yet been detected more than 10 mm beyond the tuber-sprout transition zone although it may be traced in stolons and, later, it may also be isolated from mature stems in the field.

In further studies on stem susceptibility, four cultivars were planted in blocks within which plots were randomised for cultivars and then split for date of inoculation. Stems, one per plant, were inoculated at one internode in mid-July and stems of other plants in mid-August. The lesions, examined 2, 4, 6 and 8 weeks after the first inoculation, showed that stems of cv. Majestic were the most susceptible, followed in order by those of the cultivars Pentland Crown, Pentland Falcon and Golden Wonder. Infection developed slowly in all cultivars and secondary lesions were not evident until the last examination. The order of cultivar susceptibility was the same following the second inoculation but, in contrast, lesion development was so rapid that by the second examination the spread of secondary lesions had so advanced senescence that further examination was prevented.

Evidence for the effects of soil temperature on host-pathogen interactions was sought by growing potatoes in pots in a glasshouse at temperature ranges of 8–36°C, 9–24°C and 12–14°C. These regimes greatly affected the rate of plant growth, tuber susceptibility, maturity and periderm structure at the time of harvest. The first regime gave the lowest figures for both periderm and soil isolations of the fungus and for lesion development on tubers given standard wounds, the highest figures being from the second, intermediate regime and not, as expected, from the lowest temperature range.

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

#### 02024 Autecology of the strawberry red core fungus

Systematic soil sampling on an 8 m grid was done in June 1973 on a field adjacent to the original red core infested screening field at Auchincruive. No infection was recorded when these samples were baited in the glasshouse with runners of *Fragaria vesca* clone V51, nor was it detected in October 1973 in the runners of bait plants which had been planted in June in the field at the points where the soil samples had been taken. However, by February 1974, 12% of the plants were infected. Their distribution clearly showed that inoculum had been brought into the field at the only point of entry—a gate leading from the old screening field. Thereafter the spread, following the lines of natural drainage in the field, had probably been enhanced by the wet weather in the winter of 1973–74. In two sites at Mylnefield, red core was not detected by soil sampling and subsequent baiting before planting with field experiments. After 1 year, however, the plants on one site had become infected only along that edge of the experiment immediately adjacent to a red core site. All these sites are now being used to study the epidemiology of the disease.

The Most Probable Number approach for assessing soil populations of *P. fragariae* has been developed further and, to assess its sensitivity, bait

plants were inoculated with different numbers of zoospores. Under the conditions of the glasshouse test, 3–8 zoospores were equivalent to one 'infective unit' of inoculum as detected by the MPN procedure.

Infected strawberry roots containing oospores were comminuted in a blender and mixed with field soil which was packed into 150 mm lengths of plastic drainpipe (I.D. 100 mm) which were then buried vertically with the rim level with the field soil. Other infected roots, not comminuted, were buried in the field and samples, which were recovered at intervals, were washed, teased apart in distilled water and incubated at 20°C for 48 h before being examined for oospore germination. None was recorded at the time of burial, or at 2 weeks, 1, 2, 8 and 12 months after burial, and large numbers of oospores were found unaltered in appearance even after a year. However, in the sample taken after 4 months, germination was observed by way of a stalked sporangium which released 8–14 zoospores within 1–2 h after detection. The level of germination was low, only six sporangia being seen to develop from upwards of 4,000 oospores which were examined. The level of inoculum in samples taken from the drain pipes at the same time as the whole root samples, was assessed by means of the MPN analysis. The highest levels of infection in the bait plants were recorded in samples recovered after 2 and 4 months in the field.

(J. M. Duncan)

#### 02006 Autecology of a raspberry wilt pathogen

Flooding and high soil moisture levels have long been known to have an adverse effect on populations of some *Fusarium* spp. in soil. The use of a standard soil dilution technique showed that viable counts of resting spores of *F. avenaceum* were reduced to about 2% of the original count when high soil moisture levels of about 75% of maximum water holding capacity (MWHC) were maintained for 14 days. Flooding soil for 14 days did not eradicate the resting spores but when macroconidia were subjected to the same treatments, 14 days flooding reduced the populations to levels too low to be detected on dilution plates, although both macroconidia and resting spores could just be detected after being in soil held at 80% MWHC.

Resting spores were mixed into a field soil which in turn was mixed with soil samples pre-treated to give final pH levels in the range pH 3–11. After 14 days the viable count showed that some spores survived even the extremes whilst the survival curve showed maxima at pH 4 and pH 7.

(A. J. Hargreaves)

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

##### *Diseases of peas*

*Ascochyta pinodella* was the dominant fungus isolated from two outbreaks of foot rot in Angus. When peas were inoculated by placing above seeds sown in pots, about 2 cm<sup>3</sup> dried sieved soil or dried pulverised diseased stem

and roots from the site of the outbreaks, typical lesions developed on all seedlings which emerged. The lesions were more severe and caused some mortality following inoculation with the plant material.

Extensive infection of pods by *Peronospora pisi* was also noted but inoculations with dried pulverised diseased pods, as described above, were unsuccessful.

(D. A. Perry, J. G. Harrison)

#### 02010 Seed quality-soil interactions and their effects on seedling growth

Samples of five deteriorated barley seed lots and a control were sown in double row plots 1.5 m long and 0.3 m apart on 25 February, 28 March and 25 April into untreated seed beds and into soil maintained at field capacity with a trickle irrigation system. Emergence of deteriorated seed was more adversely affected by early sowing and the wet seed bed than control seed, and the effects persisted to influence final yield. The same seed lots were sown on 25 March to obtain five similar population density ranges. At low populations, plants from non-deteriorated seed produced substantially more grain than at high populations, mainly through an increase in the number of ears, while plants from deteriorated seed were less able to compensate because they produced fewer ears at the low populations.

Emergence from moderately, slightly and non-deteriorated seed showed small significant improvements ( $P=0.5$ ) of 5 and 6% following treatment with two mercury based fungicides but was not improved by two non-mercurial substitutes. Highly significant differences between the seed lots remained irrespective of treatment and there were no significant interactions.

(J. G. Harrison, D. A. Perry)

#### 02025 Rhizosphere and allied phenomena affecting plant health

##### *Potato gangrene*

A major hindrance to investigations on the biology of potato gangrene has been the difficulty of quantifying soil populations of the pathogen. Baiting techniques, more refined than those used elsewhere, are still relatively insensitive and time consuming taking from 3-5 weeks or more to read and then requiring further culturing *in vitro* to ensure distinction between the primary pathogen *P. exigua* var *foveata* and its common relative the var *exigua*. A semi-selective medium has now been developed on which, after only 6-7 days, colonies of the var *foveata* can readily be distinguished by their intense yellow pigmentation. It has been used to follow changes at weekly intervals during the growing season of tubersphere and tuberplane populations by plating soil or periderm samples. There were greater fluctuations in the tubersphere than in the tuberplane populations but it is possible to explain the gangrene incidence which developed during storage by relating tuber susceptibility, determined at the time of harvest, with the variations in these populations.

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

##### *Red core of strawberry*

Bacteria and fungi antagonistic to *P. fragariae* have been isolated from an alkaline soil (see Project 02004) in which the disease is suppressed, as well as from acid soils. Further analysis and screening may clarify the role played by such organisms in the suppressive effect demonstrated in the alkaline soil which might eventually lead to the formulation of a method of biological control for this disease.

(J. M. Duncan)

#### PLANT AND PATHOGEN PHYSIOLOGY

#### 02018 Diseases of potato tubers

##### *Bacterial soft rot*

The growth rate of *Erwinia carotovora* var *carotovora* in potato tuber tissue under aerobic and anaerobic conditions was significantly greater than that of *E. carotovora* var *atroseptica* at both 15° and 20°C but only slightly greater at <10°C. Because var *atroseptica* usually occurs in greater numbers than var *carotovora* and because most stocks in Scotland are stored at <10°C, it is not surprising that the variety most frequently associated with soft rot is var *atroseptica*, the blackleg pathogen.

(M. C. M. Pérombelon, R. Lowe)

#### 02015 Disorders of vegetables

##### *Cavity spot of carrots*

Characteristic lesions of the disorder formed on roots when the pots in which they were growing at 20°C stood in saucers of water and the soil surface was sealed with wax for 5 days. No symptoms developed when pots were either only sealed or only waterlogged, or in untreated controls.

Field observations in England and Scotland confirmed the association of the disorder with structureless sandy or peat soils.

(D. A. Perry, J. G. Harrison)

#### 02012 Seed quality, causes of its variation and its effect on yield

##### *Causes of barley seed deterioration*

Barley seed cv. Golden Promise was stored for 21 weeks at 13.7, 15.8, 17.9, 19.8, 22.5 and 25.5% moisture contents in sealed polyethylene bags at room temperature and sampled every 3 weeks. Germination and vigour was constant at 13.7% moisture content and declined most rapidly at the highest moisture content. Seeds from every sample were dehusked, surface sterilised and plated on malt-extract agar (MEA), and seeds with husks were plated on malt-extract agar supplemented with 10% NaCl (MSA). At 13.7% moisture content the percentage of infected seeds declined with time and the dominant

fungus growing on MEA was *Alternaria alternata*. The decline of germination and vigour at 15.8% and 17.9% was slow and accompanied by extensive proliferation of *Aspergillus repens* which grew only on MSA, while it was more rapid at 19.8% and 22.5% when *Penicillium* spp. dominated the fungus flora on both MEA and MSA. All seeds were dead after 6 weeks at 25.5% moisture content and were completely colonized by *Fusarium culmorum*. The extent of colonization of embryos and endosperms estimated by plating either suspensions of ground seeds or cut pieces of imbibed seeds was, in general, thought to be insufficient to account for the loss of viability observed. The germination of healthy seeds was unaffected after being allowed to imbibe in aqueous extracts of severely deteriorated lots in which each of the fungi mentioned above were dominant.

Oxygen uptake of dehusked seed 18–20 h after the start of imbibition declined as seed deteriorated and correlated well ( $r=0.96$ ) with seedling growth from seeds after 4 days at 24°C. Diastase activity, as indicated by the diameter of clear plaques produced by seed halves in corn-meal agar, was less in deteriorated than in non-deteriorated seed. A significant negative correlation ( $r=-0.90$ ) was found between uptake of barium chloride and seedling vigour in twelve lots at various stages of deterioration and suggested that membrane integrity was affected during deterioration. The respiration rate of separated endosperms and embryos from deteriorated seeds were equally depressed and colorimetric estimation of tri-phenyl tetrazolium chloride reduction products indicated that dehydrogenase activities of embryo and endosperm were similarly affected by the deterioration process. However, reciprocal transplants of embryos on endosperms from deteriorated and non-deteriorated seed showed that seedling vigour was determined by the condition of the embryo.

Evidence from these studies indicated that seed deterioration within the range of conditions used was primarily a physiological process which was accompanied by fungal infestation.

(D. A. Perry, J. G. Harrison)

#### 02027 Studies of plant pathogens

##### *Variations in Phoma exigua var foveata*

Some isolates of the var *foveata* become unstable if cultured on simple mineral salts-sugar media, the mycelium becoming translucent and non-viable. However, sometimes in the course of routine isolations near-translucent stable colonies are obtained which are notably flat and in 4–5 days become densely covered in pycnidia which are thin walled, apparently lack a stroma, and produce smaller than normal pycnosporangia. The colonies produce in culture the yellow pigments and crystals characteristic of the var *foveata* and inocula from them induce characteristic lesions in tubers from which the fungus can readily be re-isolated.

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

#### 02003 Shoot disorders of cane and bush fruits

##### *Cane diseases of raspberry*

There are differences in the symptoms and severity of cane diseases when comparisons are made between Scotland and southern England, southern Ireland and much of Europe. Techniques were therefore developed for inoculating raspberry canes with fungi considered to cause specific cane diseases. Typical symptoms of spur blight (*Didymella applanata*), cane botrytis (*Botrytis cinerea*) and cane spot (*Elsinoe veneta*) were produced on plants both in the field and in the glasshouse.

In canes damaged by machine harvesting the vascular tissue often develops extensive browning during winter in the manner described for and similar to that ascribed to the 'die-back' or 'bud death and lateral wilt' syndrome. Large numbers of pycnidial fungi were isolated from such lesions and the most numerous isolates were assigned to *Leptosphaeria coniothyrium* the organism usually considered to cause cane blight. The symptoms of 'bud death and lateral wilt' in Scotland differ, however, from cane blight as prevalent elsewhere in Europe and S.E. England. The biology of *L. coniothyrium* and its relationship with mechanical injury and cane midge (*Thomasiniana theobaldii*) infestation is now being studied intensively. Inoculations of canes with *Fusarium avenaceum* previously causally associated with 'bud failure and lateral wilt' have not produced the characteristic vascular lesions.

(B. Williamson, A. J. Hargreaves)

In contrast to 1973, cane gall incidence in 1974 in cv. Glen Clova was very low, perhaps related to the absence of the widespread injury as was caused by late frosts in 1973. In a 4-year-old plantation of cv. Glen Clova at SHRI where 100% of the stools showed symptoms in 1973, the disease level in 1974 was less than 15%. Moreover, the galls when present were small, about 5 mm in diameter. Cane gall symptoms as severe as those found in 1973 were, however, noted on two seedlings and on some black currant varieties at SHRI.

(M. C. M. Pérombelon, R. Lowe)

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

##### *Factors affecting the development of blackleg*

The level of blackleg in commercial seed stocks in Scotland in 1974 was very low as was the disease incidence in experimental crops even when grown from seed heavily inoculated with the pathogen. No significant results were therefore obtained from field experiments which involved enumeration of

blackleg affected plants. Moreover, the pattern of daughter tuber contamination by *E. carotovora* differed from that found previously. The soil in the tuber zone had a water deficit throughout early summer until the end of August. Breakdown of the mother tuber was delayed and transmission of the bacteria from it to the daughter tubers through the soil was restricted. The incidence of progeny tuber contamination was therefore low and when it did occur *E. carotovora* var *carotovora* predominated. Although the levels of *E. carotovora* var *atroseptica* increased in October the ratio of the former to the latter variety was never less than 1.

The incidence of blackleg in plants of cv. Majestic grown in pots in the glasshouse was higher in wet than in dry soil and when ambient temperature was low (ca. 17°C) rather than when it was high (ca. 25°C). These findings are in broad agreement with the general experience that the disease incidence is greater when the soil is wet and cold.

(M. C. M. Pérombelon, R. Lowe)

#### *Contamination of VTSC stocks by the blackleg and other soft rot bacteria*

The survey in 1973-74 of VTSC stocks being commercially multiplied was repeated in 1974-75. In contrast to the widespread contamination which was found before in most stocks in the third and later years of multiplication, the incidence this season was considerably less both within and between stocks. Stocks which were heavily contaminated in 1973-74 were frequently apparently clean when examined in 1974-75. Varietal identification showed that *E. carotovora* var *carotovora* predominated this season in stocks of all ages in contrast to the changing ratios of var *atroseptica* to var *carotovora* reported last year. These results are in agreement with those noted above for field experiments at SHRI and tentatively might also be interpreted in terms of soil water deficit and late breakdown of mother tubers.

Preliminary results using serological techniques and growth inhibition by colicines (carotovocines) to type isolates of *E. carotovora* obtained from stocks grown in 1973 and in 1974 suggested that the isolates were apparently similar with any one stock in a given year but differed from year to year and from one stock to another.

(M. C. M. Pérombelon, R. Lowe)

#### *Persistence and distribution of potato gangrene*

The potential origin of new outbreaks of disease from wind-distributed inocula in infested dead potato haulm has been noted before (Rept. Scottish Hort. Res. Inst. 1973, 55). Mature spore-free pycnidia of *P. exigua* var *foveata* were examined from a range of substrates—cultures, haulm and tuber debris and soil and of varying ages up to 5 years. After various disinfection treatments, pycnidia and pycnidial fragments were held in conditions conducive to growth and examined microscopically over a 4 week period. Whole pycnidia and pycnidial fragments were often viable giving rise either to 2-3 pycnosporium-like cells by budding or germinating to form thick

walled mycelium. Previously, individual cells of thick walled resting mycelium have been observed to be viable, growth being initiated by very fine 'germ tubes' one fifth or less of the diameter of the parent cell.

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

#### 02005 *Analysis of and screening for resistance to diseases of soft fruit*

##### *Red core of strawberry*

When resistance was assessed by the per cent number and length of roots diseased by *P. fragariae*, significant differences between genotypes and standard cultivars were not always consistent, despite using a controlled environment and standardized inocula derived from one zoospore. Additional variates (plant volume, the number of leaves and of roots, and the total length of healthy root) were measured on inoculated and uninoculated paired plants of each of three genotypes and a standard cultivar. The host/inoculum interaction was significant within each pair only with the variates, total length of healthy root and per cent number and length of diseased roots, but differences between genotypes and the standard cultivar were not any more consistent using the former, new variate.

The procedures used in these experiments have given a higher level of reproducibility than other techniques for the assessment of resistance of standard cultivars and for their ranking order. The variability noted above is relatively unimportant when very high or very low levels of resistance are present and it is these which are the important groups when predicting the performance in commerce of breeders' advanced selections and when screening for sources of high levels of resistance. Most of the information so far obtained relates to host resistance to a race of the fungus which appears able to infect all genotypes. More data is now needed on levels of resistance to other races and, as a preliminary, other isolates were re-tested for their pathogenicity to differential cultivars. The pathogenicity of isolates characteristic of five physiologic races was the same as when tested several years ago, but a number of others showed a loss of pathogenicity which was not related to their sporulating ability.

The apparent variability in the resistance of some genotypes between replicate experiments did not seem to be associated with evident differences in the host or the environment. Therefore, possible variations in virulence of the pathogen are being investigated which may also have some relevance to the loss of pathogenicity of some isolates to differential cultivars.

(Isabel G. Montgomerie, Diana M. Kennedy)

##### *Stamen blight of raspberry*

A simple inoculation procedure for assessing the possible field resistance of new cultivars and genotypes gave promising results. Of four genotypes, with different combinations of the characters for hairy and spiny stems, the only one to become infected by *Hapalosphaeria deformans* was without hairs or



spines. Future modifications which are indicated include increasing the initial inoculum and prolonging exposure to infection.

Using the standard inoculation procedure, infection was recorded for the first time in cv. Malling Admiral.

(Isabel G. Montgomerie, Diana M. Kennedy)

#### PLANT PROTECTION

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

###### *Chemical control of raspberry cane diseases*

An autumn assessment of the fungicide trial started in 1973 showed that certain fungicides produced significant reductions in the incidence of cane disease (Rept. Scottish Hort. Res. Inst. 1973, 50). However, no significant reductions in the levels of cane disease were found with any fungicide treatment in a spring assessment. The difference between these results is probably due to the pruning out of diseased cane by farm staff between the two assessments. The rather low incidence of cane disease in plots produced variation between replicates and within blocks too large for meaningful analysis. The fungicide treatments produced no significant effect on yield in 1974.

The recognition of the symptoms of spur blight (*D. applanata*) on leaves in September before nodes became infected suggested that premature defoliation may aid disease control when infection occurs late in the season. A leaf excision experiment was started in 1974 to test this hypothesis.

(B. Williamson, A. J. Hargreaves)

###### *Economic importance of raspberry bud failure*

Bud failure is associated to some degree with most cane disorders but the threshold value above which the yield may be substantially reduced by bud failure is unknown. Bud failure may not necessarily lead to reductions in yield if other buds in the plant become more productive. The possibility that compensation within a cane may occur following excision during winter of buds from the mid-cane portion was tested in 1974. It was found that more buds in the lower portion of the cane produced fruit when large numbers of buds were excised from the mid cane. The experiment was conducted on mature field plants transplanted to large pots during winter but the growth of these plants was unsatisfactory and some canes wilted. The experiment is being repeated on a field scale in 1975 when compensation within whole plants will also be considered.

(B. Williamson, A. J. Hargreaves, D. T. Mason<sup>1</sup>)

<sup>1</sup>Crops Research Section.

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

###### *Chemical and cultural control*

In pot tests with cv. Redgauntlet, the fungicide prothiocarb did not decrease disease levels when used either as a drench or as a preplant dip 2 days before inoculation with *P. fragariae*. All treated plants, however, were more vigorous than the checks. Prothiocarb was therefore included with the fungicides captafol, chloraniformethan, dichlofluanid, dinocap, dithianon, etridiazol, folpet, R22395 and R45173 (Plant Protection) in two field trials planted with cv. Merton Princess. All fungicides were applied as a single soil drench in July to one trial and in August to the other. The level of disease was high in all untreated plots, approaching 100 per cent at one site, and none of the fungicides achieved a significant degree of control.

The disease levels did not differ in young runner plants of cv. Cambridge Favourite growing in soil-less composts of different pH over the range pH 4.5 to 8.8 and there was no interaction of pH with the three types of inoculum used; zoospores, oospores and mycelial discs. A sample of alkaline soil (pH 7.7), supplied by ADAS, Wye, was examined for evidence of a suppressive effect on disease development, using Universal Compost (pH 6.6) and an acid soil (pH 4.8) as standards for comparison; samples of the alkaline and acid soils were also autoclaved for 30 min before testing. Young runner plants of *Fragaria vesca*, clone V51, were rooted into the five types of growing media and subsequently inoculated with either zoospores, mycelial discs or oospores. The percent of diseased roots by number and of diseased root length in plants growing in the unautoclaved alkaline soil were significantly less than in any of the other treatments. There was no interaction of growing media with type of inoculum.

(Isabel G. Montgomerie, Diana M. Kennedy)

##### 02016 Chemical and cultural control of potato gangrene

Various field experiments to determine the effects of the timing and method of haulm destruction and intervals to harvest on the incidence of gangrene in stored tubers over the period 1967-73, showed that all within year effects were by no means always significant nor between year effects always consistent. However, in general, there were trends for consistent benefits from the results of haulm destruction early rather than late and of short intervals to harvest rather than the long intervals always advocated to avoid the supposed adverse effect of damage to immature periderms by the harvesting operation. The 1974 experiments were striking in that when the stored tubers were examined in February nearly all the results showed trends in reverse, although predictions from the results of tubersphere and tuber-plane isolations of *P. exigua* var *foveata* anticipated results confirming previous years.

Those tubers which appeared healthy were retained in store and provided a notable example of latent disease and differential host pathogen interaction when re-examined at the end of April. The results then were in accord with previous years thus virtually reversing the situation observed only 10 weeks earlier. These observations, however, can still be explained by postulating interactions of inoculum potential and tuber susceptibility.

Some of the results of an experiment on different methods of haulm destruction were also not consistent with previous years when examined in relation to timing, but the experiment did continue to demonstrate the validity of one generalisation, namely that higher levels of infection in stored tubers are associated with treatments that allow the haulm to die slowly. In this experiment remarkable differences in disease incidence, which progressively increased from block to block from the lowest to the highest part of the site, nearly doubling over a distance of only ca. 65 m, were associated with initially unsuspected minor variations in soil texture.

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

#### PHYTOPATHOLOGICAL METHODS

##### 02021 *Immunofluorescent and fluorescent techniques in histology*

Several attempts to raise antisera against *P. exigua* var *foveata* over a 3 year period have proved unsuccessful because the titres were negative or too low to be of value. Thirty 6-day inoculation schedules were started and the rabbits were bled at 4 and 6 weeks but without success. The inoculated animals were then left to rest for 19 months and subsequent bleeds indicated some enhancement but only to low titres of about 1:16. The sera had a broad spectrum but absorption against the related var *exigua* and *Phoma eupyrena*, dialysis to concentrate the antibodies, and then their utilization in the indirect fluorescent antibody antigen technique, allowed some success in detecting the var *foveata* in both *in vivo* and *in vitro* specimens. In contrast, no precipitin reaction occurred in double gel diffusion studies either against var *foveata* or var *exigua*.

Attempts to detect the var *foveata* in infected specimens using conventional transmitted light fluorescence microscopy were not successful. Narrow band interference filters with reflected light fluorescence showed that specimens of low fluorescent intensity could be examined without counterstaining for autofluorescence of host tissues.

(H. M. Wilson)

##### 02020 *Development of histological and histochemical techniques*

A technique is being developed in which an alkali-halogen solution efficiently removes the supporting epoxy resins from thin sections. Post-fixation in osmium is omitted and some specific histochemical techniques

have been successfully used on such sections, e.g. carbohydrate-periodic acid-Schiff; starch-Lugol's iodine; protein-naphthalene black 12B; lignin-phloroglucinol-HCl. The method should find wide application allowing histo- and cyto-chemical techniques of light microscopy and those of electron microscopy to become complementary.

(B. Williamson, I. M. Roberts<sup>1</sup>)

##### M42 *Plant, pathogen and soil analytical techniques*

An index of analytical methods for the rapid routine analysis of plant and soil material is being prepared.

In co-operation with Grant Ltd. (Toft, Cambridge), a converter has been developed to adapt Hg-battery operated Grant recorders for use with rechargeable Ni-Cd batteries and an adaptor providing circuit modifications to these multi-channel recorders enables them to accept inputs from Cu-Constantan thermocouples. A modified Severinghaus's semi-micro CO<sub>2</sub> electrode is being developed for monitoring P<sub>CO<sub>2</sub></sub> in soil and in plant tissues.

(J.G. Harrison, R. Lowe)

Accurate measurements of the size of potato gangrene lesions, as affected by the interactions of host, pathogen and environment, are very time consuming and it was initially thought necessary to cut tubers and make measurements in three dimensions to obtain approximations of lesion volumes calculated as prolate spheroids. Further examination showed that when using samples of 20 or more tubers, no significant differences were introduced when comparisons were made between samples, if measurements were restricted to the length and breadth of a lesion to obtain an approximation of its surface area. It is relevant that superficial assessment is the determinant for both growers and inspectorate staff. A rapid technique has now been developed in which the outlines of lesions are formed into silhouettes on transparent film and their areas then measured by scanning them with an area integrator.

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

<sup>1</sup>Virology Section.

## Virology

B. D. HARRISON

The absence overseas of two members of staff for much of the year and the arrival of four visiting workers has resulted in shifts of emphasis within some lines of research. Among the more noteworthy results obtained during the year are findings about the way in which tobacco rattle virus infects and multiplies in plant protoplasts; evidence that the particles of a semi-persistent virus are held in a specific part of virus-carrying aphids; indications that narcissus tip necrosis, a newly discovered virus, occurs widely and has affinities with tombusviruses; and further steps in separating and differentiating between the several aphid-borne latent viruses that infect raspberry.

The Section's work will be helped by the availability of the new low temperature laboratory, which became operational towards the year's end and by the modernisations made to some existing laboratories.

### TOBRAVIRUSES

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

##### *Production and infection of tobacco protoplasts*

Protoplasts have potential advantages over intact leaf tissue, in studies of virus infection and multiplication, because a large proportion of cells can be infected and infection should be synchronous. Last year we reported that tobacco mesophyll protoplasts could be infected with tobacco rattle virus. Two major improvements in technique have now been found that greatly increase both the proportion of protoplasts infected and the reproducibility of experiments. First, an artificial environment was defined in which tobacco plants, cv. Xanthi, can be grown as a reliable source of readily infectible protoplasts, a finding of particular value for laboratories where the natural environment is as variable as at Dundee. The best conditions were illumination of 10,000 lux at 25°C for 12 h per day followed by darkness at 20°C for 12 h. Increasing the photoperiod to 15 h or the light intensity to 20,000 lux decreased the proportion of protoplasts that became infected, and decreasing the photoperiod to 10 h increased the fragility of the protoplasts. In midwinter, plants grown in the defined environment were better sources of infectible protoplasts than plants grown under supplementary lighting in a glasshouse at 18–26°C. Plants grown in the glasshouse at lower tempera-

tures without extra light were poor sources of protoplasts, few of which could be infected.

The second improvement is the substitution of phosphate buffer of pH 6.0 for citrate in the inoculation medium. The optimum concentration, 0.025 M, increased infection to the same extent as a 25–50 fold increase in inoculum virus concentration. When added to the inoculum, phosphate enhanced the infection of protoplasts from leaves of four different ages but it was not effective when present only immediately before or after inoculation. Using inocula containing 1 µg poly-L-ornithine/ml, plus 0.2 µg virus/ml and 0.025 M phosphate, pH 6.0, and incubating the mixture for at least 10 min before inoculation, more than 95% of live protoplasts from defined environment plants were infected.

(S. Kubo, B. D. Harrison, D. J. Robinson)

##### *The multiplication cycle of tobacco rattle virus*

In tobacco protoplasts kept at 22°C after inoculation, about half the yield of infective particles of strain CAM was produced during the first day and almost all the remainder during the second. The final yield was about  $2 \times 10^5$  long virus particles and  $6 \times 10^5$  short particles per infected protoplast. Fluorescent antibody staining showed that virus particle antigen accumulated throughout the cytoplasm but electron micrographs of thin sections indicated that whereas the short particles were generally dispersed in the cytoplasm, the long particles were associated with mitochondria. More detailed experiments with protoplasts kept at 25°C after inoculation revealed that infective RNA increased 2 h or more before infective nucleoprotein particles and had nearly attained its peak concentration by 11 h. By contrast, infective virus particles increased about 40-fold between 11 and 13 h, and the increase curve was similar to the curves for particle antigen concentration and for percentage protoplasts stained with fluorescent antibody to virus particles. Infective RNA was also produced in protoplasts inoculated with long virus particles, but virus particle antigen, and long and short virus particles, were made only in protoplasts inoculated with both kinds of particle; infection was not detected after inoculation of short particles alone.

(S. Kubo, B. D. Harrison, D. J. Robinson)

At 22°C, two temperature-sensitive mutants (N8 and N10) of strain CAM multiplied in protoplasts to the same extent as wild-type CAM. However at 30°C, yields of infective virus relative to those at 22°C were 1% for N8, 0.3% for N10 and 28% for CAM. Yields of infective RNA were proportional to those of virus. The expression of temperature sensitivity in tobacco protoplasts therefore parallels that in intact *Chenopodium amaranticolor* and tobacco leaves. Attempts to detect complementation in protoplasts simultaneously inoculated with both mutants were unsuccessful.

(D. J. Robinson, S. Kubo)

04002 *Viruses with nematode vectors and/or multipartite genomes**Recovery of plants infected with raspberry ringspot virus*

Nepoviruses typically induce severe symptoms in the first leaves to be infected systemically whereas leaves produced later show little evidence of infection although they contain virus. This phenomenon, termed 'recovery,' was studied by comparing the quantity and quality of raspberry ringspot virus in leaves of *Nicotiana benthamiana* plants at different stages of infection.

In extracts of successive tip leaves, sampled when of a standard size, infectivity decreased with increasing time after the plants were inoculated. At 9 days after inoculation, young symptom-bearing leaves contained ten times as much virus infectivity as did similar sized recovered leaves that were sampled at 24 days. In successive samples from the same batch of symptom-bearing leaves, the virus content per cell increased 4-fold during the first few days then decreased until the leaves were fully expanded, 20 days after the first sample, and the virus content was the same as at day 1. In recovered leaves, by contrast, the virus content per cell decreased after the first sampling to only a tenth of the initial value, when leaf expansion was complete.

In purified virus preparations from leaves of the same size the proportions of top, middle and bottom component particles were fairly constant. However, there was a steady increase in ratio of amount of RNA-1 ( $2.4 \times 10^6$  daltons) to that of RNA-2 ( $1.4 \times 10^6$  daltons) in virus from successively produced tip leaves. The ratio of RNA-1 to RNA-2 was 0.53 for virus from young symptom-bearing tip leaves sampled 8 days after inoculation and 0.91 for young recovered leaves 24 days after inoculation.

(H. Barker, B. D. Harrison)

*Leaf proteins in relation to symptom production and recovery*

Workers elsewhere have reported that four new soluble proteins, detectable by disc electrophoresis of leaf extracts, are produced in tobacco leaves after infection with tobacco mosaic and some other viruses, and also after injecting leaves with polyacrylic acid which, increases their resistance to subsequent virus infection. Tests were therefore made on symptom-bearing and recovered leaves of *Nicotiana benthamiana* infected with raspberry ringspot virus, but no new protein bands were detected. Indeed, the experiments produced the unexpected results that three of the four bands referred to above could be found in leaf extracts of healthy plants of several *Nicotiana* spp. Further tests showed that infection of tobacco with alfalfa mosaic virus or injection with polyacrylic acid (mol. wt. 3500, 500 µg/ml) caused the production of one new protein band and the intensification of a second, and that the occurrence of such changes depends on the environmental conditions.

(H. Barker)

*Seed transmission of tomato black ring virus*

Last year it was reported that virus isolates had been produced containing RNA-1 of the potato bouquet (German) strain of the virus and RNA-2 of the beet ringspot (Scottish) strain. The ability of such pseudo-recombinant isolates to be seed transmitted in *Stellaria media* was compared with that of their parent isolates. The potato bouquet and pseudo-recombinant isolates were seed transmitted rarely but beet ringspot isolates were transmitted frequently. This suggests that seed transmissibility is determined by RNA-1.

(B. D. Harrison, K. Hanada)

04001 *Potato viruses, especially soil-borne viruses**A nepovirus from potato in Peru*

A virus obtained from *Solanum tuberosum* x *andigena* cv. Antarqui in Peru was found to have particles about 30 nm in diameter and to be distantly serologically related to tobacco ringspot virus; no relationship was detected to the nepoviruses occurring naturally in Britain or to tomato ringspot virus. The virus was inactivated in 10 min between 57° and 60°C, when diluted  $10^{-3}$ – $10^{-4}$  or when stored at room temperature for 9–10 days. It has a wide host range but differs from typical isolates of tobacco ringspot virus in infecting tomato readily and in consistently becoming systemic in *Chenopodium amaranticolor* and *C. quinoa*; the potato virus is also the more virulent of the two in several species.

(L. Salazar, B. D. Harrison)

## VIRUSES OF FLOWER BULBS

04010 *Viruses infecting bulbous ornamentals**Virus indexing of narcissus*

The survey of viruses in narcissus, one object of which is to find plants suitable for propagation into virus-tested clones, was continued for a third year. In stocks of the cultivars Barrett Browning, Fortune and Margaret Mitchell, 27, 70 and 100% of plants respectively contained filamentous virus-like particles. In addition, 30% of plants of Margaret Mitchell contained tobacco rattle virus and one Fortune plant contained arabis mosaic virus. Several plants of Barrett Browning and Fortune were apparently free of infection, and 1 and 2 such plants of Dutch Master and King Alfred, respectively, were also found.

More rigorous testing, by inoculation and electron microscopy of concentrated leaf extracts, of 29 clones in which virus was not found in previous tests, failed to detect any virus other than the newly described narcissus tip necrosis virus, which was not known when the survey started.

(W. P. Mowat, Aileen M. Hutcheson)

#### *Narcissus tip necrosis virus*

This is the name given to the virus with isometric particles 30–35 nm in diameter found during the narcissus survey in 1973, and discovered independently by C. J. Asjes in The Netherlands. Preparations purified from narcissus contain a single component with a sedimentation coefficient of 119S at infinite dilution, and have a UV absorption spectrum characteristic of nucleoproteins containing about 20% of nucleic acid. In polyacrylamide gel electrophoresis, the virus protein gave a major band of mol. wt. 40,500 material and a trace of 33,000 mol. wt. material. Thin sections of infected narcissus leaf revealed numerous isometric virus-like particles in several types of cell, in which they were found especially in cytoplasmic vesicles but also more generally distributed in the cytoplasm, and occurred in the cell vacuole and, possibly, the nucleus. These properties suggest affinities with tombusviruses, but no serological relationship to tomato bushy stunt virus was detected.

No indicator plant for the virus is known but infection can be detected in narcissus sap by double-diffusion serological tests in gel. By this means, it was found in 15 out of 30 plants of cv. Barrett Browning, and also in cv. Corinthian, Fortune and Sempre Avanti.

(W. P. Mowat, Aileen M. Hutcheson)

#### *Narcissus mosaic virus*

In the narcissus survey, narcissus mosaic virus was detected by inoculation tests using *Chenopodium quinoa*, but many of the isolates thus obtained caused symptomless infections. Serological double-diffusion tests in gel, using antiserum to intact virus particles, were unreliable for detecting these isolates in *C. quinoa*, but antiserum to virus protein, which was produced by disrupting virus particles with 2.5% pyrrolidine, gave satisfactory results. The reaction involved virus antigen not sedimented by high-speed centrifugation of infective *C. quinoa* sap, and its usefulness for tests on field grown narcissus is being explored.

(W. P. Mowat)

In complementary work to examine its properties, the protein was prepared from intact virus particles by treatment with lithium chloride. When kept for a few days in tris-HCl buffer (pH 8, ionic strength 0.1) containing 0.3 M-ammonium sulphate, the protein formed helical, RNA-free aggregates which looked similar to intact virus particles in the electron microscope. They were not produced when ammonium sulphate was omitted from the reaction mixture, and became less stable when it was removed after the aggregates had formed.

(D. J. Robinson, W. P. Mowat)

#### *Control of field spread of tulip breaking and lily symptomless viruses*

In 1973 encouraging results were obtained by using a barley barrier crop plus a weekly spray of 1% emulsion of Albolineum oil to protect *Lilium formosanum* plants from infection by the aphid-borne tulip breaking and lily symptomless viruses. In 1974 these treatments were tested separately and together. Of the twenty *L. formosanum* bait plants in each treatment, 17 became infected when grown within a barrier of barley, 13 in plots sprayed with the oil emulsion, one in plots with both treatments and all in the unprotected plots. Evidently both treatments are needed to give good control.

(W. P. Mowat, J. A. T. Woodford<sup>1</sup>)

#### 04011 *Production of virus-tested bulb stocks*

##### *Meristem-tip culture of narcissus*

The search for an improved culture medium continues, but so far with little success and this method of obtaining plants apparently free of virus will be used in future mainly for cultivars that seem totally infected. More than 1700 meristems of the cultivars Carlton, Corinthian, King Alfred and Rembrandt were cut during the year. A few plantlets of Fortune, from meristems cut in 1973, were potted and a few of Golden Harvest should soon be ready for potting. Thirteen virus-free plants of Double White have now been potted and three, grown from meristems cut in 1968-69, flowered in 1974.

(J. Chambers, J. Kelly)

##### *Propagation of virus-tested narcissus*

For the third successive year, clones were produced from selected bulbs by twin scaling. About 5,600 twin scales were cut from 40 bulbs of the cultivars Barrett Browning, Corinthian, Dutch Master, Fortune, Golden Harvest, King Alfred and Sempre Avanti. After incubation for 12 wk at 23°C, now the standard procedure, about 96% of the twin scales were alive and nearly 80% had produced bulbils. Of the twin scales cut in 1972 and 1973, about 25% produced bulbils that remained dormant during the first year. However, most such bulbils produced by twin scales cut in 1972 broke dormancy in 1974.

(W. P. Mowat, J. Chambers)

#### RUBUS VIRUSES

#### 04003 *Viruses infecting raspberry*

##### *Separation and behaviour of latent viruses*

Sources of raspberry leaf spot (RLSV) and raspberry leaf mottle (RLMV) viruses, each believed to be free from other detectable viruses, were obtained

<sup>1</sup>Zoology Section.

by indexing field grown raspberries that were virus free when planted. All the *Rubus idaeus* cultivars inoculated with these two viruses by grafting were susceptible to both, and most were infected symptomlessly. However, the following cultivars developed mosaic leaf symptoms: Glen Clova and Norfolk Giant grafted with the RLSV source and Malling Delight, Malling Landmark, St. Walfried, Veten and Zeva grafted with the RLMV source. By grafting to indicators, RLSV and RLMV were also detected in field grown plants of *Rubus gracilis* and Thornless Boysen, and RLMV in *R. occidentalis*.

In the field experiment to assess the ability of *Amphorophora rubi*-resistant raspberry plants to escape virus infection, tests showed that RLSV and RLMV, like 52V virus, spread slowly into cultivars with minor gene resistance (Glen Clova, Norfolk Giant) and into those with major gene resistance (Malling Orion, selection 888/49) to *A. rubi*. In contrast, spread of these viruses into *A. rubi*-susceptible cultivars (Lloyd George, Malling Jewel) was rapid.

Whereas 52V virus, RLMV and RLSV can be eliminated from raspberry plants by heat treatment, a fourth latent virus, rubus yellow net, is reported to survive. Thus when roots from field infected Malling Jewel plants were kept at 36°C for 17–21 days, and root cuttings then taken, some of the resulting plants were free of the first three viruses but contained rubus yellow net virus as assessed by grafting indexing to *R. occidentalis*. Apparently uncontaminated sources of all four of these latent viruses have therefore now been produced.

(A. T. Jones)

#### *Cucumber mosaic virus in Rubus*

In 1974, cucumber mosaic virus (CMV) was obtained from several cultivated bramble plants showing no obvious leaf symptoms and also from *R. phoenicolasius* plants showing large yellow blotches on the leaves. An isolate from *R. phoenicolasius* had *in vitro* properties and an herbaceous host range similar to those of well known strains of CMV, and was transmitted between *Nicotiana clevelandii* plants by the aphid *Macrosiphum euphorbiae*. However, several attempts failed to transmit the virus to *Rubus idaeus* either using *M. euphorbiae* or by grafting with tissue from field-infected plants. Whether CMV causes the leaf symptom in *R. phoenicolasius* is not yet known.

The CMV isolate was purified from *N. clevelandii* and an antiserum (titre 1/512) was obtained using virus fixed with formaldehyde as the immunogen. In agarose gel double-diffusion tests, CMV in *N. clevelandii* sap gave precipitin lines only when the sap was diluted at least 1/4 with buffer containing 0.001 M-EDTA.

(A. T. Jones)

#### *Tobacco streak virus in Rubus*

Further comparisons of black raspberry latent virus (BRLV) with isolates of tobacco streak virus obtained from plants of the blackberry cultivars

Aurora, Cascade and Zielinski imported from USA and with the N. American tobacco (type) isolate, showed that these isolates all have similar host ranges and properties, and have antigenic determinants in common. Purified particles of an isolate of BRLV were resolved into three sedimenting components by moving boundary sedimentation but formed a single infective band ( $\rho=1.35 \text{ g/cm}^3$ ) on isopycnic centrifugation in CsCl solution. The number and sizes of the protein and RNA components of virus particles, as determined by polyacrylamide gel electrophoresis, were similar to those reported for the type strain of tobacco streak virus.

No symptoms developed in black raspberry seedlings infected with BRLV by mechanical inoculation, nor in eight red raspberry cultivars infected by graft inoculation. However, graft inoculation of BRLV to *R. henryi*, *R. phoenicolasius* and cv. Himalaya Giant blackberry induced symptoms typical of the necrotic shock disease described in North America.

(A. T. Jones, M. A. Mayo)

#### *Rp7 virus*

Further studies on the virus with filamentous particles obtained from *R. phoenicolasius* in 1973 and now code named Rp7, were hindered by difficulties in purifying the virus in an unaggregated state. Tris-HCl buffer, pH7 was the most useful buffer for extracting the virus from inoculated *C. quinoa* leaves. The extracts were adequately clarified by *n*-butanol (9.2%), but much infectivity was lost. Several other methods of purification were unsatisfactory but precipitation in 7% polyethylene glycol (mol. wt. 6,000) solution containing 0.1 M NaCl was also useful, although the total infectivity of preparations was diminished at polyethylene glycol concentrations greater than 4%.

Rp7 virus was not transmitted by *M. euphorbiae*, nor by mechanical inoculation, to several *Rubus* species. However, *R. phoenicolasius*, blackberry cv. Himalaya Giant (*R. procerus*) and the red raspberry cultivars Lloyd George and Malling Landmark were infected by graft inoculation with field-infected *R. phoenicolasius*. Leaf symptoms developed only in Himalaya Giant, in which faint line-patterns occurred 3 to 4 weeks after grafting. Whether this symptom is caused by Rp7 virus alone, or by other viruses in the field-infected *R. phoenicolasius* acting separately or in combination, is not known.

(A. T. Jones)

#### OTHER VIRUSES

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

#### *Nicotiana velutina virus*

This seed transmitted virus, obtained from a naturally infected *N. velutina* seedling growing in the arid zone of South Australia, has particles with

superficial similarities to those of tobacco rattle and potato mop-top viruses, and a comparative study was therefore started.

Attempts to purify the virus were hindered by the tendency of particles to aggregate side-to-side in extracts of plant sap and so to sediment at small centrifugal forces. The particles were not disaggregated by changing the pH or molarity of phosphate buffers; by incorporating non-ionic detergents, urea, or chelating or reducing agents in resuspending buffers; or by sonication; but resuspending in 0.05 M-tris-HCl buffer at pH 8.1 gave the desired effect.

(J. W. Randles)

#### 04007 *Viruses infecting umbelliferous crop plants*

##### *Aphid transmission of anthriscus yellows and parsnip yellow fleck viruses*

As reported in the Report for 1973, parsnip yellow fleck virus (PYFV) is totally dependent on anthriscus yellows virus (AYV) for its transmission by the aphid *Cavariella aegopodii*, and further experiments were made to study the nature of this dependence.

Aphids carrying AYV, but not AYV-free aphids, acquired PYFV when immersed in purified preparations of PYFV, and later transmitted the virus to test plants. Acquisition of PYFV in this way was prevented by removing the aphid's stylets but not by anaesthetizing the aphids with carbon dioxide before immersion. Allowing AYV-carrying aphids to acquire ultraviolet inactivated PYFV before infective PYFV considerably decreased transmission of PYFV but not of AYV.

These and previous results suggest that there is a site between the tips of the stylets and the posterior end of the foregut of *C. aegopodii* where AYV particles are held, and that AYV-carrying but not AYV-free aphids have a similar site for retention of PYFV. It is suggested that, in the aphid, PYFV particles become attached either to AYV particles or to some 'helper factor' obtained from AYV-infected plants. The efficiency with which AYV-carrying aphids transmit AYV is correlated with their ability to acquire and inoculate PYFV from singly infected plants or purified preparations.

(S. El Nagar, A. F. Murant)

##### *Electron microscopy of aphids carrying anthriscus yellows virus*

A method was devised for sectioning the heads of aphids so that the foregut and sucking pump are seen in longitudinal section. Ultrathin sections of *Cavariella aegopodii* showed that, at the point where the sucking pump joins the foregut, close to the tentorial bar, the lining of the ventral wall of the food canal is thickened and has spike-like projections. The spiked area is 15–20 µm long and is often overlaid by a pad of material resembling mucus. Groups of several hundred virus-like particles, 20–28 nm in diameter, were found associated with the mucus in many AYV-carrying aphids but not in AYV-free aphids. The particles were not removed when AYV-carrying aphids fed on

10% sucrose solution. When *C. aegopodii* were kept on AYV-infected plants for differing periods, neither virus-like particles nor mucus were found until the aphids had fed long enough to acquire transmissible virus. In moulting aphids, the mucous pad with associated virus-like particles remained attached to the foregut lining about to be cast. Virus-like particles were not found in the posterior part of the foregut, oesophageal valve, stomach, salivary pump, or food or salivary canals within the stylets.

It is suggested that the virus-like particles are those of AYV, and that after acquisition from plants these particles are held at the mucous pad, later to be regurgitated during further feeding. This hypothesis fits with the vector relations of AYV: increased transmission with increased length of acquisition and inoculation feeding periods up to a day, persistence in the aphid for up to 3 days, and failure to be retained when it moults.

No differences were observed between aphids carrying AYV and those carrying AYV plus PYFV, which also has isometric particles about 28 nm in diameter. No particles were found in aphids fed on purified preparations of PYFV without previous access to a source of AYV.

(A. F. Murant, I. M. Roberts, S. El Nagar)

##### *Aphid transmission of carrot mottle and carrot red leaf viruses*

Both these viruses are transmitted by *Cavariella aegopodii* in the persistent manner but carrot mottle virus (CMotV) was transmitted only from plants that also contained carrot red leaf virus (CRLV). Aphids carrying CRLV did not transmit CMotV from singly infected source plants or from partially purified preparations acquired by feeding through a Parafilm membrane. In this respect transmission of CMotV differs from that of PYFV, although in both instances transmission depends on a helper virus.

*C. aegopodii* did not transmit either CMotV or CRLV after feeding through membranes on, or injection with, extracts from plants containing both viruses. Nor was CMotV transmitted when virus-free or CRLV-carrying aphids were allowed to feed on, or were injected with, partially purified preparations of CMotV; or were injected with haemolymph from aphids fed on CMotV-infected plants. However, both viruses were transmitted for at least 11 days by aphids injected with haemolymph from aphids that had fed on a doubly infected source. When haemolymph from injected aphids that had transmitted both viruses was injected into a second series of aphids, this second series did not transmit. When extracts of aphids that had fed on a doubly infected source were treated with ether before injection into virus-free aphids, the injected aphids transmitted both viruses, although ether is known to inactivate CMotV in partially purified preparations made from singly infected plants.

These results indicate that both viruses can circulate through the haemolymph, but they give no evidence of virus multiplication in the vector. They also show that transmission of CMotV depends on some interaction with

CRLV in source plants and suggest that CMotV infectivity in aphid haemolymph is more stable than that in purified preparations. Transmission of CMotV would perhaps be best explained by heterologous coating, *i.e.*, the coating of its RNA with the particle protein of CRLV.

(S. El Nagar, A. F. Murant)

## Zoology

D. L. TRUDGILL

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During the year several new pest problems have been investigated; two species of lesion nematodes (*Pratylenchus* spp.) were associated with poor growth in raspberries, a population of the nematode *Paralongidorus maximus* was discovered damaging Scots pine seedlings and the damage caused to calabrese by the cabbage stem weevil (*Ceutorhynchus quadridens*) and the cabbage leaf minor (*Phytomyza rufipes*) was studied in field trials.

The wide distribution of raspberry cane midge in eastern Scotland was confirmed and larger numbers were found on canes damaged by machine harvesting than on canes from which the fruit had been hand harvested. *Aphis fabae* populations on field beans in 1974 were exceptionally large and there were substantial increases in yield following the use of insecticides. Techniques for estimating populations of raspberry mite have been improved and the efficiency of the acaricide, vamidothion, has been confirmed.

### 05006 Nematodes associated with trees

This project, now completed, aimed to characterise the nematode fauna associated with forest trees within the UK. An initial survey showed that large numbers of plant parasitic nematodes were rarely associated with mature trees, but in contrast, large populations of *Trichodorus* and *Rotylenchus* spp. were present in several of 41 forest nurseries surveyed.

The nematode fauna associated with coniferous and deciduous trees was similar, with the exception of Criconematid species, which were mainly associated with deciduous trees. Most of the 29 Criconematid species identified were widely distributed within the UK, but some showed strong host preferences. Of the five most commonly occurring species two were most frequently recovered from grassland and three from deciduous woods.

Host range studies in the glasshouse were largely unsuccessful, only *Cephalenchus emarginatus* and *R. robustus* surviving and reproducing on any of the test hosts.

(B. Boag)



05002 Biology and ecology of Trichodorid species and their role as virus vectors

Previous surveys of Trichodorid nematodes have concentrated on crop species or on soil types known to favour these nematodes. Less biased information about their distribution was obtained by examining samples from more general surveys undertaken by the Section. Of 2,900 samples examined only 191 contained species of *Trichodorus* or *Paratrichodorus* but nine of the eleven Trichodorid species occurring in the British Isles were recorded. From the samples containing Trichodorids, *T. primitivus* and *P. pachydermus* were most frequently recovered, being present in 60% and 22% respectively. Other species occurred in less than 5% of samples.

Outline distribution maps are being produced on a 10 km grid using facilities at the Biological Records Centre, Monkswood Experimental Station, and nematode distribution is being related to vegetation and abiotic factors using the Statistical Package for Social Sciences program at Edinburgh Regional Computing Centre.

In a survey of Trichodorid nematodes and tobacco rattle virus (TRV) in bulb growing areas in eastern Scotland 46 fields on 13 farms have been examined. Nineteen fields (nine farms) contained species of *Trichodorus* or *Paratrichodorus* and of these five fields (three farms) proved infective with a virus thought to be TRV.

(T. J. W. Alpey)

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

Previous work on several *Longidorus* species showed that these could be divided into two distinct groups based on the arrangement of the oesophageal radial and stylet retractor muscles. Observations on *Paralongidorus maximus* indicate that this nematode belongs to the group typified by *L. macrosoma*. This gives added support to the groupings because the *L. macrosoma* group has a muscle arrangement similar to that in *Xiphinema* species and *Paralongidorus* has *Xiphinema*-like amphids which is the main character used to distinguish the genus *Paralongidorus* from *Longidorus*.

Sections through the oesophageal bulb of *P. maximus* have shown a previously unreported set of radial muscles which act on the cuticular platelets of the food pump. These muscles attach at the apices of the tri-radiate lumen and possibly act when the lumen begins to close. This set of muscles, although difficult to trace, has been noticed because *P. maximus* is relatively large and checks suggest that they are found in all *Longidorus* and *Xiphinema* species.

*Xiphinema diversicaudatum* were exposed to *Petunia hybrida* infected with strawberry latent ringspot virus (SLRV). Nematodes extracted after 4 weeks were found to transmit the virus to *P. hybrida* and specimens sectioned and

examined in the electron microscope were found to contain particles lining the lumen of the odontophore, slender oesophagus and oesophageal bulb. This is similar to the site of retention of arabis mosaic virus (AMV) in *X. diversicaudatum*; however SLRV has not been found in crystalline aggregates within the nematode.

(W. M. Robertson)

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

Root tips fed upon by *Longidorus* or *Xiphinema* spp. usually swell to form characteristic galls; the roots of *Petunia hybrida* growing in agar swell to form galls within 24 hours of *X. diversicaudatum* commencing feeding. This response has been used to provide a measure of nematode feeding in pot studies of the transmission of nepoviruses and, despite evidence that most nematodes fed, there were considerable differences in transmission rates of some of the nepoviruses by their specific vectors. *Xiphinema diversicaudatum* was a reliable vector of AMV; in two tests with only five nematodes per plant all the bait plants became infected with the virus, and with two nematodes per plant 67% of the bait plants became infected.

*Longidorus elongatus* is a specific vector of strain W22 of tomato black ring virus (TBRV) and strains 4B7 and Himalayan of raspberry ringspot virus (RRV). It was a comparatively efficient vector of W22, a mean of 51% of bait plants being infected with virus in three tests when five nematodes per plant were tested, but two strains of RRV were transmitted less frequently. In five tests with the 4B7 and two tests with the Himalayan strain of RRV, with 20 nematodes per bait plant, a mean of 50% of the bait plants became infected with virus. *Longidorus macrosoma*, the specific vector of the Himalayan strain of RRV in the field, was an even less efficient vector than *L. elongatus*; in two tests with 20 nematodes per plant a mean of two of 10 bait plants became infected with virus.

Transmission of TBRV (strain W22) and RRV (strain 4B7) by *L. elongatus* has been improved by lengthening the period allowed for acquisition and transmission of the virus and under optimum conditions five nematodes transmitted RRV (strain 4B7) and TBRV (strain W22) to eight of 10 bait plants.

(D. L. Trudgill)

The role of nematodes in the transmission of cherry leaf roll virus (CLR) is uncertain. When *X. diversicaudatum*, *L. macrosoma*, *L. elongatus* and *Paralongidorus maximus* were extracted from pots containing infector plants and transferred to bait plants (*Chenopodium quinoa*) growing in different containers all failed to transmit the cherry, rhubarb and elderberry strains of CLR. When the nematodes were not removed but the bait plants replaced infector plants in the same container the cherry strain of CLR was occasion-

ally recovered from the roots of the bait plants with *X. diversicaudatum* and *P. maximus*. As the nematodes apparently fed well in these tests and CLRV was recovered from macerated *L. elongatus* and *P. maximus* these results suggest that *L. elongatus* and *P. macrosoma* are non-vectors but that *X. diversicaudatum* and *L. maximus* may be non-specific vectors of CLRV (cherry strain).

(F. D. McElroy, A. T. Jones<sup>1</sup>)

Raspberry ringspot virus (4B7 and Himalayan strains) was apparently recovered from the roots of *P. hybrida* when bait plants replaced infector plants grown in a container of soil infested with *P. maximus*; TBRV (W22 and potato bouquet strains) and CLRV (cherry, rhubarb and elderberry strains) were not recovered. None of the viruses were recovered from the tops of the bait plants in any of these tests. However all the above viruses, except for the two strains of TBRV, were recovered from macerated nematodes at the end of the bait test. *Paralongidorus maximus* produced large galls on the roots of *P. hybrida*, *C. quinoa* and *S. media*.

(F. D. McElroy, D. J. F. Brown, B. Boag)

05003 Chemical control of ectoparasitic nematodes with special reference to virus vector nematodes

Investigations into the action of the oximecarbamate nematicide, oxamyl (Vydate, Du Pont), have continued. Equivalent amounts of oxamyl were added either to the foliage of *Cucumis sativa* or to the soil in pots in which they were growing. At 2 and 4 wk after application, soil from the pots was mixed with equal parts of a soil containing *L. elongatus*. Nematode numbers decreased after 1 month both in the soil from the foliage treated plants and in the directly treated soil compared with the untreated controls. This confirms that oxamyl can be actively translocated from treated leaves to roots and passes into the soil.

(T. J. W. Alphey)

Contrary to previous results, tests have shown that treatment in 100 ppm oxamyl solution for 1 h has little effect on viruliferous *L. elongatus* and *X. diversicaudatum*. In several tests treated nematodes induced almost as many root galls and transmitted virus to bait plants as effectively as untreated nematodes. In contrast, feeding as measured by gall formation, and virus transmission were decreased by relatively small concentrations of oxamyl in the soil water. Oxamyl, 0.1 ppm, in the soil water greatly decreased the transmission of AMV by *X. diversicaudatum* and the numbers of feeding galls produced. *Longidorus elongatus* was less sensitive to soil drenches of oxamyl, 1.0 ppm being required to inhibit feeding and transmission of RRV.

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

<sup>1</sup>Virology Section.

Previous observations have shown that virus vector nematodes are able to survive several weeks' exposure to oxamyl. When oxamyl, 5 lb a.i./ac (5.6 kg a.i./ha), was applied to field soil infested with *L. elongatus* the rate of acquisition and transmission of TBRV was decreased only for 10 wk after treatment. Even 20 lb a.i./ac (22.4 kg a.i./ha) had little effect on the numbers of nematodes or the rate of acquisition and transmission of TBRV 20 wk after treatment.

(D. L. Trudgill)

Two fumigant nematicides, dazomet and D-D, applied prior to planting raspberries in 1973, gave good control of *L. elongatus* and, together with quintozone, largely prevented transmission of RRV when the soil from the treated plots was bait tested. Two oximecarbamate nematicides, aldicarb and oxamyl, gave poor control of *L. elongatus* and transmission of RRV (Rept. Scottish Hort. Res. Inst. 1973, 71). In 1974 raspberry plants growing in the treated plots were examined for symptoms of infection with RRV. The incidence of RRV-infected raspberry stools was 29% in the untreated control and less than 3% in the dazomet, D-D and quintozone treated plots. In plots treated with aldicarb and oxamyl 8% and 10% of the stools showed symptoms of infection with RRV.

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

In the same experiment, at the end of the first year, dazomet and D-D had increased the amount of canes per stool and aldicarb had slightly improved mean cane height compared with the untreated control. All three chemicals decreased the numbers of a lesion nematode, *Pratylenchus crenatus*, but the quintozone, untreated control and oxamyl treated plots, which grew less well, all contained moderate numbers of this species. In two adjacent blocks of raspberry cv. Glen Clova, considerable areas of depressed growth were correlated with high numbers of lesion nematodes. The most seriously affected block, which had been treated with quintozone prior to planting in 1973, was infested with *P. penetrans* and up to 5,000 nematodes per g of root were covered from the most seriously affected plants. In a second block of raspberries, not treated with quintozone, one small area of depressed growth was associated with many *P. penetrans* but a second, less well defined area of depressed growth, was infested with *P. crenatus*.

(D. L. Trudgill)

05010 Control of potato cyst nematode in Scotland with special reference to seed potato areas

Twenty-four populations of potato cyst nematodes from different parts of Scotland have been compared on the nematode-resistant potato cv. Maris Piper. All populations produced few cysts on the M. Piper compared with the number produced on a susceptible potato cv. King Edward, suggesting that all are of the non-aggressive type, *Heterodera rostochiensis*, pathotype A.

In a test of soil from part of a plot which had grown a crop of *M. Piper* in 1973 the numbers of cysts formed on the roots of a susceptible potato cultivar were decreased by two-thirds compared with a pre-plant test. When soil from an adjacent part of the plot which had grown a single crop of King Edward was tested the numbers of cysts formed was increased fourteen-fold.

(D. L. Trudgill)

05001 *Ecology and control of pests (other than aphids) of horticultural crops in Scotland*

*Raspberry mite*

Populations of raspberry mite (*Eriophyes gracilis*) have previously been estimated from direct counts of mites over-wintering in buds. Improved techniques, which enable mites in both buds and on leaves to be extracted and counted, are now being used to monitor population changes after an acaricide treatment.

In earlier trials vamidothion (Kilval) has been applied in the spring but in the present trial it was applied at 20 fl ozs/ac (1.40 l/ha) in June and September. After treatment in 1973 the numbers of mites overwintering in buds were assessed. Vamidothion decreased mite numbers from a mean of 127 mites per bud in the untreated control to a mean of 2.8 mites in the June and 6.5 mites per bud in the September treated plots. The following year mite numbers in the untreated plots reached a maximum in mid July of 56 per leaf on the fruiting canes and 81 per leaf on the primocanes in late September. Mite numbers in the plots treated in June remained less than 5 per leaf and remained small throughout the whole of the year following treatment. In the plots treated in the previous September mite numbers increased in mid August, probably due to migration from adjacent untreated plots. In the untreated plots numbers of mites overwintering in 1974/75 were many fewer (14 mites/bud) than in 1973/74 (127 mites/bud). An early frost in late September may have killed many mites before they migrated to their overwintering sites in the buds.

(S. C. Gordon)

*Raspberry beetle*

An improved technique has been adopted for assessing the field resistance of raspberry breeding lines to raspberry beetle (*Byturus tomentosus*). Adult beetles taken from the primocanes before flowering are now caged in groups of six on selected laterals and left until the fruit ripens. The ripe fruit and receptacles are examined for eggs and larvae.

(S. C. Gordon, D. L. Jennings<sup>1</sup>, A. Dale<sup>1</sup>)

<sup>1</sup>Plant Breeding Section.

*Raspberry cane midge*

A survey of midge (*Thomasiniana theobaldi*) distribution, begun in 1973, was repeated in August and September 1974, and samples were taken from 22 plantations of cv. Glen Clova and 26 plantations of cv. Malling Jewel. The greatest incidence of cane midge was again in Glen Clova in eastern Perthshire (36% of 150 canes from six sites) and at SHRI where 73% of 150 canes examined contained larvae. Infestations remained small in northern Angus, but midge larvae were found this year in samples of Glen Clova from Ayrshire and at a site in Lanarkshire where both Glen Clova and Malling Jewel were heavily infested.

A plantation of Malling Jewel in which plots had been harvested either mechanically or by hand was sampled in September for cane midge larvae. Samples of two primocanes were taken from randomly selected stools in the mechanically harvested plots; one cane in each sample was chosen because it was deeply scarred at about 50 cm above the ground by the fish plates on the machine, the other cane was relatively undamaged. The mechanical damage provided ideal sites for the development of cane midge larvae and more than twice as many larvae were found on these as on the undamaged canes. The numbers on the damaged canes were four times as great as on canes from hand picked plots.

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

*Cabbage leaf miner*

In England, damage by larvae of the cabbage leaf miner (*Phytomyza rufipes*) can make calabrese unacceptable for processing, but until recently there was little evidence of damage to calabrese grown in Scotland. Observations at SHRI on crops of calabrese (cv. Rex) sown on 27 April, 6 May, 3 June and 11 July showed that tunnelling damage by leaf miner was infrequent in crops sown before mid May (2-4% of spears tunnelled) but increased in later sown crops. The first generation of flies emerged in June, and in July eggs were found on 60% of the June sown crop as compared with less than 25% of the earlier sown plants.

Leaf miner damage was also uncommon in the cultivars Corvet, Gem and Harvester sown before mid May, but increased in later sown crops. The incidence of damage was more closely related to the dates of harvest than to sowing dates. Many of the spears were tunnelled by small larvae which had hatched from eggs laid on upper leaves or bracts. These small larvae produced inconspicuous fluid-filled tunnels, but older larvae, which developed from eggs laid on the lower leaves, made conspicuous dry hollow tunnels in the spears. Many eggs failed to develop because they were crushed or lost from the oviposition pouch as a result of hypertrophy of the adjacent parenchyma. Many larvae were unable to cross the abscission layer at the base of the petiole. This occurred most frequently during a spell of dry weather in July.

The efficiency of three insecticides, dimethoate (0.075% a.i. and 0.05% a.i.), azinphos methyl (0.1% a.i. and 0.05% a.i.) and trichlorphon (0.1% a.i.) for controlling leaf miner damage was tested in three trials on calabrese sown in mid June. In one trial a later application of an experimental insecticide, NRDC 143, was also tested. At SHRI where numbers of larvae were small (5-9% on the untreated controls, cultivars Rex and Gem) the performance of a single application of dimethoate, applied soon after the formation of the fourth true leaf, was not improved by repeated sprays at weekly intervals. Similarly in Fife where numbers of larvae were greater, dimethoate again gave the best control, decreasing damage by up to 97%. A single application of dimethoate (0.075% a.i.) 17 days before harvest was almost as effective as five applications applied at weekly intervals from the formation of the fourth true leaf. NRDC 143, which was applied only 12 days before harvest, decreased damage by 68%.

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

#### *Cabbage stem weevil*

Although the early sown crops of calabrese mostly escaped leaf miner damage, cabbage stem weevil (*Ceutorhynchus quadridens*) was widespread in some crops of early sown calabrese in the Fife region. As this weevil has only one generation per year crops sown after the second week of June in 1974 escaped damage. Most eggs were laid on the lower leaves but larvae emerging from eggs laid on the upper leaves, bracts or upper part of the stem, tunneled the harvested heads. Tunnels were conspicuous, brown and filled with frass. When larvae were many, some florets turned brown because of the extensive tunnelling.

Of three cultivars sampled, Gem was the most susceptible (48% of heads damaged), followed by Grande (33%), with Rex (13%) the least susceptible but even this lower level of damage was unacceptable.

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

#### *Bryobia mites*

Brussels sprout seedlings cv. Sigmund growing in an unheated glasshouse at SHRI were damaged by an infestation of mites of the *Bryobia praetiosa* complex. Feeding damage on the cotyledons and leaves took the form of numerous small punctures but on a glossy leaved seedling line the feeding punctures developed into swellings. The infestation was thought to have originated from mites feeding on the surrounding grass. This is the first record of Bryobid mites damaging Brassicas in Scotland.

(S. C. Gordon)

#### *Glasshouse whitefly*

A parasitic chalcid wasp, *Encarsia formosa*, was tested for controlling glasshouse whitefly (*Trialeurodes vaporariorum*). It gave only poor control

probably because the glasshouse temperature (mean 19.8°C) was well below the minimum required for the parasite (21°C). Also the low light intensity during the winter, when this test was undertaken, seemed unfavourable to the parasite.

(S. C. Gordon)

#### 05008 *The ecology and control of aphids infesting raspberries and other crops*

##### *Field beans*

Experiments to determine the effect of *Aphis fabae* on the yield of field beans were continued in 1974. Aphid populations were monitored on cv. Herz Freya, sown on 26 March and 9 April grown at 3 plants/ft<sup>2</sup>. Bean aphids first colonised the crops in late June when the plants were flowering. By the end of July, 25% of the first sown plants and 48% of the plants sown in April were infested in untreated plots. Infestations were significantly decreased by phorate (10% granules), applied at 10 lb/ac (11.2 kg/ha) before flowering, pirimicarb (50% D.P.), applied at 4 oz/ac (0.28 kg/ha) during flowering, or demeton-S-methyl (58% e.c.) applied at 6 fl oz/ac (0.4 l/ha) after flowering.

Yields were significantly increased by demeton-S-methyl (55% above control) and pirimicarb (39% above control) and by a pre-flowering spray of menazon (40% e.c.) at 10 fl oz/ac (0.7 l/ha) (32% above control). On untreated bean plants aphid populations were large by August.

In two small plot experiments heavily infested plants were sprayed with menazon in the third week of August and harvested at the end of September. Aphid eradication at this late stage of plant growth improved yields significantly in both experiments, due mainly to an increase in the number of pods on the sprayed plants. There was also a small increase in seed weight following spraying.

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

##### *Raspberries*

Studies on the ecology of aphids infesting raspberries have been continued in a plantation of cv. Malling Jewel. Fundatrices of *Amphorophora rubi* hatched from overwintering eggs in early April and populations reached a peak of 660 per primocane in late August. In September populations declined rapidly over 4 weeks to 25 per primocane then slowly to 18 per primocane in late October when sampling ceased. The decline in population was associated with a rapid increase in the numbers of predators, notably Syrphid and Coccinellid larvae and an epizootic of the pathogenic fungus *Entomophthora*.

*Aphis idaei* was the second most numerous aphid on primocanes in 1974 appearing in mid-June and increasing to a peak in the latter part of September with 30 per primocane. Small numbers of the potato aphid *Macrosiphum euphorbiae* were found from May to late August and a few *Myzus ornatus* were present from May to late October.

In an experiment to determine the effect of predation on aphid populations, six raspberry cultivars were sprayed with carbaryl at monthly intervals to kill predators; in May and June at 8 oz a.i./ac and in July, August and September at 16 oz a.i./ac. Aphids were unaffected by these rates of insecticide and populations on the sprayed plots exceeded those on control plots by an average of 2.5 times for the season and were 18.7 times greater in late September when aphid populations were declining. A fungal epizootic in September, which spread rapidly in the densely packed populations, was the main factor limiting aphid numbers in the sprayed plots. Predator populations also increased in the sprayed plots in the latter part of the year.

On unsprayed plots, populations of *A. rubi* were slightly greater on cv. Malling Promise than on cv. Malling Jewel. Populations of *A. rubi* were greatest on the lower leaves of cultivars Malling Promise, Malling Admiral and Glen Clova but on the upper leaves of Malling Jewel.

(A. T. Dickson)

#### *Control of the spread of non-persistent viruses in lilies*

The effects of a barley barrier crop and a weekly spray of 1% Albolineum were compared separately and in combination in a field experiment on the spread of the non-persistent aphid-borne tulip breaking and lily symptomless viruses. The results are summarized in the Virology Section report.

(J. A. T. Woodford, W. P. Mowat<sup>1</sup>)

<sup>1</sup>Virology Section.

## Farm and Experimental Crops

W. I. A. JACK

The only features seriously to mar what otherwise was a very favourable farming year were escalating costs and material and labour shortages; although these difficulties have been with us for some time, the financial problems became particularly acute this year due to the enormous increase in oil prices which affected the cost of all goods and services. However, SHRI was more fortunate than some in this respect as record yields of barley and fruit, together with higher market prices, helped to redress the financial balance.

Farm crops included 5 acres (1.6 ha) field beans, 70 acres (28.3 ha) barley, 29 acres (11.7 ha) hay, 15 acres (6.1 ha) winter wheat, 12.25 acres (5 ha) permanent grass, 2 acres (0.8 ha) potatoes, 18 acres (7.3 ha) fallow.

A mild and wet first quarter to the year resulted in a late start to planting spring crops. Field conditions improved towards the end of March and field beans sown on 24 March, over a month later than the previous year, grew well producing a good crop of 35 cwt/ac (4.4 t/ha) when combined on 4 October.

Barley sowing was completed by 2 April, the latest sowing date for 10 years; establishment and growth were good, and the crop was affected little by the weather with only one field lodged and mildew (*Erysiphe graminis*) incidence the lowest for some years. The only problem encountered was sparrow feeding damage which is becoming more widespread. Combining started on 19 August about a week later than the previous year and, although interrupted by broken weather and uneven ripening, an excellent harvest was completed by 27 August. Yields off the combine averaged 48.8 cwt/ac (6.1 t/ha), an increase of 7.5 cwt/ac (0.9 t/ha) on the previous year, with the best field giving 68.2 cwt/ac (8.6 t/ha); quality and nitrogen content was such that all went for malting.

Hay cutting started on 14 June and although rain on 17 June held up operations, baling was completed by 28 June. The yield of 80 cwt/ac (10 t/ha) was an increase of 19.6 cwt/ac (2.5 t/ha) on the previous year.

Winter wheat combined on 11 September yielded 42.1 cwt/ac (5.3 t/ha), 9.1 cwt/ac (1.1 t/ha) less than the previous year, due mainly to a widespread attack of a black mould. The potato yield showed an increase on 1973 at 20.5 ton/ac (28.8 t/ha); good grading standards produced a higher return, which careful dressing deserved.

Field experiments included 37.75 acres (15.3 ha) raspberries, 6.5 acres (2.6 ha) strawberries, 12.5 acres (5.1 ha) black currants, 1.25 acres (0.5 ha) blackberries, 1.0 acre (0.4 ha) blueberries, 14.0 acres (5.7 ha) vegetables, 7.0 acres (2.8 ha) potatoes, 2.0 acres (0.8 ha) nursery crops, 2.75 acres (1.1 ha) ornamental bulbs, 2.25 acres (0.9 ha) other crops; this shows an increase of 3.0 acres (1.2 ha) upon the previous year.

Strawberry picking started the soft fruit season on 1 July, followed by raspberries on 11 July, black currants on 26 July, blackberries and blueberries on 16 August and finally cranberries on 29 September. Losses through botrytis were negligible, but high winds on 20 and 21 July caused considerable damage to exposed raspberry plantations. However, in spite of this setback, the yields were considerably higher than previous years and included 51.1 tons (51.9 t) raspberries, 14.7 tons (14.9 t) strawberries, 0.4 ton (0.4 t) black currants.

Calabrese maintained its popularity as a fresh vegetable locally and a supply was offered twice weekly to the local vegetable market from July to October. Vegetable trials also provided small quantities of beetroot, Brussels sprout, cabbage, carrot, leek and onion, all of which were marketed locally.

General estate work included the routine maintenance of lawns, fences, dykes, windbreaks and roadways. Amenity plantings were made round the new laboratory block and a new lawn was sown to improve the appearance of the site in time for the official opening. The Institute is grateful to Mr E. E. Kemp of the Dundee Botanical Gardens for help with plant material and the laying-out of the ornamental borders.

The estate was enlarged by 1.7 acres (0.7 ha) when Kingoodie field was acquired from Perth County Council. A clearing operation was started and steady progress made towards having the field ready for cropping in 1975.

New farm equipment acquired during the year included a grass cutting machine, a spiked rotary cultivator with crumbler attachment, a spring-tine raspberry cultivator, and a bale transporter designed and built by the farm workshop staff.

Although there were several vacancies on the estate staff a high standard of service was maintained and a large and varied programme of work was accomplished.

## Glasshouse Section

J. CANTWELL

Because of the need to reduce expenditure, a considerable amount of maintenance and renovation work normally placed with outside contractors was done during the year by the glasshouse staff, thereby extending their experience and interest, while helping to keep down costs.

It has always been the policy of the Section to have at least one construction project in hand and the 120 kph winds of mid January provided the work for 1974 when one very old Dutch Light house was blown down and required replacing. Also, the opportunity was taken to replace the four Plant Breeding 'Bee Houses' whose roofs of small glass panes were always susceptible to wind damage and expensive to maintain, so in all five new Dutch Light houses were erected. Only three of the 'Bee Houses' were demolished, the fourth being retained as an isolation/quarantine house and this was re-roofed with Dutch Light glass clipped into aluminium glazing bars left over from a more sophisticated structure. Funds were also made available in 1974 to extend the Mycology Section aluminium glasshouses to the road line envisaged in the definitive plan for the glasshouse area. This was a combined operation with a local builder putting in the foundations, the Glasshouse Section erecting and glazing the structure and the Maintenance Section installing the environment control equipment.

Because of staff shortages, the full construction programme and the changes in management policy, the experimental programme was extremely limited. It was shown, however, that the virus-tested raspberries propagated from root cuttings could be potted into re-cycled peat/sand compost and successfully grown on to the field planting stage. As up to 20,000 plants are produced annually in this programme this will mean a noticeable saving of raw materials.

Glasshouse Whitefly (*Trialeurodes vaporariorum*) is now a serious pest at SHRI and various methods of control are being investigated. From January to March 1974 in conjunction with the Zoology Section the possibility of biological control by *Encarsia formosa* was investigated. It was concluded that this method of control poses severe problems in research glasshouses and is not entirely satisfactory at SHRI for three reasons. Firstly, the high temperatures necessary for sustaining *Encarsia* populations are not always attainable in the older glasshouses, or the associated heating costs may not be economically acceptable. Secondly, both daylength and light intensity may be below the levels necessary for *Encarsia* development for all but 5 or

6 months of the year. Finally, the whitefly populations necessary to maintain an adequate *Encarsia* population are unacceptable in the glasshouses used for plant virus work. The smoke formulation of the insecticide Resmethrin was tested against Glasshouse Whitefly, under SHRI conditions. Control of whitefly was ineffectual and at low concentrations of the insecticide several plant species were damaged. The situation is being kept under constant review.

Mites of the *Bryobia praetiosa* complex (Kock) were seen on Brussels sprout seedlings in 1973 and again in early May 1974, in an unheated glasshouse. In early June, damage was severe enough to necessitate control of the mite, and this was obtained with two sprays of malathion at 7-day intervals.

Two members of the Glasshouse Section attended a training course on the use of the fork lift truck and the Glasshouse Manager attended a course on Decision Making and Delegation. It is hoped that in-post training will become a much more prominent feature within the Section, especially when a proposed re-organisation becomes effective. All members of the Section contributed to an exhibit for the Open Day in July illustrating the raspberry root propagation technique.

## Information Services

R. J. A. EXLEY

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In July, the inauguration of the new laboratories provided an opportunity to demonstrate, by means of manned static exhibits and guided tours of some of the field experiments, the very wide spectrum of research done at the Institute. It was the first occasion of its kind in the history of the Institute and as well as the very genuine interest shown by the official Opening Party there was a rewarding response on the day following when over 1,200 members of the public came to visit. Not surprisingly, the event created an unprecedented work load on the Visual Aids staff although financial constraints somewhat restricted the choice of media and style of presentation of information.

If a good standard of technical competence is to be maintained, staff in support roles require time to meet with others of similar professional interests and the opportunity for further education concerning new methods and materials. Despite the problems raised by the continuous requirement for service from such staff, the Senior Photographer and Illustrator were able in 1974 separately to attend different trade exhibitions in London and together to attend a 4-day symposium in Aberdeen organised by the Institute of Biological Illustration.

### *Library*

Library finances again were severely restricted during 1974 and the purchase of only four books and one new journal subscription were sanctioned. Internal borrowing was similar to 1973 although the number of external loans rose slightly both from the British Lending Library and other sources.

A new method of distributing reprints was proposed in an effort to economise on the number of reprints purchased. Evaluation of the scheme by the Virology Section was commenced towards the end of the year and although first results appear to be favourable the final outcome is awaited with interest.

(Margaret Mitchell)

### *Visual Aids*

The demand for applied photography has continued to increase with the commencement of several new research projects. A false colour technique for the assessment of tulip ground cover proved successful, and this has been standardised for routine field work. A preliminary investigation into the

recording of nematode feeding behaviour has produced encouraging results; further work in this area will include time lapse cinematography and possibly video-recording. Photography of ultra-violet fluorescing gel diffusion plates, aphid instar development and stereo photography of raspberry canes were also investigated.

Much of the routine photography is now restricted to the 35 mm format and has resulted in financial savings particularly at a time when the cost of photographic materials has increased by 50%. Despite the reduction in film size, quality has been maintained through the use of improved equipment and materials.

The new Visual Aids suite, with 120 square metres of floor space, permits more efficient equipment usage, with facilities for permanent sets if necessary. Darkroom facilities are improved with a forced air heating and ventilation system giving safer, more comfortable working conditions. The increased floor space was a great asset when preparing for the Open Day; eighteen exhibits were produced in the 6 weeks before 13 July. As this was the first public Open Day for 18 years a great deal was learned, which will be of considerable value when the next event of this type is staged.

As a result of improvements in lecture illustration many enquiries have been received regarding the production of slides. Details of the process used at SHRI have been sent to Nigeria and Italy, as well as to interested parties in this country. Further improvements in this area will be possible when a better quality typewriter is available.

During the year 372 jobs were completed, requiring a total of some 1,500 negatives and transparencies. The printing of electron microscope plates which is a service required by the Virology and Zoology Sections, remained much the same as in 1974 with 3,000 prints.

(J. I. Campbell)

## Scottish Horticultural Research Institute Association

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The Association was formed to promote the interchange of information between the Institute and the horticultural industry; membership is on an individual or corporate basis. A Bulletin is published at irregular intervals and the articles are intended to communicate the results of experimental work, sometimes at an incomplete stage, between research workers and growers.

Exhibits prepared by all Sections of the Institute on the occasion of the inauguration of the new laboratories on 13 July provided members for the first time with the opportunity to view and informally discuss with staff the whole spectrum of their work. During the afternoon, however, there was no break with tradition when the membership took the opportunity to view in the field the soft fruit cultivar trials. The occasion was also marked by the publication of a Bulletin which contained review and scientific articles representative of the contributions to knowledge and scientific achievements made by the Institute in the 21 years since its incorporation.

### *Bulletin No. 8 (April 1974)*

Papers presented at a meeting on 'The Mechanical Harvesting of Raspberries' held by the Association on 15 November 1973.

Raspberry production for mechanical harvesting in N. America *by* P. D. Waister, pp. 4-10.

Raspberry mechanical harvesters in America *by* A. M. Ramsay (National Institute of Agricultural Engineering S.S.), pp. 11-15.

Engineering problems associated with mechanical harvesting of raspberries in Scotland *by* G. Gilfillan (National Institute Agricultural Engineering S.S.), pp. 16-26.

Raspberry production for machine harvesting *by* M. R. Cormack and P. D. Waister, pp. 27-33.

Breeding raspberries for machine harvesting *by* D. L. Jennings, pp. 34-37.

Some economic implications of harvesting raspberries by machine *by* Edith Wright (East of Scotland College of Agriculture), pp. 38-44.



SHRI-The Genesis by C. E. Taylor, pp. 3-7.

Crop growth in the northern environment by P. D. Waister, pp. 8-18.

Achievements and objectives in soft fruit breeding at the Scottish Horticultural Research Institute by C. North, pp. 19-26.

Soil-borne viruses by B. D. Harrison, pp. 27-36.

Viruses affecting raspberry in Scotland by A. F. Murant, pp. 37-43.

Recent developments in nematocidal research by D. L. Trudgill and T. J. W. Alpey, pp. 44-48.

Problems of seed quality and field establishment by D. A. Perry and T. W. Hegarty, pp. 49-55.

Detection of soil-borne plant pathogens by M. C. M. Pérombelon and J. M. Duncan, pp. 56-59.

## Meteorological Records 1974

D. K. L. MACKERRON, G. NICOL

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### MYLNEFIELD

#### *General*

Since 1968, weather data from Mylnefield have been compared with the average from the 15-year period 1954-1968. Six more years' recordings have been made since then and it has been decided to refer data to an average which is reasonably current and which is taken over a sufficiently long period to minimize the influence of any one year. Averages have been reworked therefore for the period 1954 (when measurements began) to 1974. The contents of the table of weather data have also been changed in part. The soil temperature at 0.1 m has been included as has an estimate of evaporation (after Penman). Wind records are presented as an average speed for the month rather than as total windrun in the belief that these figures are more readily appreciated.

#### *Wind*

Windspeed over the year was about 11% above average, with January and December being the windiest months. May and July also had much higher than average windspeeds, and in particular, strong winds gusting to 60 km h<sup>-1</sup> on 28 May caused soil blow on light soils.

#### *Temperature*

The mild weather of January and February meant that the winter 1973-1974 was the third mild winter in succession. December 1974 has also shown higher than average maximum and minimum temperatures. Summer weather which was slightly cooler than average was followed by a cold September and October.

#### *Rainfall*

Above average rainfall in the first 3 months of the year probably meant that the soil was at field capacity at the beginning of April. Thereafter until August and again in October rainfall was below average. The estimated\* soil moisture deficit during the growing season reached a peak of 107 mm in the first week of August.

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\* 'Potential Transpiration.' Technical Bulletin No. 16. MAFF (1967).

## Sunshine and Radiation

The first 3 months of the year were rather dull, but thereafter the weather was generally sunnier than average. In particular this April was the sunniest since 1967 and June which was also much sunnier than average had the highest receipt of Total Solar Radiation in any month since June 1968

## MYLNEFIELD 1974

Month	Daily Air maxima		Daily Air minima		Accumulated Day-Degrees		0.1m Soil		0.3m Earth		Days Ground Frost	Potential Evaporation mm	Rainfall		Bright Sunshine		Mean daily Solar Radiation		Windspeed	
	Mean °C	DFA*	Mean °C	DFA*	Above 6°C	Below 6°C	Mean °C	DFA*	Mean °C	DFA*			Total mm	DFA*	Total h	DFA*	mWh cm <sup>-2</sup>	Mean km h <sup>-1</sup>	DFA	Mean km h <sup>-1</sup>
January	8.0	+2.6	2.6	+2.6	25	47	3.2	+1.8	4.2	+1.9	20	15.9	97.9	+37.5	39.3	-13.0	36	20.5	+7.9	
February	6.9	+1.2	2.2	+2.1	14	49	3.0	+1.5	4.6	+2.1	18	11.0	50.1	+6.7	62.9	-15.9	96	13.7	+2.0	
March	6.9	-1.1	2.3	+0.7	10	61	3.5	+0.3	5.0	+0.7	14	23.2	49.0	+5.9	88.8	-16.2	163	11.6	-3.1	
April	10.9	-0.3	3.0	-0.1	53	26	7.4	+1.2	8.0	+1.1	13	51.4	11.3	-29.6	180.6	+18.8	358	9.4	-5.5	
May	13.7	+0.4	6.0	+0.2	113	9	10.3	+0.2	10.3	-0.4	10	84.5	52.0	-6.7	187.9	+7.6	485	15.2	+3.1	
June	16.7	+0.4	7.8	-0.6	174	0	14.0	+0.2	13.2	-0.3	0	96.4	46.9	-4.3	206.5	+26.0	522	11.4	-0.6	
July	18.1	-0.1	9.3	-0.6	232	1	14.3	+0.7	14.9	-0.1	0	96.6	47.4	-19.1	182.9	-10.0	435	13.6	+2.8	
August	18.4	+0.6	9.1	-0.8	234	0	13.8	+0.1	14.3	-0.3	0	72.8	50.0	-23.6	156.0	+7.1	345	11.8	+1.9	
September	14.3	-1.6	6.9	-1.6	141	7	9.4	-2.2	11.7	-0.9	6	42.1	57.7	+1.2	140.4	+18.9	264	11.5	+1.4	
October	10.0	-2.7	4.3	-1.8	62	21	5.7	-2.5	7.6	-2.1	15	20.5	29.4	-25.4	86.3	-5.5	135	9.8	-1.2	
November	8.3	+0.1	1.8	-0.9	21	52	3.6	-0.4	4.3	-1.2	18	4.1	78.2	+19.5	86.1	+20.9	65	14.0	+2.0	
December	8.8	+2.6	2.8	+1.9	44	44	3.9	+1.6	4.9	-0.6	17	6.9	55.1	-10.1	62.4	+19.0	38	20.3	+8.2	
TOTALS	—	—	—	—	1123	317	—	—	—	—	131	—	625.0	-45.7	1480	—	—	13.6	+1.4	

\*DFA — Deviation from average 1954-1974.

†DFA — Deviation from average 1959-1974.

Month	Mean of daily maxima	Deviation from average*	Temperature (Centigrade)		Soil Temperature at 30 cm depth		Rainfall		Sunshine	
			Highest Max. Temp.	Lowest Min. Temp.	Mean	Deviation from average*	Milli-metres	Deviation from average*	Hours	Deviation from average*
January	8.3	+2.2	11.0	-0.2	5.9	+2.0	182.7	+101.2	38	-18
February	7.9	+1.5	11.1	-0.6	5.5	+1.9	44.5	-3.8	59	-19
March	8.7	-0.1	15.1	-2.8	5.5	+0.8	33.6	-20.0	90	-15
April	13.5	+2.1	20.5	-1.1	7.2	-0.1	4.3	-47.1	226	+73
May	14.3	0.0	19.6	0.0	10.1	-0.2	52.3	-3.7	185	-9
June	17.4	+0.2	26.9	1.9	12.7	-0.4	55.6	-9.5	237	+55
July	16.4	-1.6	20.0	5.4	14.0	-0.4	59.7	-26.3	145	-14
August	17.5	0.0	20.2	4.8	14.1	-0.1	56.6	-38.6	154	+5
September	13.7	-2.3	17.1	-1.0	12.3	-0.6	107.4	-0.6	122	+5
October	10.6	-2.5	14.3	-1.7	8.8	-1.8	47.6	-57.6	109	+26
November	8.7	-0.3	12.4	-3.1	6.8	-2.0	124.1	+43.7	54	-4
December	9.4	+2.4	12.9	-0.4	6.7	+1.4	160.2	+66.2	28	-11
Year	12.2	+0.1	—	—	9.1	+0.5	928.2	+3.9	1448	+74

\*Recorded at Weather Station, Department of Plant Pathology, Auchincruive, 1954-1968.

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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, NOR 70F                        |
| Institute of Animal Physiology            | Babraham, Cambridge, CB2 4AT                         |
| Institute for Research on Animal Diseases | Compton, Newbury, Berks.                             |
| Letcombe Laboratory                       | Letcombe Regis, Wantage, Berks.                      |
| 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                       |
| Glasshouse Crops Research Institute            | Worthing Road, Rustington, Littlehampton, Sussex    |
| Grassland Research Institute                   | Hurley, Maidenhead, Berks SL6 5LR                   |
| Houghton Poultry Research Station              | Houghton, Huntingdon PE17 2DA                       |
| John Innes Institute                           | Colney Lane, Norwich NOR 70F                        |
| Long Ashton Research Station                   | Long Ashton, Bristol BS18 9AF                       |
| National Institute of Agricultural Engineering | Wrest Park, Silsoe, Bedford                         |
| National Institute for Research in Dairying    | Shinfield, Reading RG2 9AT                          |
| National Vegetable Research Station            | Wellesbourne, Warwick                               |
| Plant Breeding Institute                       | Maris Lane, Trumpington, Cambridge CB2 2LQ          |
| Rothamsted Experimental Station                | Harpenden, Herts.                                   |
| Welsh Plant Breeding Station                   | Plas Gogerddan, Aberystwyth, Cardiganshire SY23 3EB |
| Wye College, Department of Hop Research        | Ashford, Kent                                       |

*State-aided Institutes in Scotland*

Animal Diseases Research Association

Moredun Institute, 408 Gilmerton  
Road, Edinburgh EH17 7JH

Hannah Dairy Research Institute

Ayr, Scotland

Hill Farming Research Organisation

29 Lauder Road, Edinburgh EH9 2JQ

Macaulay Institute for Soil Research

Craigiebuckler, Aberdeen AB9 2QJ

National Institute of Agricultural Engineering  
(Scottish Station)

Bush Estate, Penicuik, Midlothian

Rowett Research Institute

Bucksburn, Aberdeen AB2 9SB

Scottish Horticultural Research Institute

Invergowrie, Dundee DD2 5DA

Scottish Plant Breeding Station

Pentlandsfield, Roslin, Midlothian

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