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The Scottish Horticultural Research Institute

20th Annual Report for the year 1973

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West of Scotland Unit
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Governing Body

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John Arbuckle, Esq., O.B.E.

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M. Douglas Henderson, Esq.

Ian D. Lowe, Esq.

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Robert S. M. Milne, Esq. *Resigned* March 1973

J. Philp, C.B.E., B.Sc., Ph.D., F.L.S. *Resigned* March 1973

A. Gordon Porter, Esq.

Professor W. D. P. Stewart, B.Sc., Ph.D., D.Sc., F.I.BIOL.

Professor P. E. Weatherley, M.A., D.Phil., F.R.S.E., F.R.S.

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

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M. R. Cormack, N.D.H.

J. B. Cowan, B.Sc.

P. A. Gill

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H. M. Lawson, B.Sc., M.AGR.SC., Dip.AGRIC.

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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 Mrs Janet Black

D. G. Cathro

R. J. Clark

D. Crabb

Elizabeth Lowe

Katherine R. Myles

G. C. Nicol

Heather A. Ross

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.

Eleanor Carmichael

Sheena K. Fyfe

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.

Assistants Joyce E. T. Fyffe

G. Steele

J. M. Wardlaw

Mrs Eveline M. Wiseman

West of Scotland Unit (Auchincruive)

Officer-in-Charge H. J. Gooding, B.Sc., Ph.D., F.L.S.

K. C. McConnell, S.D.H.

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.
W. R. Jarvis, B.SC., PH.D., D.I.C., 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.
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
Mrs Caroline M. Gill
Mrs Georgina A. Laing, B.SC.
Mrs Moira E. Mackenzie
Sheena McNiven

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 Eileen Harrison

Visiting Worker S. El Nagar, B.SC., M.SC.

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
Irene E. Niven

Estate

Manager W. I. A. Jack

Foreman R. W. Reid

Farm Workshop

W. R. S. Batchelor

G. W. Pollock

Glasshouses

Manager J. Cantwell

Foreman R. D. Taylor

Information Services

Information Officer R. J. A. Exley, C.D.H.

Photography J. I. Campbell, A.I.I.P.
S. F. Malecki

Graphics Maureen I. McMaster, D.A.

Librarian Mrs Kathleen J. Harrison, M.A., A.L.A.
Mrs Margaret Mitchell

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

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 Agnes 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

This year we are losing the services of three members of the Governing Body. Mr W. J. Alexander has served since 1968 and is retiring because of many commitments with his nursery business in the West of Scotland. Mr R. S. M. Milne has served the Governing Body for 12 years and his counsel and expertise, particularly in the area of flower bulb production, have been generously given and much valued. Dr J. Philp C.B.E. was appointed as a Governor on his retiral as Director of the National Vegetable Research Station, Wellesbourne; we are sorry to lose the benefit of his valuable advice and experience but the age rule of retiral deprives us of his services.

Plans for research during the next 6 years were examined by a Visiting Group constituted by the Agricultural Research Council and welcomed to the Institute on 11-13 June. The Group comprised the Hon. J. Addington (Chairman), Professor J. Colhoun, Professor A. Milne, Professor P. Wildy and Professor Watkin Williams, and were accompanied by Dr C. C. Webster, Dr J. V. Lake, Mr E. Lester, Mr G. M. P. Myers, Mr G. C. Stevenson and Mr E. S. Coltman of the ARC Headquarters staff; Dr W. M. Henderson, Secretary of the ARC, was present for the first day of the visit. The occasion provided a useful opportunity for frank discussion and an exchange of viewpoints on the Institute's affairs, and the Group are thanked for their helpful advice and criticism. The research programme generally met with the approval of the Group, who considered it to represent an acceptable balance between applied and strategic elements, and to have a content that was appropriate to the aim of undertaking scientific research for the benefit of the horticultural industry as well as maintaining particular areas of scientific expertise.

The Visiting Group also gave their support for the completion of the final stage of the Building Development Scheme which came into existence in 1967 at the instigation of the late Director, Dr C. H. Cadman. New farm buildings and glasshouses for Mycology and Plant Breeding Sections formed the initial phases of the Scheme. The next stage was the building of laboratories for Crops Research, Mycology and Plant Breeding Sections, a Visual Aids suite, and a staff restaurant on the site of the old steading; this building was virtually completed in December and it will be officially inaugurated on 12 July 1974. The rate of progress of the Scheme has fluctuated with finance made available to us through the good offices of the Department of Agriculture and Fisheries for Scotland. With the financial constraints that are in

evidence at the time of writing we are fortunate in having the Department's approval to make a start in late 1974 to the much needed library which is to be built as an east wing to the main building.

From a perusal of this report it will be evident that our research programme ranges over many crops, several different sciences, and with investigations conducted at fundamental, strategic, and applied levels. Sustaining such a broad programme, without considering the needs for expansion, is becoming increasingly difficult under present circumstances when resources, including finances, facilities and the scientists themselves, are not unlimited and indeed appear relatively to be diminishing. Thus, judgment of priorities is now a *sine qua non* of current research administration requiring the evaluation and selection of projects from among the many alternatives. The Joint Consultative Organisations have within their remit the optimization of resource allocation, as have the ARC or the Department of Agriculture for Scotland who are responsible for funding institutes and their research programmes. But decisions or recommendations by these bodies nevertheless will remain dependent on the recognition and evaluation of the present and future needs of the industry made at institute level. Thus, forecasting developments in areas where we have a research capability is a very necessary activity for the deployment of resources, which often have to be committed for several years in advance.

Several years ago it was recognised that the trend towards increasing unavailability of casual labour eventually could have serious consequences for the Scottish raspberry industry and it was decided therefore that research should be initiated on machine harvesting of the crop and on breeding new cultivars suitable for this operation. There is little doubt now that this decision was a correct one and that collaborative work with the National Institute of Agricultural Engineering (Scottish Station) on the development of a machine, and the production of new cultivars, will play an important part in the maintenance, if not expansion, of the Scottish raspberry industry. Other examples of calculated speculations made with research resources are the production and propagation of virus-tested narcissus, and the breeding of high yielding black currants with tolerance to low temperatures; both projects were established to solve recognised problems and in anticipation of benefits that will accrue from improvements in productivity in the two crops. In a different category are projects on the structure of viruses or on the genetics of brassicas; such studies not only contribute to our fundamental knowledge but are important in strengthening the basis for applied research and technological development. Moreover, such research is indispensable in maintaining and motivating the scientist's ability which is the catalyst for any successful research programme.

Several of our projects are undertaken in collaboration with colleagues in other Institutes, the Scottish Colleges, the Advisory and Development Service, Universities, commercial firms and with growers, and we are grateful to them for their willingness to help both in planning and undertaking the

work. Particularly, as an example of effective conservation of scarce resources by international co-operation, I would mention the project on tulip production undertaken in association with the Netherlands Centre for Bulb Research, Lisse.

Appointments

Dr B. Williamson was appointed as HSO in the Mycology Section in October to undertake research on raspberry cane disorders. He was previously at Aberdeen University where he held a Research Assistantship from NERC to work on the 'premature needle-cast' diseases of Corsican pine, in the Department of Forestry. Also in October, Miss Sheila Royle was appointed as SO in the Crops Research Section to assist with investigations into various aspects of soil capping.

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

Erica M. Bell	Virology Section
Sandra A. Birrell	Zoology Section
Mrs Janet Black	Crops Research Section
D. Crabb	Crops Research Section
Sylvia R. Hebbourn	Zoology Section
Elizabeth A. Lowe	Crops Research Section
Mrs Moira E. Mackenzie	Mycology Section
Sheena McNiven	Mycology Section
G. C. Nicol	Crops Research Section
R. N. Wilson	Crops Research Section

Mrs Margaret Sinclair was appointed as Laboratory Attendant in the Virology Section in September but resigned in February and was replaced by Mrs Eileen Harrison in March.

Mrs Sarah Borland was appointed as Laboratory Attendant at the West of Scotland Unit in place of J. C. Alexander.

Mrs Margaret Mauchland was appointed in August to fill a newly created typist post, and Mrs Agnes Bertie was appointed to the new Clerical Officer post in Administration.

Resignations

Miss Margaret Sedgley completed her 3-year appointment as Scientific Officer in the Plant Breeding Section and left to take up a post in the Department of Pathology of the Medical School of the University of Edinburgh. Her studies on the S-allele incompatibility system in *Brassica oleracea* have been submitted as a thesis to the University of St. Andrews for the degree of Ph.D.

In December Miss Patricia Irons resigned her appointment as Scientific Officer at the West of Scotland Unit to undertake teacher training.

The following Assistant Scientific Officers have resigned:—

J. M. Anderson	Crops Research Section
Mrs Morag Crichton	Crops Research Section

R. Crichton	Zoology Section
W. L. Dick	Crops Research Section
K. Doyle	Mycology Section
Elaine Fox	Crops Research Section
Rhonda MacLagan	Virology Section
Mrs Maureen Nicol	Mycology Section
E. Sweeney	Crops Research Section

and the following Laboratory Attendants resigned:—

Mrs Margaret Sinclair	Virology Section
J. C. Alexander	West of Scotland Unit

Visiting Workers

Miss Tunçay Cetinel from the Agricultural Research Station, Eskisehir, Turkey, worked in the Plant Breeding Section from 8 January to 25 September. Sponsored by the FAO and the British Council, Miss Cetinel worked mainly on incompatibility in *Brassica*.

Dr L. B. Forer, a plant pathologist from Pennsylvania Department of Agriculture worked in the Zoology Section for a year until September. Sponsored by Rotary International, he was engaged in research into the action of nematocides on virus vector nematodes.

Professor J. R. Bloom from the Department of Plant Pathology, Pennsylvania State University, worked in the Zoology Section for the latter half of the year while on sabbatical leave. He was engaged in research on the feeding of virus vector nematodes on seedlings growing in agar cultures.

Dr H. S. Abu Salih (Hudeiba Research Station, Sudan), sponsored by the Sudan Government, worked in the Virology Section for 6 weeks during June–July making collaborative studies with A. F. Murant on viruses infecting broad bean in the Sudan.

Research Students

S. El Nagar (UAR), sponsored by UAR Government, continued his studies on aphid transmission of some viruses of umbellifers.

Mr A. T. Dickson continued his DAFS sponsored post-graduate student-ship work in the Zoology Section upon population dynamics of aphids infesting raspberries.

Sandwich Course Students

Mr A. Paterson from West of Scotland Agricultural College assisted during July–December in many aspects of breeding fruit and vegetables.

Mr S. W. Johnson (Trent Polytechnic, Nottingham) worked during April–September in the Virology Section on meristem-tip culture of narcissus.

Courses attended

P. A. Gill of the Crops Research Section attended an ARC sponsored practical course on environmental instruments at Nottingham University School of Agriculture.

J. H. Raschké of the Virology Section attended a course, for technicians, on radiological protection.

Pauline B. Topham, J. B. Cowan and several members of staff attended a Genstat Computer Programming Course organised by the Edinburgh Regional Computing Centre.

Conferences at which papers were given

4 January	Virus Group of Society for General Microbiology, London.	
	M. A. Mayo	UV induced cross linking of RNA in raspberry ringspot virus particles.
	A. F. Murant	Protein and RNA components of tomato black ring virus.
13 March	British Crop Protection Council: second Symposium on Herbicides in British Fruit Growing, London.	
	H. M. Lawson	Weed control in raspberries and other cane fruit.
	H. M. Lawson	Programmed weed control for fruit crops.
3–4 April	ARC Plant Virus Workers Conference, Norwich.	
	B. D. Harrison	Clues from surveys.
	M. A. Mayo	Ultraviolet radiation as an aid to studying the packing of RNA molecules in virus particles.
	A. F. Murant	Membrane feeding studies with a semi-persistent virus.
	D. J. Robinson	<i>Ts</i> mutants of tobacco rattle virus.
10 April	Virus Group of Society for General Microbiology, London.	
	B. D. Harrison	Raspberry ringspot virus hybrids.
16 May	Peruvian Plant Pathologists Meeting, Lima, Peru.	
	B. D. Harrison	Soil borne plant viruses.
14 June	Association of Applied Biologists Nematology Workshop, Rothamsted.	
	C. E. Taylor	Structure and musculature of the feeding apparatus in <i>Longidorus</i> and <i>Xiphinema</i> .
9–13 July	Eucarpia Conference on 'Aseptic culture methods in plant breeding,' Leeds.	
	C. North	New <i>Lilium</i> cultivars obtained by embryo culture.

18 July	Association of Applied Biologists Summer Conference. D. L. Trudgill	Effects of nematode infection on patterns of root growth and leaf development.
28 July-5 August	Meeting of European Botrytis group, Teresin, Poland. W. R. Jarvis W. R. Jarvis	Tolerance of <i>B. cinerea</i> to benomyl Strawberry crown death.
14-18 August	Second International Symposium of the European Invertebrate Survey, Monks Wood Experimental Station. B. Boag D. J. F. Brown	Results of a survey of nematodes associated with forest and woodland trees. A preliminary report on <i>Longidorus</i> and <i>Xiphinema</i> distribution survey within the British Isles.
5-12 September	Second International Congress of Plant Pathology, Minneapolis, USA. B. D. Harrison B. D. Harrison	Hybrid isolates of raspberry ringspot virus. Specificity of retention and transmission of viruses by nematodes.
2 November	Federation of British Plant Pathologists, London. D. T. Mason A. J. Hargreaves J. M. Duncan	Observations on the incidence of spur blight and <i>Botrytis</i> cane diseases following the use of fungicides to investigate yield components. Raspberry wilt and bud death. Quantal and other assays for <i>Phytophthora fragariae</i> , the causal organism of strawberry root red core disease.
8-9 November	Institute of Food Science and Technology, Peebles. P. D. Waister	Prospects for the food crops of Scotland.
21 November	East of Scotland Bulb Growers Meeting, Montrose. W. P. Mowat	Production, propagation and protection of virus-tested stocks of narcissus.
27 November	ADAS Conference, Great Yarmouth. C. E. Taylor	Tomorrow's horticulture—fruit and vegetables.

2-9 December	3rd International Symposium on Tropical Root Crops, Ibadan, Nigeria. D. L. Jennings D. L. Jennings	The utilization of cassava variability on an international basis. Electron microscopy of cassava leaves with African cassava mosaic.
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Visits abroad

From 25 April to 11 May, B. D. Harrison (jointly with Professor R. E. F. Matthews, Auckland, New Zealand) gave an advanced course of instruction at the Instituto Venezolano de Investigaciones Cientificas, Caracas, Venezuela, to S American plant virus workers, on 'Diagnosis and characterization of plant viruses.'

Dr B. D. Harrison visited the International Potato Center, Lima, Peru, for a week in May to discuss research on viruses affecting the potato.

Dr C. North was Chairman of the Eucarpia meeting 'Genetics and breeding of muskmelon' held in June at Avignon, France.

Dr D. A. Perry visited centres of seed testing and research in Denmark, Sweden and Norway in March in connection with his work on seedling establishment and his membership of the Vigour Test Committee of the International Seed Testing Association.

In January I. M. Roberts visited Eindhoven, The Netherlands, and in February he visited Berlin, W. Germany, to test the latest models of Philips and Siemens electron microscopes, respectively.

Dr C. E. Taylor attended meetings of the Consiglio Scientifico del Laboratorio de Nematologia, Bari, Italy, in August and November.

Dr C. E. Taylor and W. M. Robertson visited the Instituut voor Dierkunde, Gent, and IPO, Wageningen, in September to discuss research in nematology.

Dr P. D. Waister visited Oregon, Washington and British Columbia during June/July to study research, development and commercial use of mechanical harvesters for cane fruits.

Exhibitions

In April, at the request of the Institute of Biology, an exhibit was mounted at Edinburgh which illustrated several of the SHRI's research projects.

At the Kirton Experimental Horticultural Station Open Days in May an exhibit was featured which illustrated the Crops Research Section investigation on weed competition in narcissus.

With the assistance of the Department of Education and Science, SHRI again provided an exhibit in the scientific section of the Royal Chelsea Flower Show. The exhibit explained aspects of research at SHRI concerned with commercial calabrese growing, and the increasing importance of the crop to Scottish horticulture.

In June a pictorial exhibit illustrating the distribution and ultrastructure of *Longidorus* and *Xiphinema* species was mounted at an Association of Applied Biologists Nematode Workshop convened at Rothamsted.

Radio and Television

Dr D. L. Jennings discussed the decision to release M14 raspberry on the BBC Scottish Region Farming Journal programme of 16 November, and all regions Farming Week programme of 26 November.

Editorial duties

- Dr C. E. Taylor Member of the Board of Editors of *Annals of Applied Biology*.
Member of the Board of Editors of *Journal of Horticultural Science*.
Member of the Board of Editors of *Nematologia Mediterranea*.
Member of the Board of Editors of *Horticultural Research*.
- Dr B. D. Harrison Editor of *Journal of General Virology*.
Editor of *Commonwealth Mycological Institute/ Association of Applied Biologists Descriptions of Plant Viruses*.
Member of Editorial Board of *Intervirology*.
- Dr W. R. Jarvis Editor and Member of Editorial Board of *Horticultural Research*.
- Dr A. F. Murrant Editor of *Commonwealth Mycological Institute/ Association of Applied Biologists Descriptions of Plant Viruses*.
Member of Editorial Board of *Annals of Applied Biology*.
Member of Editorial Board of *Journal of General Virology*.
- Dr P. D. Waister Associate Editor of *Journal of Horticultural Science*.

Awards

The Degree of Doctor of Philosophy from the University of Dundee was conferred on M. C. M. Pérombelon of the Mycology Section.

Service on committees

- Dr C. E. Taylor Journal of Horticultural Science Publications Committee.
University of Strathclyde/West of Scotland Degree Advisory Board.

West of Scotland Agricultural College Glasshouse Advisory Committee.
NFT Advisory Committee.
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.
ACAS Advisory Committee.
HEA Scottish Branch.

- Dr C. North Eucarpia Member of Board of Directors.
Eucarpia Chairman Vegetable Section.
Dundee University Botanic Garden Committee.
- Mr M. M. Anderson NFT Black currant Sub-Committee.
- Mr J. I. Campbell City and Guilds of London Institute 344/345 Objective Examination Item Writing.
City and Guilds of London Institute Item Writing Workshop.
- Mr R. A. Fox Chairman, Pathology Section EAPR.
- Dr H. J. Gooding 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.
- Dr B. D. Harrison 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.
- Mr H. M. Lawson ISHS Working Group on Weed Control in Vegetables.
British Crop Protection Council Sub-Committees, weed control meetings and publications.
Joint Consultative Organisation Member of Vegetable Committee.
- Dr J. L. Jennings NFT Raspberry Sub-Committee.
NFT Scottish Trials Committee.
SNSA—Adviser to Committee.
- Mr K. C. McConnell HEA Scottish Branch.

Dr A. F. Murant	International Organisation of Citrus Virologists Liaison Committee on Citrus and other fruit plant virus diseases.
Dr D. A. Perry	International Seed Testing Association, Vigour Test Committee.
Mr R. Thompson	ADAS Vegetable Storage Panel. NIAB Vegetable Trials Advisory Committee; Vegetable Trials Advisory Committee on Brassicas.
Dr D. L. Trudgill	Nematology Group Association of Applied Biology.
Dr P. D. Waister	Joint Consultative Organisation Member of Fruit Committee. Scottish Council/DAFS Joint Committee on Food Processing.

Crops Research

P. D. WAISTER

A record ground frost for April of -12°C on the second last day of the month provided the first opportunity for several years to evaluate critically the effects on yield of blossom damage in raspberries. Despite appreciable destruction of first formed flower buds, there was a marked degree of compensation from later developing laterals and axillary buds, and yields from protected and unprotected plots were similar. It is doubtful whether artificial frost protection for raspberries is economically justifiable in Scotland, because of the very few occasions when spring frosts of this severity are recorded in fruit growing areas.

Investigations of environmental restrictions on seedling establishment have led to the identification of soil crusting as the major factor for which quantitative information is still needed. The appointment of Miss Sheila Royle will allow this topic to be explored in depth, with the aim of complementing the continuing programme of research on direct effects of temperature and soil moisture on seed and seedling behaviour.

Apart from this project the Section's programme remains the same as in 1972, with only minor changes in emphasis.

CROP ENVIRONMENT

Crop response to shelter

For the sixth successive year, Cambridge Favourite strawberries grown in shelter produced more crowns and more trusses than when exposed, but for the first time there was no corresponding yield increase. Measurements of leaf water potential and soil water content gave conflicting results. There may be a link between the yields in this experiment and the unusually large response to irrigation obtained in the experiment reported below assuming sheltered plants were using more water than exposed plants at a critical period for flower initiation or fruit set.

Stereoscan observations of the epidermis of wind rubbed strawberry leaves showed considerable disruption of the wax-like reticulum accompanied by an apparent loss of cell turgor.

A shelter experiment to measure the response of 10 strawberry cultivars and seedlings produced increases in crown numbers in most cultivars but no yield increases. With several cultivars there was an indication of an adverse

effect of shelter on yield. Until these effects are better understood it is probably prudent to assume that experience with Cambridge Favourite should not be extrapolated to other cultivars. (This also applies to two other aspects of its behaviour, its response to defoliation and its susceptibility to crown death).

Pilot experiments on French beans and carrots indicated yield responses to shelter in both species. Extensive leaf damage was shown in exposed beans but not in carrots.

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

Irrigation and water use

Yields of unirrigated strawberries (Cambridge Favourite) were compared with those from plants irrigated at pink fruit stage, and from plants irrigated whenever soil moisture tension reached 30 cm as measured by a mercury manometer. The two irrigation treatments gave yield increases of 19% and 23% respectively but these were not attributable to larger berries, suggesting that the response to the pink fruit irrigation may have been a carry-over effect from the same treatment in the previous year.

In the first year of a similar irrigation experiment in raspberries, yields were unaffected by treatment, and increases in cane growth were not statistically significant despite evidence of lower leaf water potentials in the control plots. Soil moisture changes in the root zone were monitored with a neutron probe. Though irrigated plots lost more water than controls, the drainage and evaporation components could not be separated. However, in this relatively dry season, drainage losses in the controls probably were negligible and the ratio between soil moisture depletion in the root zone and evaporation estimated by the Penman formula could be computed. Between the end of April and the middle of July the ratio doubled, reflecting the change in leaf area as young cane developed. Further refinements in soil moisture measuring techniques are needed before absolute values for the ratio can be used in estimating irrigation need. Both the trickle irrigation and the wide row arrangement of raspberries lead to lateral and vertical variation in soil moisture content.

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

Flower blindness in narcissus cv. Double-White

It has been suggested that the incidence of flower 'blindness' in this cultivar is affected by planting depth. Temperature regimes of bulbs planted at 3 in, 6 in and 9 in depths have been recorded over a 2 year period, but during that time flower blindness has been insignificant. However, a 33% reduction in flower yield between 3 in and 9 in planting does not support the idea that this cultivar should be planted more deeply than others.

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

Low temperature injury in raspberry

For the first time since a sprinkler frost protection system for raspberries was installed in 1970, a severe ground frost (-12°C) occurred during late spring, after fruit buds had appeared. Records taken a few days after the frost showed that the survival of visible buds was 20% greater with protection; the earliest flower buds suffered most damage, and the less mature axillaries the least.

A survey of buds during July showed a marked recovery in unprotected plots with the development of secondary laterals and more axillary buds. This resulted in similar total fruit yields from protected and unprotected plants. The greater proportion of damage to the first-formed buds was verified at the first harvest, when the protected rows gave 30% more fruit than the control.

A portable frost chamber was constructed to investigate the role of low temperature in bud failure and 'dieback' in raspberries. The cylindrical chamber has hollow walls containing industrial alcohol cooled by tubes through which liquid nitrogen is pumped. The chamber is placed over raspberry canes in the field and the cold treatment applied by regulating the flow of liquid nitrogen. Samples of canes are being subjected to a minimum air temperature of -8°C for 5 hours at weekly intervals throughout the winter. Pith and bud temperatures are monitored with thermistor probes, and will be related to the subsequent growth of canes and buds.

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

Low temperature injury in strawberry

Artificial frosting of Cambridge Favourite strawberry plants in the field was carried out throughout the winter of 1972-3, using a portable frost chamber, with a mean cooling rate of $3-4^{\circ}\text{C h}^{-1}$. The two treatments applied to the crop at weekly intervals were equivalent to the lowest ground temperature recorded over the last 20 years, and the lowest recorded minimum ground temperature for the month of treatment.

Fruit yields were greatly reduced in plants exposed to the 20 year minimum, especially in early and late winter. Often this was accompanied by an increase in vegetative growth. Effects of exposure to the monthly minimum temperature were small.

Pith browning was evident in those crowns not killed outright, but the symptoms differed from the crown necrosis commonly found in the field in Cambridge Favourite. Frequently there was a pronounced line of demarcation between dead and living tissue, with little or no intermediate damage.

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

Soil conditions and field emergence:

Continuous sowing experiment

Seeds of seven crop types (Brussels sprouts, cabbage, calabrese, carrot, cauliflower, onion, red beet) were sown at approximately weekly intervals

over a period of 18 weeks commencing 13 March. The results confirm those obtained in previous years suggesting that there is no simple relationship between soil temperature and final emergence percent. As in previous years there was a striking linear relationship in all crops between rate of emergence and soil temperature, approximately 80% or more of the variation in rate of emergence being accounted for by this single factor.

(T. W. Hegarty)

Seedling establishment and soil treatment

Seeds of calabrese and of carrots were sown by hand on six occasions in 1973: 21 and 30 March, 16 April, 2, 14 and 28 May. Soil was removed to a constant depth and then replaced after sowing (control, C), replaced and rolled (R), replaced and sprayed with Huels 801 soil stabiliser (Huels UK) at a rate of 30g emulsion in 2 l/m² (S) or replaced by vermiculite and rolled (V). Seedling emergence was counted at intervals until maximum establishment. Mean emergence over all treatments and over the six sowing occasions was 88% for the calabrese and 79% for the carrots. There was no overall significant effect of soil treatment but there was a highly significant interaction between soil treatment and sowing date. At the second sowing, emergence from the C and R plots was 93% for calabrese and 79% for carrots, from the S plots 78 and 70%, and from the V plots 65 and 76%. Under the dry and windy conditions following this sowing it appears that the soil stabilizer caused soil crusting and reduced emergence, whereas in the V plots the dry vermiculite may have competed for moisture causing a reduction of almost 30% in the emergence of the fast-germinating calabrese seeds.

The sixth sowing was followed 2 days later by heavy showers (total 11 mm), a period of light rainfall for 4 further days, and then by consecutive days without rain. Emergence from the C, V, S and R plots was 87, 97, 83 and 82% respectively for calabrese and 72, 83, 81 and 60% for carrots. There was evidence of slight soil crusting effects in the control plots. Emergence from the vermiculite plots was very high under these conditions.

(T. W. Hegarty)

Seed quality in calabrese and leeks

Twenty seed lots of calabrese were sown in the field on four occasions, 6 March, 2 and 24 April, 16 May, and nine seed lots of leeks were sown on three occasions, 26 February, 14 March, 2 April. Laboratory germination of the calabrese was between 76 and 100%, and of the leeks between 82 and 96%. The field factor (*i.e.* proportion of viable seeds that emerged in the field) for the calabrese seed lots ranged from 0.17 to 0.92 (mean of sowings 1 and 2) and from 0.40 to 0.91 (mean of sowings 3 and 4). The use of covariance analysis indicated that differences in field factors between seed lots was not due to differences in seed size. Field factors for the leek seed lots ranged from 0.52 to 0.77 (mean of sowings 1 and 2) and from 0.38 to 0.72 at sowing 3. Differences within the calabrese and leek seed stocks were considered to

represent differences in seed quality, a factor needing to be taken into account with direct drilling.

(T. W. Hegarty)

Effect of seed source, seed size and depth of sowing on establishment of carrots

Carrot seed of the same initial stock but grown on in different regions of the USA, California (C), Idaho (I) and Washington State (WS), was obtained for an investigation of the effects of seed source on seed quality. To test for the possible interaction in the field between seed size, sowing depth, and seed quality, two size grades of seed were sown at 1 or 2 cm depth. Laboratory germination of the different stocks and grades of seed varied from 79 to 85%. Establishment (the expression of seed quality) was measured as the fraction of viable seeds sown that produced plants at harvest. All seeds were dressed with captan and were sown into dry soil on 11 April. There was a significant difference in establishment between seed lots ($P < 0.05$). This was related to a significant interaction ($P < 0.05$) between source and sowing depth in which the establishment fractions of the seed lots C, I and WS were 0.50, 0.55 and 0.54 sown at 1 cm, and 0.45, 0.49 and 0.38 respectively sown at 2 cm. Establishment of large seed was better than that of small and this advantage was significantly greater at 1 cm than at 2 cm. There was no significant seed source/seed size interaction. The results show that though seed quality in carrots may be affected by seed source, the magnitude of the effects on field establishment varies with seed environment. Seed size was shown, under these experimental conditions, to be an important additional aspect of seed quality, though unrelated to seed source.

(T. W. Hegarty)

Field beans

Reported effects of seed treatment and plant topping on seed production were investigated. Seed of the cultivars Herz Freya and Ostlers (0.42 and 0.70 g per mean seed weight respectively) were soaked in vitamin B₁₂ solution (100 µg l⁻¹), in water or left unsoaked; after 48 h the beans were dried in a forced draught without heating. Severe damage to a number of beans due to cracking of the cotyledons subsequently affected field emergence and growth. The seeds were sown on 5 March and emergence was first noted in the last week of March. Seedlings of Herz Freya emerged faster than those of Ostlers and control seedlings (C) faster than those of soaked seeds (S). Plants from soaked seeds did not differ in attributes and are considered collectively. Emergence of C and S were 87 and 46% for Herz Freya, and 81 and 62% respectively for Ostlers by 13 April. Plants were topped on 29 June when the height of treatment C was 1.35 m and for treatment S, 1.23 m in Herz Freya, and 1.40 m and 1.33 m respectively in Ostlers. Topping reduced plant height by approximately 200 mm and resulted in a yield reduction of 11%. This loss of yield was due to a reduction in the number of

Pods per stem in Herz Freya, but to a reduction in seed weight in Ostlers. Soaking reduced yield by 18%. The lower plant stand in S plots was not compensated by tillering, but the number of pods per stem increased from 7.4 to 10.3 in Herz Freya. Ostlers outyielded Herz Freya by 21%. Although the number of beans per pod was higher in Herz Freya than Ostlers, this was offset by a higher seed weight in Ostlers. The results suggest that topping may have removed some of the potential pod bearing nodes in the case of Herz Freya, whereas it may have removed photosynthetic material contributing to seed yield in the case of Ostlers.

(T. W. Hegarty)

WEED INVESTIGATIONS

Weed competition

Appreciable decreases in yield of fruit and production of young canes in the first cropping year resulted when raspberry plants cv. Malling Jewel were exposed to weed competition for varying periods during the year of establishment (1972). The presence of weeds during the first 8 weeks after planting had no adverse effect on fruit yield, provided the weeds were then removed. Delaying weeding for a further 4 and 8 weeks resulted in yield reductions of 50% and 74% respectively. Weed growth left undisturbed throughout the growing season killed many plants and reduced fruit yield in 1973 by 90%. Measurements of cane production at the end of 1973 indicated that the carry-over effect of the first year's weed competition was likely to persist into the 1974 harvest.

Competition between transplanted spring cabbage cv. Early Offenham and a pure stand of overwintered chickweed (*Stellaria media*) resulted in a yield reduction of 42% of marketable heads cut in mid June. Removal of chickweed in another experiment left a flora dominated by a late winter germination of fumitory (*Fumaria officinalis*), which resulted in a reduction in crop yield of 62% compared with 75% on totally unweeded plots.

Narcissus cv. Carlton planted in early October 1972 were kept either weed free or allowed to compete with the natural spring germinating weed flora from late March until early August 1973. The yield of bulbs lifted in August was 36% lower on weedy plots.

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

Herbicide evaluation

Very dry weather in late winter/early spring 1972-73 emphasized the need for effective selective post-emergence contact or translocated herbicides for a wide range of horticultural crops. Comparison of a number of herbicide programmes for canning carrots showed that trifluralin incorporated before drilling followed by prometryne, metoxuron or linuron applied when the

carrots had reached the two rough leaf stage, gave the best levels of weed control. The spring drought made surface-applied pre-emergence herbicides relatively ineffective, with the result that fumitory and knotgrass (*Polygonum aviculare*) were too large for satisfactory control by post-emergence herbicides by the time the crop reached the two rough leaf stage.

In leeks cv. Malabar, dry soil conditions also resulted in failure of pre-emergence herbicides; emergence was slow and erratic, and there was already considerable weed competition by the time the majority of the crop plants had reached the three leaf stage. Ioxynil plus linuron applied at this stage, followed by methazole 11 days later, gave the most effective weed control, but the former application caused some crop injury. All other combinations of herbicides used gave either poor weed control or injured the crop.

Weeds in peas cv. Sprite were more effectively controlled by cyanazine than by other available pre-emergence herbicides. Bentozone plus MCPB was compared with dinoseb-amine as a post-emergence treatment and gave very satisfactory weed control without crop injury, and at a 50% rate was very effective as a supplementary treatment on plots already treated with pre-emergence herbicides.

In an experiment comparing cyanazine and desmetryne applied in early March, April and May for weed control in transplanted spring cabbage cv. Early Offenham, desmetryne was slightly more effective at all dates. Though both herbicides initially gave good control of chickweed and fumitory, sufficient plants survived to interfere with crop harvesting. However, results showed that either herbicide could be used to save a crop in which early spring weed growth threatened to cause crop suppression.

Knotgrass was the main resistant species in narcissus cv. Carlton treated with a range of herbicides during flowering. Only metribuzin gave better control of this weed than the standard pyrazone/chlorbufam. Both metribuzin and metoxuron produced yellowing of crop foliage and slightly reduced the weight of bulbs lifted in early August, but no visible evidence of damage was found when bulbs were subsequently forced. Bentozone had no adverse effect on crop foliage or bulb yield and produced no visible symptoms in forced bulbs.

These three herbicides were also evaluated in established strawberries cv. Cambridge Favourite as possible post-emergence treatments for the control of spring-germinating weeds. All three, particularly metribuzin, injured the crop plants, reducing fruit yield and the formation of new crowns.

Metribuzin also proved too injurious to young raspberry canes for use after spawn emergence. Directed application of glyphosate along the base of raspberry canes cv. M. Jewel in early March before bud-break subsequently resulted in yellowing and distortion of laterals at the top of the fruiting cane, although similar treatment using paraquat had no adverse effect. Results suggest that glyphosate is too readily translocated for safe use in the raspberry crop, even during winter.

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

Raspberry management

Contact herbicides have not proved effective for sucker control in raspberry plantations, and translocated herbicides have been avoided because of the danger of movement to the cane row. An uncultivated plantation of M. Jewel was disced to a depth of 8 in (20 cm) close to the row either once in early spring or several times during spring and early summer, over a 4 year period, without adverse effects on fruit yield or cane production. An experiment in 1973 indicated that this treatment was effective in preventing the movement of translocated herbicides from treated suckers to the cane row.

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

Weed control in the crop rotation

Investigations into soil residues following the use of herbicides in raspberries have been reduced and now involve routine monitoring of previous trial sites for injury to following crops.

A number of long term experiments on the effects of crop rotation and weed control systems on weed seed populations have been initiated.

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

VEGETABLE CROPS AND FLOWER BULBS

Calabrese: cultural techniques

Rex, the most widely grown cultivar in Scotland, and a promising F_1 hybrid Corvet were grown either on the square or in 24 inch rows at populations ranging from 1 to 16 plants/ft². The maximum yield of Rex (3.2 ton/ac) was obtained at a population of 2.5 plants/ft², but Corvet reached its peak (3.6 ton/ac) at 9 plants/ft². In neither case did spatial arrangement affect yields at these populations. Over the whole population range, yields of Rex were unaffected by plant arrangement, but in the case of Corvet low populations favoured the square spacing and high populations the rectangular.

Corvet was sown on 19 occasions at weekly intervals between 28 February and 4 July. The number of days to 50% maturity declined almost linearly from 132 days to 87 days between the first sowing and the 9 May sowing. For sowings between mid May and 20 June values were constant at about 83 days. Maturity of subsequent sowings was progressively delayed, those after the end of June producing only small crops.

(R. Thompson and H. Taylor)

Red beet: production for processing

'Seeds' of a multigerm cultivar Avonearly and of a monogerm cultivar Monoking Explorer were sown with a Stanhay precision drill at low (*ca.* 4 plants/ft²) and high (*ca.* 9 plants/ft²) density. Seedlings were tagged on the

day of field emergence and, once establishment was completed, interplant distances within each row were recorded. Seedling size at emergence was not assessed. At harvest individual roots were lifted and weighed. Initial analysis of the results shows no correlation between root size and either date of emergence or interplant competition as assessed on a seedling distance-to-neighbour basis.

(T. W. Hegarty and R. Thompson)

In studies on cultural factors affecting variability in root size, attempts have been made to induce controlled variability. With cv. Boltardy and Avonearly effects of sowing differing proportions of seed between the inner and outer rows of a three row 'minibed' were examined and also the effect of removing 10 in lengths of minibed at 16 in intervals. Populations of 10 and 25 plants/ft² were used and preliminary results show that although a bimodal size grade distribution was obtained from certain treatments, effects were small, and thus consistent with the results on spatial distribution recorded in the project above.

(R. Thompson and H. Taylor)

Brussels sprouts: cultural factors and genotype efficiency

Cv. Peer Gynt was sown in rows 24 in apart to give populations of 0.5, 1.7, 2.9 and 4.2 plants/ft² and samples destructively harvested on 5 November and 4 December 1973 and 16 January 1974. In agreement with previous findings, the number of plants contributing to yield declined as population increased. In this experiment 85% of the plants from the lowest population contributed to yield, whereas the value for the two highest populations was 45%. Total plant weight per unit area was unaffected by population at any harvest date. Yield of sound buttons declined with increase in population at the first two harvest dates, but was not significantly affected by population at the last harvest date, average yields by then being 7 ton/ac. Freezing grade buttons (0.71–1.25 in size grade) showed a similar pattern of response to that for the total yield, with an average yield of 5 ton/ac at the final harvest. When grown in wide rows, self thinning occurred in populations above about 1 plant/ft², so minimising the effects on yield of widely differing populations.

(R. Thompson and H. Taylor)

Vining peas: cultural factors and genotype efficiency

The response to competition of mutant forms supplied by the John Innes Research Institute was examined to see whether it differed from conventional cultivars. A high yielding cv. Green Shaft was compared with a leafless mutant (1) and a mutant (2) with many small leaves, at populations of 0.5, 6 and 12 plants/ft².

Initial analysis showed that total plant weight per unit area was greater for mutant (1) at the low population than that of either of the other genotypes,

but at the higher populations weights were similar for all three genotypes. As a proportion of the total plant weight, the weight of shelled peas increased as population was increased tending towards a plateau for mutant (1) and Green Shaft, but apparently still increasing at the highest population examined with mutant (2). Maximum proportions of peas to total plant weight were about 40% for Green Shaft, 35% for mutant (1) and 31% for mutant (2).

Effects of population on average pea weight were small and the value for this character was greatest for Green Shaft (0.618 g) and least for mutant (1) (0.501 g) with mutant (2) (0.545 g) intermediate in value. The number of pods/plant declined with increasing population but was in general greater for the two mutants than for Green Shaft. However, because the number of peas/pod was greater for Green Shaft (5.6), than for either mutant (1) (4.0) or mutant (2) (3.8), the number of peas/plant and hence per unit area was greater for Green Shaft than for either mutant.

(R. Thompson and H. Taylor)

Field beans: growth and yield analysis

In a sowing date experiment, plots sown on 23 February, 8 March and 22 March all yielded about 40 cwt/ac, but delay until 6 and 19 April decreased yields to 36 and 28 cwt/ac respectively.

The growth and development of the cultivar Herz Freya were recorded in plots sown on 7 March at a density giving 6 plants/ft². Preliminary analysis shows that leaf area reached a peak in late July, dry weight per plant and fresh weight of beans were at their maxima by early August, but the maximum dry weight of beans was not reached until the end of August. Between 21 June and 10 July, the balance between pods set and those retained became constant at about 10/plant. Yield at 15% moisture was at the rate of 46 cwt/ac.

Three cultivars, Maris Bead, Herz Freya and Ostlers were each grown at populations of 1, 6, 11 and 16 plants/ft². The optimum spacing was 6/ft² for all cultivars and respective yields were 44, 48 and 54 cwt/ac. Though pod number was the most important factor in determining maximum yield within cultivars in response to changing populations, there were differences between cultivars in the three yield components, pods/plant, beans/pod and bean weight. The last of these was the overriding factor in yield ranking.

Samples of Herz Freya harvested on four occasions between 30 August and 23 October together with samples of Maris Bead and Ostlers harvested on 23 October were analysed for amino acids and assessed for feeding value by the Rowett Research Institute. Differences between any of the samples in either amino acid composition or in feeding value were insignificant. Feeding trials with rats gave no evidence of anomalous net protein utilisation, which has been reported previously in feeding studies of pigs.

(R. Thompson and H. Taylor)

Scottish tulips: cultural methods and forcing performance

Perhaps the most interesting result of practical significance to emerge from this year's studies on tulips came from a comparison of annual and biennial lifting. 8–10 cm bulbs of Apeldoorn, Merry Widow, Paul Richter and Aureola, planted at 174,000 bulbs per acre in 1971, were treated either conventionally and replanted in 1972 or left undisturbed in the soil until 1973. At the end of the 2 year period, annually lifted Merry Widow and Paul Richter produced many more and Aureola slightly more bulbs than when lifted biennially. Apeldoorn produced similar numbers in the annual and biennial crops. However, when considering bulbs with the highest economic return *i.e.* >10 cm in size, Merry Widow produced 60% more and Paul Richter 20% more from the biennial system. With Apeldoorn and Aureola the number of bulbs >10 cm was similar whether lifted annually or biennially.

This influence of biennial lifting is particularly significant in the case of Merry Widow and Paul Richter, both of which tend to produce too many small and too few large bulbs. An additional economic benefit would accrue from the omission of a season's harvesting, grading and storing operations.

Both mother bulb size and initial population will influence response to biennial lifting and further experiments are in progress to measure their effects.

Investigations have continued into the effects of lifting date on yield and forcing performance with the cultivars Apeldoorn, Merry Widow, Paul Richter and Aureola. Lifting in mid-June resulted in a mean yield depression of 42% relative to harvesting at maturity. However, no significant change in numbers of bulbs 10–12 cm in size occurred for Apeldoorn after 25 May, for Paul Richter after about 4 June and for Aureola after 14 June. No harvests were made between 14 June and 1 August during which time bulb numbers (10–12 cm) for Merry Widow reached a maximum.

Bulb numbers greater than 12 cm in size increased rapidly between 14 June and maturity for all cultivars except Merry Widow, which produced very few in this size grade even at maturity.

Thus to produce the maximum proportion of 10–12 cm bulbs suitable for early forcing, considerably earlier than normal lifting dates may be appropriate for certain cultivars.

Apeldoorn and Merry Widow, cultivars differing in vigour, were each grown at populations ranging from 1.4–14 bulbs/ft² from each of five bulb sizes, 2.8–47g for Apeldoorn and 1.8–37g for Merry Widow. Total yield and bulb number for both cultivars increased as population increased and also as mother bulb size was increased.

The greatest number of 10–12 cm bulbs per unit area (14/ft²) was obtained from the highest population and largest mother bulb size combination for Apeldoorn, but from the highest population and intermediate mother bulb size for Merry Widow (3.7/ft²). As a proportion of bulbs planted, the numbers harvested were about 300% and 400% for these treatment combinations respectively.

Maximum numbers of bulbs greater than 12 cm in size were obtained for both cultivars from the intermediate population, but from a smaller bulb size for Merry Widow than for Apeldoorn.

Co-operative work with the Glasshouse Investigational Unit of the West of Scotland Agricultural College is assessing the forcing behaviour of bulbs produced in these experiments, and studies on biochemical changes during the storage phase are being monitored at the University of Bath.

(R. Thompson and H. Taylor)

Potential of new vegetable crops

A range of courgette and pickling cucumber cultivars was raised under glass and transplanted out of doors on 1 June at 3 ft x 2 ft spacing. Yields of the better courgette cultivars were about 27 ton/ac (with 5.4 fruits/ft²), and of pickling cucumber 17 ton/ac (7.4 fruits/ft²). The only problem identified was cucumber mosaic which killed just under 2% of the courgette plants and weakened others.

Overwintered onions, in a collaborative project with NVRS, grew successfully, reaching maturity in late July.

(R. Thompson and H. Taylor)

FRUIT CROPS

Raspberries

National Fruit Trial

Two weather events probably influenced considerably the relative yields of of the 12 seedling lines and 7 cultivars in this experiment. There was a frost of -12°C on 29 April, and in mid July strong easterly winds did considerable damage, especially to those cultivars whose primocanes were sufficiently developed to swing in the wind and damage laterals on the fruiting cane. Malling Orion topped the yield figures, followed by four SHRI seedlings, Malling Delight, Malling Admiral and Glen Clova.

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

Propagation and cultural methods

Investigations continued on alternative methods of increasing virus-tested material with a view to greater economy of production. Plants raised in the glasshouse and planted outside in March gave rise to as much new cane as those planted in May, despite rosetting. Autumn planting is now being compared with spring planting using both pot plants and root cuttings.

In the fifth cropping year of an experiment designed to measure potential production of raspberries in the absence of constraints on alley width, the narrowest (3 ft) spacing yielded 33.5% more per acre than the conventional 6 ft spacing.

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

Cultural methods for machine harvesting

Biennially cropped cv. Malling Jewel this year gave 43% more fruit than the annual system, representing a mean decrease over 2 years of 33.5%. There was a larger yield response in cv. Norfolk Giant, resulting in a mean yield decrease of only 13.5% per annum; this cultivar is not suitable for mechanical harvesting, but it does indicate the potential for this system given the right genotype.

The mechanical harvester imported from the USA and modified by NIAE Scottish Station was available this year for extensive tests of the influence of cultivar and cultural systems on harvesting efficiency. Predictions of diurnal change in ease of harvest were not confirmed on the three occasions when the machine was operated during day and night periods. Change in training systems from stool to hedgerow had no significant effect on machine efficiency, nor had differing methods of attaching the cane to wires (clips versus lacing). Fruit recovery was not improved by removal of the young cane which it was thought might interfere with the vibrating action of the picker head.

Yields from four cultivars harvested by machine throughout the season were only 30% to 60% of those from hand-harvested controls. Losses included dropped fruit and berries harvested while green, but there remained an appreciable percentage unaccounted for. Shrivelling of overripe fruit and losses due to botrytis probably contribute, but detailed investigation is required. Plots harvested by machine at 3 day intervals yielded 17% more fruit than those harvested every 6 days.

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

Postharvest investigations

Following successful small scale transport experiments, work this year was directed towards examining problems of bulk transport. Fruit of the cultivars Glen Clova, Malling Jewel and Malling 'M' was cooled immediately after picking and held for 1 day at 2°C before freightliner transportation to a southern supermarket depot; in-transit cooling was by sachets of water ice in each tray. On arrival 45 h after picking, all fruit was judged to be in good saleable condition. Sampling by Food Research Institute staff and shelf life tests indicated adequate 'holding' ability in all cultivars, though M. Jewel was somewhat overripe. Malling 'M' and Glen Clova samples were judged to be saleable after 8 days at 2°C. However, the bulk in the depot cold store showed appreciable juice loss within 10 h of arrival, and no adequate explanation has been found.

(D. T. Mason)

Mechanical harvesting

Positive linear relationships were recorded between titratable acidity of fruit and log_e fruit retention force for the three cultivars Glen Clova, Malling M, and M14, as found previously for Malling Jewel. The slope of the relationship

was unique for each cultivar. The mean retention forces were calculated from values for titratable acidity for hand and machine picked samples of the four cultivars. The retention force of hand picked samples was about 1.5 times that of machine picked.

At each pass the mechanical harvester recovers less than 70% of the available ripe fruit. To measure the effect of fruit position on ease of harvest, berries in different zones of the plant were marked with emulsion paint and their fate recorded after passage of the machine. 36% of the berries within 5 cm of the centre of the row and 22% of those greater than 15 cm from the centre remained attached, although tests for titratable acidity showed that on average the inner fruit was riper than the outer.

Fruit retention force measurements were made in the field using a modified Correx tensiometer gauge. The performance of this instrument was checked against an Instron Universal Testing Machine in the University of Dundee. Load/time traces were obtained for berries of several cultivars at varying stages of ripeness, during removal of the receptacle. The maximum loads recorded by the Instron machine were similar to those obtained for berries of the same ripeness using the Correx gauge. Characteristic traces were produced for each cultivar and the significance of these in determining relative ease of harvest is being investigated.

(D. T. Mason)

Raspberry bud and cane death

In several experiments fungicide applications designed to control cane disease have produced increased yields by improving numbers of fruits harvested per cane; there has been no consistent decrease in either dead canes or dead buds. More commonly the increase in fruit numbers has resulted from greater numbers of harvested fruits per lateral. As treatments have been applied throughout the growing season the yield response may have resulted from either cane or fruit disease control.

(D. T. Mason)

Strawberries

National Fruit Trial

Yields of twelve cultivars and seedlings were compared in defoliated and undefoliated plots. Only cv. Cambridge Favourite failed to respond and yielded the same with and without defoliation. Without defoliation, only three of the cultivars and seedlings outyielded Cambridge Favourite, but when defoliated seven were superior. Defoliation did not appear to affect yield components in the same way for all lines. In some, the major effect was on barrenness (truss numbers per crown), but in others the effect was spread over crowns per plant, trusses per crown, fruits per truss, and mean berry weight.

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

Cultural methods and yield components

Two experiments on the influence of crown populations on fruit size and defoliation response were terminated this year. Preliminary results indicate that fruit size cannot be readily changed by increasing planting density, that denser crown populations do not require additional nitrogen, and that attempts to influence defoliation response by increased plant competition have failed.

Deblossoming of three cultivars in the year of planting did not significantly affect yields in the first harvest year. However, when runner removal was delayed until the end of the first growing season, the subsequent year's yield was depressed by 20%.

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

Crown death

No specific pathogen has been found to be associated with crown necrosis and death nor has there been any strong indication of causes from a survey of affected plantations. Twelve different soil and cultural factors were significantly correlated with the disorder, but several appeared to be inter-related.

(D. T. Mason)

Yield analysis

A survey of 69 plantations of cv. Cambridge Favourite in Scotland showed that under field conditions the major yield determinant is crowns per unit area ($r=0.82$ for yield and crown number) despite the decrease in other yield components as crown number increases. This is not true of certain other cultivars in which barrenness (reduced trusses per crown) can have an overriding effect.

(D. T. Mason)

Vaccinium: cultivars and cultural methods

To improve the speed of establishment of highbush blueberries, four pruning treatments of varying severities were imposed on the cultivar Earliblue at the beginning of 1973. Production of new wood was linearly related to the severity of pruning as measured by weight of prunings.

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

Blackberries: cultivar assessment

None of the American cultivars recently imported has outyielded Ashton Cross, though some have more desirable features such as upright habit or thornlessness. The mechanical raspberry harvester was used on a single row of Ashton Cross and produced an excellent sample at the first harvest. However, at the time of the second harvest much of the fruit (unripe as well as ripe) showed desiccated drupelets following rupture either by the machine's fingers or by vibration against thorns.

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

Black currants: mechanical harvesting

SHRI's advanced seedlings have been planted to assess whether there are machine harvest problems peculiar to northern conditions and whether newer genotypes show any superiority over cv. Baldwin.

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

STATISTICS AND COMPUTING

Design and analysis of experiments

Limitations on land and other resources have increased consultancy work concerning the layout of experiments. The increase in the number of experiments analysed and evaluated also has led to an increased awareness of the benefits of sound design.

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

Use of computing facilities

Computing jobs rose to 873, an increase of 45% on 1972. The number of variates analysed rose to 9610, an increase of 61%, partly due to a backlog of longterm field trial data, partly to the increased number of staff involved in field experimentation, and partly to the expertise of certain experimenters which has resulted in large bodies of data passing routinely through the system almost as soon as recorded. The proportion of jobs originating in each section has changed towards greater equality of computer usage:—

Section	1972		1973	
	Jobs	%	Jobs	%
Crops Research	368	61.0	469	53.7
Plant Breeding	140	23.2	146	16.7
Mycology	65	10.8	93	10.7
Zoology	21	3.5	134	15.3
Virology	9	1.5	31	3.6

The main non-numerical uses of the computer did not change; mapping nematode distributions and maintaining a bibliography of *Botrytis* references both involved considerable work in maintaining the data base.

Use of the Edinburgh Multiple Access System (EMAS) to edit jobs for batch processing on the IBM 370/158 computer at Edinburgh has been systematised, and a program developed to compare files before and after editing and to punch amended records so that card decks can be updated. This has eliminated one postal journey on jobs for re-running, and most staff now prefer to use it routinely despite occasional difficulties due to breakdowns in the EMAS system.

The Wang programmable desk calculator has been used more, mainly in conjunction with one of the six statistical programs with typewritten output which were developed during the year. During November and December the machine was in use for 41% of the available time. J. B. Cowan gave staff tuition in using the Wang and P. B. Topham gave three seminars on elementary applications of Genstat.

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

Statistical studies on plant variation

Serial correlation techniques have been used to study spatial variation in raspberry growth and in red core infection of strawberry plants—in both instances with negative results. Management practices impose a uniformity on raspberry plantations which masks natural variation.

(P. B. Topham)

Design and layout of genetic experiments

Models to explain genotype-environment interactions in terms of linear responses are proving generally useful in assessing cultivar behaviour. Some programming to fit genetic models by least squares methods has been undertaken.

(P. B. Topham)

Plant Breeding

C. NORTH

The year was notable for its productivity in terms of new cultivars; decisions were made to recommend the release of two raspberry, two black currant and five lily cultivars. Furthermore, the multiplication of Celtic Cross cabbage has been put on a firm basis so that moderate quantities of seed are now available and stocks will be built up to meet requirements in succeeding years. In addition, genetic material carrying marker genes to aid the early identification of sibs in F_1 seed stocks of *Brassica* has been passed on to commercial breeders.

Breeding disease resistant strawberry cultivars

Much time has been devoted to virus testing advanced selections and to propagation of their healthy clones under insect free conditions. Differing numbers of selections have been sent for agronomic tests at the following centres: Brogdale nine, Clonroche four, East of Scotland Agricultural College seven, Loughgall seven, Luddington seven, Mylnefield seven. Those from family 65G generally produce fruits which have a long shelf-life, travel well and retain a bright appearance, but tend to be orange fleshed and fairly difficult to decap. Two selections produced the highest yields of large and medium fruit in a first main crop trial at Brogdale and had relatively low levels of infection with *Botrytis*. Another from the same family had similar good fruit quality characteristics but gave poor yields under certain conditions, probably due to a shortage of trusses, a fault which possibly may be corrected by defoliation.

The screening of advanced selections for performance on red core (*Phytophthora fragariae*) infested land has been extended to include land on a farm in Kent and at Ellbridge Experimental Horticulture Station (EHS); this will help to ensure that apparent resistance due to escape from infection may be recognised early.

Attempts to devise a suitable laboratory screen for *P. cactorum* show that runners can be infected by immersing them for 24 hours in a suspension of the fungus grown on strawberry fruit agar. The growth rate of the fungus on agar depends on the strawberry clone used in preparing the medium.

(H. J. Gooding, K. C. McConnell and P. R. Irons)

Breeding systems of strawberry

The reciprocal recurrent selection programme started in 1970 with seedlings from one family 66AQ bred from Cambridge Favourite, Talisman and Siletz and another 65G of complex origin from US.2650, has been continued. The objective is to maximise the effects of general and specific combining ability in the production of new cultivars and to test the feasibility of F_1 cultivars raised from seed on a commercial scale. This approach has now shown sufficient promise to make it worth while going ahead with the project on a larger scale and 25 crosses, involving 1500 seedlings have been planted for field assessment in 1974. Because June Yellows occurred recently in a 66AQ seedling, a second reciprocal recurrent selection programme has been started using the 65G seedlings as one parent line and a population derived from *Fragaria virginiana* 1, Redgauntlet, Crusader and Gorella as the other.

(H. J. Gooding and K. C. McConnell)

Genetic factors affecting yield in strawberries

The analysis of a complete 7 x 7 diallel in which inflorescence number, fruits per inflorescence and fruit size were recorded, gave significant results for the effects of both general and specific combining ability, but with all characters the general combining ability was by far the most important. The cultivar which transmitted the highest expression of the yield components was Senga Sengana for inflorescence number and Redgauntlet for fruits per inflorescence and fruit size.

(H. J. Gooding and P. R. Irons)

Breeding autumn fruiting strawberries

Two seedlings derived from cv. Nisqually and raised and selected at Mylnefield gave considerably lower yields when grown in small plots at Auchincruive probably due to their susceptibility to red core disease. Marketable yields harvested between 7 August and 2 October at Mylnefield were in excess of 96 cwt/ac (12 mt/ha). The major faults in Scotland of 'double croppers' have been the failure of the fruit to ripen because of their lateness, and indeterminate ripening rendering harvesting expensive. However, with both these new selections the peak harvest of 24 cwt/ac (3 mt/ha) was obtained on 11 September at a time when locally produced strawberries are not normally available. These two selections therefore have been sent to Brogdale for inclusion in a trial of cultivars with similar cropping characteristics. Further crosses have been made at Auchincruive to incorporate field resistance to red core in this material.

(H. J. Gooding, D. L. Jennings and P. R. Irons)

Breeding disease resistant raspberries

The selection M14 gave a high yield in the Scottish National Fruit Trials and its good fruit qualities were again notable in experiments with the machine

harvester; it was therefore proposed that the selection should be released as a new cultivar. Favourable assessments were received for the fruits' suitability for canning and quick-freezing, but opinions varied on its suitability for jam.

The release of M31 was recommended despite unfavourable assessments of its suitability for all forms of processing; growers consider that the fruit is well suited for marketing because of its large size.

Large differences in the susceptibility of fruit to *Botrytis* were found between progenies of a diallel cross. Analyses showed that M14 was the best of six parents as a source of resistance, and superior to four derivatives of the cultivars Carnival or Cuthbert chosen for their resistance; there were interactions between M14 and two of the latter, leading to a higher expression of resistance. It is possible that resistance is associated with firmness of fruit texture in the M14 progenies, because the resistance of selections in a yield trial was highest for those with firm fruits.

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

Genetic factors affecting yield in raspberries

In a study of the inheritance of 'multilaterals'—the capacity to develop more than one lateral per node—severe April frosts caused complications by damaging a high proportion of fruiting laterals, and caused secondary laterals to develop which would not otherwise have done so. The results showed that the inheritance of the capacity to produce multilaterals was multigenic and completely additive; more reliable data will be sought in 1974. Positive correlations between multilateral production and cane diameter were again found, but correlations between cane diameter and the proportion of lateral-bearing nodes tended to be quadratic rather than linear, showing an optimum cane diameter at an intermediate level. Gene L_1 , which confers large fruit and has pleiotropic effects on plant growth, reduced both the number of nodes present, and the proportion of them which bore either single or multiple laterals. Gene H, which gives disease-escaping hairy canes, had no effect on lateral production in two groups of families in 1973, but analysis of 1972 data for one of the groups with a higher disease incidence showed that the gene gave an overall increase of 3.3% in the proportion of lateral-bearing nodes present and an increase of 5.6% in the proportion on the lower half of the canes. In this material the combination of gene L_1 and the recessive allele h gave a serious reduction in lateral production compared with the combination HL, emphasising the need to avoid the former combination in breeding.

Observations suggest that an important factor affecting yield is the proportion of flowers which develop fruits, and that the proportion is low in selections where the number of flowers per lateral is high. This weakness may be less in genotypes with very large fruit because these probably have genes which promote strong growth at this final development stage. To test this hypothesis a series of progenies were raised in which selections with very

large fruit were crossed with selections with high flower number per lateral. These families will be available for study in 1975.

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

Breeding early, erect blackberries

Some 25 tetraploid progenies were raised to combine the capacity for rapid fruit ripening derived from *Rubus ursinus* with the improved growth habit of selections derived from cv. Early Harvest and cv. Darrow progenies. Five hexaploid progenies of similar genetic constitution to the Loganberry were also raised. It is hoped that the latter will segregate types which are more productive and have more erect growth habits than the Loganberry.

Two tetraploid selections were obtained, one a blackberry and one a blackberry-raspberry hybrid, which carry the dominant epistatic thornless character found in the octoploid cv. Austin Thornless. This material will be particularly valuable for breeding blackberry-raspberry hybrids if progress can be made in improving its fertility and hardiness.

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

Breeding disease resistant black currants

Two selections from a cross between *R. ussuriense* and *R. nigrum*—93/16 and 93/20—performed well in their third year of cropping and have been recommended for release. Cuttings have been supplied to the Scottish Nuclear Stock Association for propagation and planting material is expected to be commercially available in autumn 1976. Both selections have an upright growth habit and thin flexible branches which tend to overhang the rows when in full crop. They are notable for their large uniformly ripening fruits of good appearance; 93/20 ripens a few days earlier than 93/16 and about 1 week earlier than Baldwin. Suitability for machine harvesting has not been tested fully, but this aspect is being examined at Luddington and Efford EHS.

New selections sent to the National Fruit Trials and Luddington EHS include derivatives of 93/20, second and third backcross derivatives of *Ribes dikuscha* and selections from crosses between the two productive progenies Anger von Oeffelt x Sztahanovka and Goliath x Öjebyn. Two of the selections were outstanding for their freedom from premature fruit drop.

Twenty-three clones were assayed for ascorbic acid content by Beecham Products Ltd. Values ranged from 52 to 215 mg/100g of fresh fruit, compared to 158 mg for Baldwin. 93/16 and 93/20 had values slightly lower than Baldwin but the value of one other selection was 35% higher.

Crosses with a number of cultivars, including Westra and Black Reward, were made to introduce improvements into the family 93 material such as freedom from premature fruit drop, disease resistance, erect habit, stouter and less flexible branches, long racemes, several racemes per node and late flowering with a shorter ripening period.

The 1972 Annual Report mentioned a progeny especially resistant to premature fruit drop derived from crosses involving three species *R. nigrum*, *R. dikuscha* and *R. hudsonianum*. Whereas in black currant, good fruit set is correlated generally with large numbers of seeds, the number of seeds per fruit of an outstanding selection of the above progeny was relatively low – 12 as compared with 30 for Brödrtorp – though they were larger and weighed 35% more. This selection and others were distributed to other Institutes so that their fruit-setting potential can be assessed in different environments.

Screening progenies in nursery rows for mildew and leaf spot susceptibility reduced the number of one-year-old plants transplanted. Clear-cut segregation was shown for resistance to American gooseberry mildew (*Sphaerotheca mors-uvae*), but less well-defined segregation for resistance to leaf spot (*Pseudopeziza ribis*). The data obtained support the belief that two genes for mildew resistance are segregating in some families. The most potent sources of resistance were derivatives of Scandinavian origin, *R. nigrum sibiricum*, an accession of *R. hudsonianum*, and hybrids between *R. nigrum* and species of the *Ribesia* group.

(M. M. Anderson)

Isolation and identification of S-alleles in B. oleracea

Work relating to allele identification has been restricted to routine analysis of breeding lines and to the maintenance of a standard collection of 20 incompatibility alleles.

(J. R. T. Hodgkin)

Studies on the inheritance of self compatibility

Investigations of variation in self compatibility and fertility under field conditions have been continued by measuring seed set and related factors in two experiments. The first compared 28 progenies of 10 related parents homozygous for the incompatibility allele S_5 , and the second, the selfed progenies and F_1 hybrids of unrelated Brussels sprout lines and Jersey Kale, Portuguese Cabbage, pointed headed cabbage and kohlrabi. The most useful measurements of self compatibility and fertility were seeds per flower in bagged and unbagged inflorescences respectively.

The first experiment showed a clear correlation between number of seeds set by selfing and by crossing and this was reflected in the similarity of the results obtained from a combining ability analysis. Most of the line differences observed for both parameters were additive.

In the second experiment there was evidence of pronounced heterosis for fertility but not for self compatibility. The correlation was much weaker between selfed and crossed seed set than in the first experiment.

Time of flowering was found to differ considerably between lines in the two experiments but this did not appear to contribute significantly to any of the differences observed in the seed-set parameters measured.

(J. R. T. Hodgkin)

Marker genes for hybrid-inbred discrimination in Brussels sprout

The combining abilities of various potential glossy parent lines were assessed by crossing them to four commercial F_1 cultivars and recording the progenies for yield of sprouts in various size grades, sprout number, stem length and various sprout quality characters. The lines differed for general but not for specific combining ability.

Continued selection of the inbred glossy lines has produced substantial improvements in their suitability as parents for F_1 cultivars and it is now apparent that the presence of the glossy gene itself is no barrier to the attainment of commercial quality. The possibility that commercial breeders could utilise these lines at their present stage of development was discussed at a meeting with the British Association of Plant Breeders. Sib markers are considered to be of value to the F_1 brassica plant producer and are potentially of even greater value to the seedsman as an aid to early assessment of the sib content in 'growing on' tests. It was agreed that demonstration trials of 'glossy' hybrids would be grown at Mylnefield and at Wellesbourne in 1974; commercial breeders have been supplied with seed of glossy lines for crossing tests with their own inbred parent material.

(A. J. Redfern and C. North)

Breeding hybrid cultivars of Brussels sprout

When the hybrid 'Gleneagles' was first introduced in 1970 relatively few hybrid sprout cultivars were available but by 1973 49 hybrids were listed in the Plant Varieties and Seeds Gazette – special EEC edition April 1973. Since the performance of many of the newer cultivars surpasses 'Gleneagles' no further seed of it has been produced.

(A. J. Redfern and C. North)

Breeding hybrid cultivars of cabbage

Growers have shown considerable enthusiasm for Celtic Cross cabbage and it was decided to build up seed stocks as quickly as possible. By arrangement with the National Seed Development Organization (NSDO) a $\frac{1}{2}$ acre (0.14 ha) seed crop was planted 7 miles from the Institute in July 1972 and a yield of 231 lb (105 kg) cleaned seed was obtained; tests show it contains a very low percentage of sibs. A further 1 acre (0.4 ha) seed crop was planted locally for harvesting in 1974. Commercial rights for Celtic Cross have now been granted to a seed firm which will assume responsibility for F_1 seed production.

Further ways of utilising the parent lines of Celtic Cross were explored by producing and growing hybrids between one of the lines and a number of savoy cultivars. All the hybrids thus obtained were much more savoyed than Celtic Cross and showed a very wide range of maturity. A few lines overwintered at least as well as Celtic Cross.

(A. J. Redfern and C. North)

Seed production characteristics of a parent of Celtic Cross

A number of sub-lines exist of one parent of Celtic Cross representing different cycles of propagation. To assist in selecting the best of 17 sub-lines, a study was made of variation in factors influencing yield of F_1 seed and its contamination by sibs. When mass pollinated by bees, from 0.4 to 4.4 seeds per flower were obtained, whereas when individual flowers were hand pollinated, or inflorescences bagged and shaken to distribute the pollen, virtually no seed was produced. These results indicate a relatively low level of self compatibility. There were line differences between the earlier selections ($P=0.001$) but current lines did not differ significantly from each other.

Fertility of each line was measured by seed set from test pollinations using pollen from the other parent. There was considerable variation among some of the earlier selections and, six current lines were noticeably more fertile than the remainder.

Analysis of flowering time in three different environments showed a significant genotype environment interaction. However, there were line differences suggesting that parent selection for later flowering would be feasible in order to achieve greater coincidence of flowering with the other parent.

(J. R. T. Hodgkin)

Isozyme analysis in Brassica oleracea

Isozymes of alpha and beta acetylsterases extracted from dry cabbage seeds were compared by mixed substrate staining after electrophoresis in a tris/glycine buffer system at pH 8.6 using 10% acrylamide gels. Six slow moving esterase bands were identified in each of the parent lines and the F_1 Celtic Cross cabbage, and each could be grouped into two sets of three bands. It appeared that the slowest of these could be under the control of a single gene and therefore possibly useful as a marker for distinguishing sibs in seed of this hybrid cultivar.

Serology of incompatibility in B. oleracea

It was hoped that this 3 year project might lead to a routine serology technique for identification of S-alleles based on the work of Dr Nasrallah, Cortland College, New York State University. Of 11 rabbits injected with stigma extract 4 produced S-protein specific antibodies, two of them only after booster injections. These results are comparable with those of Nasrallah who similarly treated 12 rabbits and obtained 3 with the relevant antibodies. Intensive attempts to improve on the technique were unsuccessful and the project has been discontinued. Nevertheless, some interesting results were obtained. It was indicated that stigmas of plants homozygous for S-alleles contain about twice the amount of the appropriate S-protein as those of plants which are heterozygous.

(Margaret Sedgley and C. North)

Acid phosphatase and α and β -acetylsterase isozyme complements of dry seeds of 10 commercial cabbage and Brussels sprout hybrid cultivars were examined using a similar system. For esterases at least 10 bands were observed and enzyme production appeared to be under complex genetic control. Acid phosphatase by contrast showed four isozymes determined by co-dominant alleles of a single gene. In three of the cultivars each of the parents was homozygous for different acid phosphatase isozymes while in four others the isozymes were segregating and the material could be selected to produce homozygous parent lines. In the remaining three cultivars both parents showed identical isozyme bands. One fast-moving β -acetylsterase band was of different intensity in the parents and hybrids of some cultivars and may prove useful.

Recent refinements in enzyme extraction have eliminated the need for seed grinding and considerably reduced the time taken for analysis, and thus the cost. The prospects are therefore most promising for analysis of sib proportions in commercial seedstocks, especially if enzyme systems additional to acid phosphatase can be used.

(Sheena K. Fyfe)

Breeding hybrid Brussels sprout from seed exchanged between SHRI and NVRS

Certain hybrids grown in the initial trial will be pollinated using bees to investigate seed production problems; the best material will be subjected to further yield trials. It is proposed to concentrate on two test hybrids and to build up stocks of one 'good combining' SHRI parent.

(J. R. T. Hodgkin)

Genetics and cytology of B. oleracea

The gene collection was enlarged by the isolation from cabbage of two dwarf types, one yellow green and the other normal coloured; and a distinct new morphological variant in which the first leaf of seedlings is twisted downwards, the lamina folded upwards and the base of the lamina generally chlorotic. The conditions appeared to be associated with pale coloured cotyledons.

The genetics of albinos have been neglected somewhat because the aberrant segregations they cause make linkage study difficult; occurrence was so frequent, however, that determination of the number of loci involved became necessary. Test crosses showed that only two albino genes were present in SHRI material.

Because of the interest shown by seed producers in simple, reliable and rapid tests for sib counts in F_1 seed, continued emphasis is placed on the study of characters expressed in the seedling. Two such characters in addition to 'glossy' (gl) are hairy leaf (Hr) and fused cotyledon (fc). Hairy leaf has been isolated from several different sources and can have a widely differing intensity of expression. In one family the expression of Hr-z was apparently complicated by gene interaction. Similar gene interaction was reported in

unrelated material (Ann. Rept. 1971). Further Hr-z families were grown and seedling scores gave apparent segregation of 1 strong hairy: 1 weak hairy: 2 non-hairy in outcrosses, and 4 strong: 5 weak: 7 non-hairy in F₂. The latter result is probably due to classification of some strong genotypes as weak.

Fused cotyledon, first isolated from Brussels sprout Cambridge Special (Ann. Rept. 1968) has been isolated now from two other sources (fc-2 and fc-3). Tests have shown that fc-1 and fc-2 are not identical and have also indicated absence of linkage between fc-1 and Go-b, and fc-2 and gl-c. Since fused cotyledon can be recognised easily very soon after germination its use as a sib marker in Brussels sprout breeding seems very promising.

Families flowering in 1973, grown to investigate anomalous linkage relationships between cp-1, Wh and gl-b (Ann. Rept. 1971) again gave contradictory results. The anomalies probably result from disturbances due to differential winter survival of glossy plants and the segregation of other genes conferring hardiness.

Differential survival giving a significant deficit of glossy at flowering was also observed in an F₂ segregating cp-1, As and gl-el. No other ratio was distorted. Linkage of cp-1 and As, already confirmed (Ann. Rept. 1972), was seen again while cp-1 and gl-el linkage was observed for the first time. Results from a series of families either in backcross or F₂ showed no linkage of cp-1 with two further glossy genes, viz: gl-e2 and Go-b.

Joint segregations of cp-1 and a strongly expressed hairy leaf genotype occurred in a backcross and an F₂ and gave no evidence of linkage. However, linkage was detected in a backcross of a sibling F₁ and is probably to be explained by the presence of at least two Hr genes in the original hairy line. Segregation of Wh, Go-b and Hr-k in a further unrelated family were all independent.

(A. B. Wills and P. Smith)

Quantitative genetics of Brassica oleracea

An investigation was begun on the genetical bases of variation in seedling and mature plant quantitative characters in calabrese, to relate these to the choice of breeding options available for this crop. Plants from four cultivars were pollinated in an incomplete series of diallel crosses. Some within-cultivar F₁ families of two cultivars were grown and length measurements of the stem and of a selected leaf were made on seedlings to assess methods of making repeated measurements.

(P. Smith and A. B. Wills)

Breeding white seeded French bean cultivars

Progenies from selected single plants of cv. Glendoick were grown in a field trial to reselect for uniformity.

(A. J. Redfern)

Breeding anthracnose-resistant French bean cultivars

Selection to improve quality and uniformity of some anthracnose resistant lines was continued in field and glasshouse.

The initial objectives of the bean breeding project were met with the release of Glamis in 1969. However, because the Scottish bean processing market has not developed and the fresh market is very limited, both the above projects are in abeyance.

(A. J. Redfern)

Breeding disease-resistant lily cultivars

Propagation of the five selected clones mentioned in the 1972 Annual Report has been continued so that flowering size bulbs can be distributed to commercial propagators through the NSDO at the end of 1974.

More crosses were made between hybrids involving Asiatic species, especially to obtain dwarf types suitable for forcing.

Further efforts also were made to cross the hybrids of *Lilium lankongense* x *L. davidii* to cultivars of the Asiatic group. This type of cross produces only small embryos which have to be cultured on sterile nutrient medium to obtain plants; in two previous attempts only 14 plants were obtained. Based on earlier observations, at flowering time the temperature of the glasshouse was raised to approximately 25°C day, 15°C night, shading applied and the humidity raised. These conditions gave a much higher seed set, though again seed was produced with only small embryos and no endosperm. The culture tubes containing embryos were kept in a growth cabinet at 25°C with a high light intensity of approximately 1000 f.c. More embryos developed into flowers and growth was considerably faster than on previous occasions when culture tubes had been kept in the laboratory without additional lighting. Finally, plantlets were kept in a mist propagator for 2 weeks after transferring to soil and nearly all survived; 50% losses occurred in previous years in a dry atmosphere. Over 400 plants were obtained from this type of cross, representing 1.2 per pollination and thus a much more efficient result than in previous years. Some of the plants obtained will flower in 1973 and all by 1974.

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

Mycology

R. A. FOX

It is now possible to make reproducible numerical statements about the relative infectivity of soils infested with *Phytophthora fragariae*, the cause of red core disease of strawberry. Although much detailed work remains to be done the present position is a great advance on that extant 2 years ago. We are not, unfortunately, in a similar position regarding the potato gangrene fungus *Phoma exigua* var *foveata*, despite intensive work on baiting techniques and attempts to develop a selective medium.

Reports on the occurrence of blackleg in the early stages of multiplication of virus tested stem cutting (VTSC) stocks of potatoes caused concern. Surveys showed that re-infection by *Erwinia carotovora* occurs readily and other work indicates that several previously unsuspected sources and vectors may be implicated. Haulm debris may well prove to be an underestimated source for the survival and dissemination of the gangrene fungus, also in relation to the recontamination of VTSC stocks.

Acknowledgment is made of the co-operation received from staff of the East of Scotland College of Agriculture, the Commonwealth Mycological Institute and many co-operating farmers, and for gifts of various compounds from manufacturers and suppliers of agricultural chemicals.

RED CORE OF STRAWBERRY

Chemical and cultural methods of controlling red core disease of strawberry, Phytophthora fragariae

In further evaluations of fungicides for activity against *Phytophthora fragariae*, captan, dichlofluanid, fentin hydroxide and streptomycin when applied as soil drenches in pot tests decreased the percentage of diseased roots. Only dichlofluanid was better than Dexon which was included as a standard. Eighteen compounds were ineffective. The effects upon sporulation, tested by using mycelial discs, and on the duration of motility, tested by using zoospore suspensions, of various concentrations of some previously tested fungicides was studied after leaching them through potting compost. All fungicides depressed sporulation and shortened the period of motility but the concentrations at which they achieved these effects differed greatly and bore little relation to the results of the infection experiments in the pot tests. Nabam, ineffective in pot tests, was the most effective preventing sporulation at 10 ppm and inhibiting motility within 2 h at 100 ppm. Terrazole and

R22395 (Plant Protection) were both effective in controlling infections in pots but whereas the former checked sporulation at 100 ppm, the latter did not completely prevent it at 6,000 ppm. R22395 affected motility within 5 h at 100 ppm while terrazole caused cessation of motility within 2 h at 500 ppm.

A field trial of drazoxolon, mancozeb and terrazole applied as drenches in 1972 was assessed in 1973. Only terrazole decreased the percentage of diseased roots. Mancozeb was slightly phytotoxic. Fruit yield was high in all treated plots but did not differ from the untreated. Perhaps because of low rainfall during the winter of 1972/73, disease levels were very low and did not provide an adequate test of the drenches. Another trial, consisting of drenches of captafol, R22395 and R45173 (Plant Protection) developed insufficient red core for any assessment of the fungicides to be made.

When mycelial discs were irrigated with leachates from unsterilised peat, vermiculite, and various peat/vermiculite mixtures, sporangial production was almost completely inhibited and no zoospores were produced in the peat leachate. Maximum production of sporangia and zoospores occurred in a peat:vermiculite (10:90 v/v) mixture to which trace elements had been added. Rooting runner plants in a peat:sand (75:25 v/v) compost for 3 weeks before planting into infested soil did not delay the onset of severe symptoms of red core when compared with planting runners directly into infested soil. No infection occurred in two out of five runners planted into the same compost surrounded by infested soil.

(Isabel G. Montgomerie and Diana M. Kennedy)

Analysis of components of field resistance to red core disease of strawberry, Phytophthora fragariae

Significant differences between cultivars in their susceptibility to race B66-11, were compared in a series of experiments using five replicates for each cultivar under standard conditions. Some of the differences were not reproducible but the 16 cultivars examined could be assigned to three broad groups depending on the percent by number of roots and the percentage of total root length that became infected. The results of inoculating 3 and 6 month-old plants over a period of 17 and 33 weeks respectively did not contribute more information on their relative susceptibility than did inoculating 2-3 week-old runner plants and assessing the level of infection after 14 days. The volume of crowns, number of crowns, area of longitudinal section of rootstock and number of roots did not appear to influence the response of the older plants to disease.

A preliminary examination of the sporulating ability of the fungus on a very susceptible, a susceptible and a slightly susceptible cultivar indicated that the number of sporangia produced on standard lengths of root from the slightly susceptible host was less than half that produced on the other two which were similar. There was little difference between the hosts in the number of oospores formed.

(Isabel G. Montgomerie and Diana M. Kennedy)

Qualitative and quantitative methods of detecting Phytophthora fragariae in soils

A procedure has been developed using bait plants for assessing soil inoculum of *Phytophthora fragariae*. The soil under test is mixed in various proportions with a solid diluent such as sand or Universal Compost and the mixtures planted with runners of *Fragaria vesca*, clone V51, previously rooted in a mist propagator. This bait plant is susceptible to all the tested isolates of a range of races, and symptom expression is clear and rapid. The plants are kept in the glasshouse for 5 weeks at $16 \pm 2^\circ\text{C}$ and either watered thrice daily by hand, or continuously watered for 6 h daily using a mist irrigator. A most probable number of 'infective units' per ml of soil can be calculated from the number of infected plants at the different dilutions. Inoculum levels at Mylnefield have been estimated as lying in the range of 0.05–0.5 infective units/ml of soil, depending on site, plot and time of year. Comparisons of dilutions made by adding oospore preparations to sand suggest that one infective unit is equivalent to about 160 oospores of the fungus or that inoculum levels in the field are equivalent to a range of 10^1 – 10^2 oospores/ml. There are significant variations in inoculum levels in one field and the fungus has been detected in soil samples only from sites where the disease has previously been recorded.

Recent work suggests that detached leaves and petals of strawberry plants could be used as baits. Leaves inoculated with zoospores or mycelium or infested root material often develop characteristic dark spreading lesions within which oospores typical of *Phytophthora fragariae* can often be found.

(J. M. Duncan)

Autecological studies on Phytophthora fragariae

Further improvements in the medium used for producing oospores in culture have been made by increasing the concentration of French beans from 40g/litre to 160g/litre, the beans being first boiled and then blended in a Waring blender. Nearly all isolates produce oospores on this medium, the numbers being significantly higher, up to 8/mm², where glass fibre tapes have been placed in contact with the cultures. When such tapes are stored in compost or soil the hyphae usually disappear within 2 weeks but the oospores appear unaltered for up to 2 months when the tapes will still cause infection when inoculated to the roots of bait plants.

The inoculum level of a field soil was assayed before and after various pasteurisation treatment in the laboratory. No infection was detected by bait plants after a treatment at 54°C for 10 minutes. This regime is promising in relation to the possible use of steam-air mixtures for disinfecting sites for runner beds providing the depth of treatment needed is not too great.

(J. M. Duncan)

INTERNAL NECROSIS OF STRAWBERRY CROWNS

Etiology, epidemiology and control of strawberry crown necrosis

A survey of the edaphic and management factors which may affect the incidence of crown death in the cv. Cambridge Favourite (Crops Research Section p. 33) suggests that autumn application of the annual dose of the herbicide simazine led to more crown death than a split application in the autumn and spring. However, a field experiment at Mylnefield, over 2 years, gave no differences between autumn applied, spring applied, autumn and spring applied simazine, autumn applied lenacil and hand weeded treatments.

Previous mycological studies suggested that *Fusarium avenaceum* Sacc. might be a contributing factor. Pot tests simulating herbicide dosages and timing, with and without various inocula of the fungus, also showed no differences in the incidence of crown death.

(W. R. Jarvis and A. J. Hargreaves)

RASPBERRY CANE DISORDERS

Raspberry cane diseases

Thirty canes of cv. Malling Jewel were housed under glass (minimum temperature 20°C) in early February, the buds forced and their health status recorded 4 weeks later. Isolations were made from each bud to map the distribution of fungi. *Fusarium avenaceum* was found to be more common towards the cane bases, *Didymella applanata* was more common on the mid cane section and *Botrytis cinerea* was distributed over the canes except at the base. Bud failure was most severe at the cane bases but analysis showed that it was not correlated with the presence of *F. avenaceum* nor with that of the other fungi. Inoculation experiments on plants raised from root cuttings showed that both *F. avenaceum* and *B. cinerea* could infect and kill 7 cm high canes if infection was predisposed by cane injury; similar inoculations with *D. applanata* were unsuccessful.

Attempts to devise screening tests for *F. avenaceum* using excised leaves were inconclusive. All cultivars and selections wilted but with varying severity.

(W. R. Jarvis and A. J. Hargreaves)

An outbreak of cane gall disease, characteristically restricted to fruiting canes, was noted in several plantations of cv. Glen Clova both at Mylnefield and in commercial crops in Angus and Perthshire; other cultivars were little or not affected. The typical galls, initially white then becoming brown, were detected in late May often along the whole length of the canes. In one 6 year old planting 100% of the stools were affected by mid August and root galls up to 30 mm in diam. were present in more than 50% of the diseased stools examined in October. The high incidence of the disease this year might be associated with the occurrence of widespread late frosts.

Isolations from gall tissue yielded bacteria which could be assigned by physiological tests to *Agrobacterium radiobacter* var. *tumefaciens*, but they were sensitive to streptomycin, chloramphenicol and kenamycin and gave a negative reaction in the 3-ketolactoside test.

(M. C. M. Pérombelon, A. J. Hargreaves and R. Lowe)

Design and trial of control measures for raspberry diseases

An experiment comparing early and late tying-in (early September or January) was started in 1972 to see if wind damage predisposed canes to fungi. There were no significant differences in bud failure between treatments in the first year when the experimental area was badly affected by a late spring frost.

An early assessment of a fungicide experiment started in 1973 showed that thiophanate-methyl, captan, carbendazim, dodine, captafol and thiram significantly reduced the level of cane spot (*Elsinoe veneta*) whereas nabam had an adverse effect causing blotches on canes. Captafol, thiram and dichlofluanid reduced the number of purple lesions, historically associated with *D. applanata* on the green primocane.

(W. R. Jarvis and A. J. Hargreaves)

AUTECOLOGY OF FUSARIUM AVENACEUM

Autecology of Fusarium avenaceum

Resting spores of *F. avenaceum* have been produced only by burying macroconidia in natural soil. In soil sterilised by autoclaving, fungistasis does not occur and the macroconidia germinate and form a mycelial mat. Non-sterile soil leachate has a fungistatic effect, which is lost on dilution, whereas leachate from sterile soil allows germination and growth. The atmosphere at the surface of natural soil also inhibits germination. Resting spores are more resistant to wet soil regimes than are fresh macroconidia. They also show a greater heat tolerance, surviving 20 minutes exposure at 56°C, whereas macroconidia lose viability at 47°C.

Soil populations present under different crops have been estimated. Using a selective medium, high populations were detected in fields planted to raspberry and strawberry (increasing with the age of the plantations) and permanent pasture land and barley plots, whereas low populations were found in plots of field beans and calabrese.

(A. J. Hargreaves)

RASPBERRY FLOWER AND FRUIT DISORDERS

Design of techniques for screening raspberry progenies for susceptibility to stamen blight, Hapalosphaeria deformans

Using pre-germinated spores in a spore suspension, or mycelium, as inocula did not improve the standard inoculation procedure. Attempts to initiate infection through stem wounds were unsuccessful.

(Isabel G. Montgomerie and Diana M. Kennedy)

Epidemiology and control of narcissus smoulder Botryotinia (Botrytis) narcissicola

The fungicide benomyl at 100 ppm was incorporated into a standard hot water treatment of narcissus bulbs cv. Golden Harvest, and also into a 30 minute cold dip treatment. Over a 2 year period the incidence of primary, lesions of smoulder was not more than 1 to 2% and no differences were detected between the treatments and no treatment. However the heat treated bulbs yielded 91 flowers per 30 bulb plot in the first year and 213 in the second, as against 82 and 157 flowers from the cold dipped bulbs, in the 2 years respectively, and only 74 and 118, respectively, from the control bulbs. The differences were highly significant. Moreover, the yields of bulbs harvested per 30 plant plot were 14.4, 10.4 and 5.0 kg, respectively, the differences again being highly significant. Unmarketable bulbs, badly infested by the bulb mite *Rhizoglyphus echinopus*, but not at all by *B. narcissicola*, amounted to 0.50, 1.7 and 2.7 kg per plot respectively, in the three treatments. No isolates of the fungus from the bulbs showed tolerance to benomyl.

(W. R. Jarvis and R. Thompson¹ with W. Fordyce²)

PLANT ESTABLISHMENT STUDIES

Studies on the effect of seed vigour on barley seedling establishment and growth

In continuing studies of the effects of seed deterioration on establishment and yield of barley, 27 lots of seed cv. Golden Promise, stored at room temperature, 30° and 40°C for varying periods of time were sown in single row plots. Non-deteriorated seed was sown at five densities, and all lots were sown either treated or not treated with an organo-mercury seed dressing. Laboratory germination of the deteriorated lots averaged 80% while field emergence averaged 50% and was significantly less than that of the controls in 16 of the 17 lots. Plants which emerged from deteriorated seed produced more grain, mainly by increased tiller number, and compensated for the lower stand. However, when yields were compared with the population-yield relationship obtained from the control seed at different densities, several of the deteriorated lots yielded significantly less than expected. Mercury seed dressing had no effect on the numbers of seedlings emerging but it retarded emergence and was associated with a significant 8% reduction in yield.

The performance of five of the deteriorated lots with laboratory germination varying between 84 and 92% in excessively wet soil was compared with that in a normal soil. The emergence of one lot was significantly lower than

¹Crops Research Section.

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the control in normal soil but in wet soil all were lower and there was a highly significant interaction between lots and soil condition. Grain yields were similarly affected. Vigour of coleoptile growth in rolled paper towels provided a consistently better correlation with emergence and yield in these trials than did the laboratory germination test, particularly under the adverse conditions of a wet seed bed.

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

The rate of leaf growth from deteriorated seed in field soil in a growth cabinet at 9°C was less, resulting in 65% shorter leaves after 27 days than that from non-deteriorated seed. The onset of tillering was delayed by 1.5 days at 20°C but the rate of tillering was unaffected. Leaf length correlated well ($r=+0.92$) with grain weight of non-deteriorated seed and less well ($r=+0.53$) with deteriorated seed.

(J. G. Harrison)

Causes of variation in seed vigour in barley

Investigations of the viability, vigour and fungus flora of seed kept at room temperature at 14, 16, 18, 20, 22 and 24% moisture content for 122 days showed that germination fell markedly at the highest moisture content and, in addition, vigour was affected at 20 and 22% moisture content. Seeds were plated on malt extract agar and Czapek-Dox agar containing 20% sucrose after de-husking and surface sterilizing in 5% Chlorox for 5 min. The dominant fungi in seeds at the start of the experiment were *Alternaria alternata* and *Epicoccum purpurescens* and remained so at the low moisture contents. At the end of the storage period, *Aspergillus repens* was dominant at 18 and 20% and *Penicillium* spp. at 22 and 24% moisture content. Dilution series of seed tissue ground in water indicated that fungi had extensively colonized seeds only at the highest moisture content, and no marked inhibition to barley seed germination was detected in sterile filtered extracts of the dominant fungi grown on sterilised barley mash.

(D. A. Perry)

When varying areas of the aleurone layer of dry seeds were destroyed by heat, seedling growth was more closely related to the estimated amount of undamaged aleurone tissue ($r=+0.77$) than with the grain weight ($r=+0.27$). A colorimetric method of estimating the reduction product of triphenyl tetrazolium chloride in ground endosperm tissues indicated that dehydrogenase activity in deteriorated seed was approximately half that in non-deteriorated seed although germination capacities were 89 and 99% respectively. These experiments suggest that degradation of the aleurone tissue may be partly responsible for the reduction of growth from deteriorated seeds.

(J. G. Harrison)

CAVITY SPOT OF CARROTS

Cause and control of cavity spot of carrots

Survey forms provided information of soil type, fertility and structure, previous cropping and husbandry techniques for cavity spot outbreaks in Scotland and, with the co-operation of ADAS staff, for some in England. Of the 10 outbreaks recorded, nine were associated with structureless sandy or peat soils.

Symptoms closely resembling cavity spot were obtained when carrots growing in a growth cabinet at 20°C were subjected to anaerobic conditions around the roots for periods up to 5 days. The soil surface was sealed with low melting point wax and nitrogen was passed through the soil from the base to exhaust through a U-tube in the wax covering. The end of the U-tube dipped into water. Young roots were more sensitive to the treatment than old roots.

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

BACTERIAL SOFT ROT AND BLACKLEG IN POTATO

Factors affecting the development of blackleg in potato crops

Further evidence was obtained that the development of blackleg occurs in two steps which may involve different resistance mechanisms. When mother tubers of cv. Majestic plants growing in pots in a cool glasshouse were heavily inoculated with *E. carotovora* var. *atroseptica* on different dates, the number of blackleg affected plants progressively increased for 4-6 weeks following inoculation. Little or no blackleg developed subsequently until early September when symptoms appeared simultaneously in all treatments. By that time the mother tubers were completely disintegrated and the development of symptoms must have arisen from the activity of bacteria hitherto dormant in the basal portions of stems, the aerial parts of which then had become more susceptible to rotting.

In an experiment where cv. Majestic was planted in the field on six different dates, blackleg levels were highest in crops planted in late April and lowest when planted in March in contrast to the results obtained in a similar experiment in 1972. These differences may be explained in terms of rainfall distribution and the results of the two experiments suggest that wet and cold soils 4-6 weeks after planting are conducive to blackleg development.

(M. C. M. Pérombelon and R. Lowe)

Studies on the recontamination of virus tested stem cutting potato seed stocks (VTSC) by the blackleg and other soft rot bacteria

The role was confirmed of groundkeepers, insects, and aerosols of sap generated when pulverizing haulms, as potential sources or vectors of the pathogen for recontamination of VTSC and derived stocks.

Plants affected by blackleg have been observed in several stocks of stem cutting origin. Surveys, similar to those carried out in 1966-1967, were therefore made of stocks of different ages to assess when and to what extent contamination by *E. carotovora* was occurring. The results of examining samples of over 80 stocks obtained from 16 growers from Peebleshire to Ross-shire show that all VTSC derived FS1 and FS2 stocks were extensively contaminated, as were, to a lesser extent, many of the non-commercial VTSC stocks in the process of multiplication. Varietal identification shows that the proportion of var. *carotovora* to var. *atroseptica* was greater in the early stages of stock multiplication.

Notwithstanding the extensive contamination, blackleg levels in VTSC derived stocks are lower than in stocks of equivalent ages not of stem cutting origin. This observation confirms experimental results of blackleg incidence in crops of cv. Majestic and cv. Redskin grown from VTSC and ordinary FS seed both heavily inoculated with the blackleg organism.

(M. C. M. Pérombelon and R. Lowe)

Factors affecting latency, initiation and development of bacterial soft rot in stored potato tubers

Susceptibility to rotting by *E. carotovora* var. *atroseptica* of turgid tuber discs kept at 15°C in atmospheres of different O₂, CO₂ and N₂ concentrations was as high at <1% O₂, >99% N₂ as at 100% N₂ and decreased progressively as the O₂ level was raised until at 5% rotting equalled that in air. At an O₂ concentration of 1.5% rotting was unaffected by up to 15% CO₂. At higher levels of CO₂ rotting decreased and was almost inhibited at a concentration >50%.

(M. C. M. Pérombelon and R. Lowe)

Cultural and chemical methods for the control of potato gangrene

For the fourth successive season the incidence of gangrene in stored tubers, from the 1972 field experiments, was lower in crops which were lifted in early rather than late autumn provided the haulm was sufficiently destroyed. Pulling again gave the best control and was the only treatment which markedly reduced gangrene in late harvested tubers. Mechanical destruction reduced infection in early but not late lifted tubers. Burning off with diquat only slightly reduced gangrene compared with the no kill treatment, a result possibly associated with slow haulm death. However, when sprayed stems were examined in October their colonisation by *Phoma exigua* var. *foveata* and *P. exigua* var. *exigua* was less than that of unsprayed stems though the occurrence of *Phoma eupyrena*, *Fusarium* spp. and *Alternaria* sp. had increased.

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

Factors affecting infection of potato tubers and the potato plant by the potato gangrene fungus, Phoma exigua var. foveata

Seed tubers of cv. Pentland Crown were infected with the var. *foveata* about 2 months before the end of the storage season. When planted in the field they had evident gangrene lesions. Nevertheless when pycnidia in stems growing from these seed tubers were sampled in mid September and early October, the incidence of the var. *foveata* was low and that of the var. *exigua* correspondingly high. This observation confirmed previous findings that irrespective of the infection status of the seed tuber or of the proximity of stems artificially inoculated with var. *foveata*, naturally developing pycnidia on stems at harvest time are most commonly those of the var. *exigua*. However, haulm debris has again been shown to be an important potential overwintering substrate and many samples collected in early spring not necessarily bearing pycnidia, have yielded the var. *foveata* when cultured. In exposed areas haulm debris is scattered for considerable distances and could well account for isolated outbreaks of the disease in otherwise clean stocks.

Stems, roots and stolons growing from infected seed tubers were sampled at intervals throughout the season. They yielded but few isolates of the var. *foveata*. Of those that were obtained, most came from underground stems, stolons and roots adjacent to the infected mother tuber, the incidence decreasing with distance from the source.

Further work was done on the pronounced inhibition of the growth *in vitro* of the var. *foveata* by volatiles produced by soft-rot bacteria. The inhibition induced by *Erwinia carotovora* could be eliminated by the presence of acidified filter paper or by using strongly buffered agar, suggesting that the inhibition is no more than a simple pH effect. Preliminary experiments suggest that the presence of soft-rotted tubers is unlikely to have an effect on the development of gangrene in a crop stored in bags.

Previous experiments in which dry heat treatment of tubers (2 h at 45°C) was tested as a control method gave erratic results and, indeed, it sometimes increased the incidence of gangrene. The results of an experiment in which heated tubers were wounded, dipped in a spore suspension and later scored for infection, supported an hypothesis of heat induced susceptibility. In addition, it was found that following regimes of slow drying, pycnidia, spores, mycelium (in agar), infested toothpicks and infected potato discs all survived 8 h at 45°C. Observations of increased incidence could thus be explained by increased host susceptibility induced by a heat treatment which, at the same time, allowed the pathogen to survive in an infection court which had been partially disinfested of potential antagonists by heat.

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

Survival of the potato gangrene fungus in soil, groundkeepers and alternative hosts

Continuing studies on symptomless hosts showed that infected barley plants, besides appearing healthy, had similar dry weights and shoot growth rates

as check plants. Root extension was, however, reduced by approximately half and this was accompanied by increased branching.

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

Histology of the Phoma exigua complex in potato and alternative hosts

Field experiments continued to compare the effects of haulm inoculation (one stem/plant) at 3 different dates on the development of stem lesions in six cultivars. Following inoculation in late June or mid July lesions in all cultivars remained small although on average they were larger following the later date of inoculation. The time of senescence was not advanced and following its onset the lesions did not extend rapidly being apparently limited by the early development of wound periderm. After inoculation in late July lesion development was rapid, the onset of senescence advanced, and, in some stems, pycnidia formed more than 20 cm away from the point of inoculation.

In 1971 and 1972 stems of cv. Majestic were very susceptible to lesion spread but this year is appeared as the most consistently resistant cultivar with Record and King Edward as the most susceptible cultivars. A review of the results of 3 seasons stem inoculation experiments show that relative susceptibility between cultivars cannot yet be assessed, the causes of variation between and within years remaining largely unknown.

(H. M. Wilson and R. A. Fox)

Virology

B. D. HARRISON

As in previous years, part of the Section's effort was devoted to studying specific virus diseases of crop plants, and part to research on the mechanisms underlying the properties and transmission of selected viruses. During the year, conditions were found for infecting tobacco leaf protoplasts with tobacco rattle virus, strong evidence was obtained that the coat protein of raspberry ringspot virus plays a crucial role in transmission by nematode vectors, two kinds of bacilliform virus particles were discovered in ultrathin sections of infected raspberry cells and in collaboration with Zoology Section, it was found that the use of oil sprays and a barrier crop can prevent virus spread in field plantings of lilies.

The electron microscope suite was redesigned and extended to accommodate a second machine, a Philips 301, which was installed in December. Work was temporarily interrupted by this and other laboratory refurbishings, and was somewhat slowed by the restrictions on use of electricity.

TOBRAVIRUSES

Coat protein of virus particles

Previous estimates of the mol. wt. of tobnavirus coat proteins, based on electrophoretic mobility in polyacrylamide gels containing sodium dodecyl sulphate (SDS), were found to be incorrect. Electrophoresis of these proteins in acrylamide gels of different strengths showed that the complexes formed between SDS and protein from either the CAM or the PRN strain of tobacco rattle virus (TRV) are less negatively charged than are the complexes formed with most proteins. Thus the electrophoretic mobilities of TRV protein complexes were less than those of similar sized but conventionally charged protein complexes, and the sizes of the TRV proteins were over estimated. Allowing for this effect the estimated mol. wt. of strain CAM protein is 22,500. Strain ORE-mild is serologically related to strain PRN, but mol. wt. estimates of its coat protein are little affected by acrylamide gel strength, being about 23,000 in both 7.5% and 10.5% gels. Corrected estimates of the mol. wt. of the protein in particles of pea early-browning virus strains SP5, Shern and IT6 were about 22,000. It therefore seems likely that the mol. wt. of different tobnavirus coat proteins are more similar than was previously suggested, and the revised estimates are close to those derived from amino-acid analyses.

(M. A. Mayo)

Previously it was reported that the protein in TRV particles is partially degraded when virus preparations are stored without anti-microbial agents, and that a similar degradation is caused by culture filtrates produced by bacterium P179. This bacterium was tentatively identified as an atypical *Xanthomonas* sp; an isolate deposited with the National Collection of Industrial Bacteria, Torry Research Station, Aberdeen, is coded NCIB 10939. Proteolytic activity in cultures in nutrient broth+1% glucose was greatest when the cultures were in a stationary phase of growth. In crude preparations the enzyme was remarkably stable; activity was undiminished after 3 days at 25°C or 10 min at 55°C and was decreased about 50% after 10 min at 65°C and about 70% after 26 days at 4°C. The protease appeared as a single component when analyzed by electrophoresis in polyacrylamide gel or by gel filtration in Sephadex G-100; gel filtration indicated that the mol. wt. was about 45,000. Enzyme activity did not require the presence of thiol reagents, but was reversibly inhibited by ethylene diamine tetra-acetic acid.

(M. A. Mayo, D. J. Robinson, with M. C. M. Pérombelon¹)

Enzyme-treated coat protein of TRV strain CAM behaved almost normally in polyacrylamide gels and seemed to have a mol. wt. about 1,000 smaller than untreated protein. The coat proteins of pea early-browning virus strains SP5 and Shern were affected like that of TRV strain CAM, but the protein of TRV strain PRN was affected much more slowly, and that of TRV strain ORE-mild was not affected. Action of the enzyme on CAM particles did not reveal a new N-terminal amino acid on the protein nor did it release lysine. Possibly it cleaves one or more peptide bonds near the C-terminus. However, carboxypeptidase A did not imitate its action.

As previously reported, the enzyme reveals an antigenic determinant absent from or hidden in unaltered CAM virus particles. Subunits of both the unaltered and the altered protein were able to aggregate to form double disc structures of about 36S at pH 7, and these discs retained the antigenic difference between enzyme-treated and untreated virus particles. The discs were reversibly dissociated at pH 4.6 unless fixed with 0.2% formaldehyde. The protein in formaldehyde-fixed discs was altered by the enzyme in the same way as in intact virus particles, but unfixed protein, or protein fixed while dissociated at pH 4.6 and then aggregated at pH 7, was extensively degraded. Thus it would seem that peptide bonds that are cleaved in the disaggregated protein are not accessible to the enzyme in fixed discs or assembled virus particles.

(M. A. Mayo and D. J. Robinson)

Mutants of tobacco rattle virus

Early events were studied in the infection of *Chenopodium amaranticolor* leaves with TRV strain CAM and two previously described temperature sensitive mutants, N8 and N10. In experiments in which infected plants were

kept at 30°C for varying periods and then transferred to 20°C, the greater part of the inactivation of potential lesions occurred within the first 24 h at 30°C, and the difference between mutants and wild-type was apparent well before this time. In experiments in which freshly inoculated plants were placed at 20°C and subsequently transferred after various times to 30°C, the difference between mutants and wild-type was observed only when the shift occurred within the first 5 h after inoculation. At 20°C, the resistance to inactivation by ultra-violet radiation of potential lesions of all three strains increased rapidly beginning at 1.5 to 3 h after inoculation. When the plants were kept at 30°C between inoculation and irradiation, and at 20°C thereafter, the resistance of potential CAM lesions to inactivation developed similarly, but more slowly. However, under these conditions the two mutants showed only a very slow increase in the proportion of potential lesions resistant to inactivation. These observations suggest that the functions altered in the mutants are normally active at an early stage in the infection of *C. amaranticolor* leaves. Genes coding for enzymes involved in virus RNA replication, notably RNA-directed RNA polymerase, are obvious candidates for the location of the mutations. Experiments which showed that lesion formation in *C. amaranticolor* inoculated with RNA extracted from mutant virus particles was temperature sensitive, suggested that uncoating of RNA is not the temperature sensitive event.

A variant of strain CAM that appeared spontaneously in the glasshouse was isolated by single lesion passage. This strain, code named YS, was indistinguishable from CAM in particle length distribution or reaction in immunodiffusion tests. However, it induced different symptoms in a number of test plants, notably systemic yellowing and stunting of several species, including *Nicotiana clevelandii*. The ability to induce these symptoms was determined by the RNA of the short particles.

(D. J. Robinson)

Infection of protoplasts by tobacco rattle virus

Many aspects of the multiplication of TRV could best be investigated using a system in which the stages of infection are synchronized. Progress has been made toward achieving this by infecting protoplasts from leaves of *Nicotiana tabacum* cv. White Burley. Protoplasts were produced, using methods developed by workers in Japan and at the John Innes Institute, and were inoculated with mixtures of particles of TRV (strain CAM) and poly-L-ornithine. After incubation for 20–24 h newly synthesized virus was detected as specific antigen using fluorescein-labelled antibodies to CAM and by infectivity assay of buffer or phenol extracts of protoplasts. Optimal final concentrations of the constituents of the inoculum were 2 µg/ml virus and 1 µg/ml poly-L-ornithine. Up to 20% of the viable protoplasts were infected and it was estimated that as few as 1,000 infected protoplasts could be detected by infectivity assay 20–24 h after inoculation. This suggests a mean yield of 10⁵–10⁶ virus particles per infected protoplast. The 200 nm long

¹Mycology Section.

virus particles were found packed around protoplast mitochondria 20 h after infection with strain CAM, the same distribution as is observed in newly infected cells of *Nicotiana clevelandii* leaves.

(M. A. Mayo, D. J. Robinson and Aileen M. Hutcheson)

NEPOVIRUSES

Pseudo-recombinant isolates of raspberry ringspot virus

In further work to identify the functions of the two RNA species of raspberry ringspot virus, additional properties of pseudo-recombinant (hybrid) isolates were studied. Ability to infect Lloyd George raspberry was determined by RNA-1, whereas transmissibility by the nematode *Longidorus elongatus* was determined by RNA-2. It is therefore suggested that the vector specificity of strains of this virus depends critically on properties of the virus coat protein, because the gene for the coat protein is also in RNA-2. However, preliminary work failed to reveal any simple relation between the surface charge density of virus particles and transmissibility by any one nematode species.

(B. D. Harrison, A. F. Murant, M. A. Mayo, R. A. Goold and H. Barker)

Pseudo-recombinant isolates of tomato black ring virus

Previous work has shown that this virus, like other nepoviruses studied, has two functional RNA species, RNA-1 (mol. wt. 2.5×10^6) and RNA-2 (mol. wt. 1.5×10^6). A pseudo-recombinant isolate, made by infecting plants with RNA-1 from the German potato bouquet isolate together with RNA-2 from a Scottish beet ringspot isolate, possessed the serological specificity of the Scottish isolate. This suggests that with tomato black ring virus, as with raspberry ringspot virus, the coat protein is coded for by RNA-2. An attempt to produce the reciprocal type of pseudo-recombinant did not succeed.

A third RNA species, RNA-3 (mol. wt. 0.5×10^6) occurs in particles of some isolates of tomato black ring virus but not in those of others. It is not essential for multiplication of the virus. Plants inoculated with RNA-3 alone develop no symptoms nor do they contain infective virus particles or RNA. RNA-3 from the Scottish (beet ringspot) isolate of tomato black ring virus multiplied in the presence of RNA-1+RNA-2 from either a Scottish isolate or a German potato bouquet isolate, but RNA-3 from the German isolate multiplied only in the presence of RNA-1+RNA-2 from the homologous isolate. Neither kind of RNA-3 multiplied in the presence of RNA-1+RNA-2 from an English strain of raspberry ringspot virus.

(A. F. Murant, M. A. Mayo, B. D. Harrison and R. A. Goold)

Components of particles of strawberry latent ringspot virus

Particles of strawberry latent ringspot virus were shown to contain two polypeptide components of mol. wt. 44,000 and 29,000. This polypeptide

composition was the same for two different isolates and was unaltered when virus was purified either from different host species or using different techniques. RNA from either isolate comprised two components, of mol. wt. 2.6×10^6 and 1.6×10^6 , and that from the type isolate also contained a rather polydisperse RNA of mol. wt. 0.4×10^6 .

Most of the virus particles had a sedimentation coefficient ($s_{20,w}^0$) of 126S but particles of 58S were also detected; the 126S particles tended to aggregate. Virus particles were homogeneous in both immunoelectrophoresis and acrylamide gel electrophoresis; they were retarded more by polyacrylamide, and were less dense in caesium chloride solution, than were particles of raspberry ringspot virus. These results indicate that each particle of the 126S component contains about 3×10^6 mol. wt. RNA in a protein shell, which possibly contains 60 molecules of each polypeptide species. Thus in the size and number of its polypeptide species, strawberry latent ring spot virus differs from other nepoviruses and resembles the aphid transmitted broad bean wilt virus and the beetle transmitted comoviruses; however, no reaction was detected between particles of strawberry latent ringspot virus and antisera to seven of these viruses. The cryptogram of strawberry latent ringspot virus is R/1:2.6 (or 2×1.6)/(38):S/S/S/Ne.

(M. A. Mayo, A. F. Murant, B. D. Harrison and R. A. Goold)

Serological specificity of isolates of cherry leaf roll virus

Isolates of cherry leaf roll virus from cherry, elm, rhubarb and *Sambucus nigra* were previously reported to be serologically distinguishable. Isolates from four additional hosts, *Sambucus ebulus* (supplied by M. Mamula), blackberry (supplied by P. J. Ormerod), dogwood (supplied by H. Waterworth) and birch (supplied by J. I. Cooper) similarly were found to be serologically distinguishable from one another and from each of the isolates previously studied. Cherry leaf roll virus seems more prone to antigenic variation than other plant viruses.

(A. T. Jones)

VIRUSES OF FLOWER BULBS

Survey of viruses in narcissus stocks

In 1973, 420 individual plants in 14 stocks of five cultivars were examined by infectivity tests and by electron microscopy of sap. Filamentous virus-like particles were found by electron microscopy in all 120 plants of King Alfred, all 90 of Rembrandt and in some plants of Corinthian, Dutch Master and Fortune. Tobacco rattle virus was detected in six stocks including at least one of each cultivar; the greatest incidence was 50% in a stock of Rembrandt. All nepoviruses indigenous to Britain were detected. The commonest were arabis mosaic and tomato black ring viruses and the greatest incidences in a stock were 43% and 33% respectively. All stocks except those of Dutch Master contained plants infected by nepoviruses. Some plants of Corinthian

and Fortune seemed free of virus infection and no one virus occurred in every plant of Dutch Master, suggesting that virus-free plants may exist.

Further tests were made on apparently virus-free plants by clarifying sap from 5–6 g leaf using diethyl ether, concentrating the extract by one cycle of differential centrifugation and testing the final preparations for infectivity and by electron microscopy. These revealed isometric virus-like particles which did not infect hosts of other isometric viruses known to occur in narcissus. Such particles were found in most plants examined of Carlton and Sempre Avanti, and also occurred in Corinthian and King Alfred.

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

Production of virus-tested narcissus clones

Continuing the programme to produce clones from selected bulbs by a twin-scaling method, about 3,600 twin-scales were obtained from 28 bulbs of the cultivars Carlton, Sempre Avanti, Corinthian and Golden Harvest. Most twin-scales weighed 0.5–0.8 g, and about 90% of them survived treatments of 12 weeks at 23°C, or 6 weeks at 23°C followed by 6 weeks at 12°C. About 80% of the survivors formed bulbils in 12 weeks; larger bulbils were produced by the twin-scales kept at 23°C throughout but the two-temperature regime was better for root production.

(W. P. Mowat and J. Chambers)

In complementary work intended to produce virus free master plants for further propagation, 2,500 meristem tips were cut from bulbs of the cultivars Golden Harvest, Fortune and Sempre Avanti. Preliminary results of a test with Golden Harvest and Fortune, in which the composition of the culture medium was varied, showed that none of the modified media had any obvious advantage over the standard medium. However, meristem tips of Fortune grew and differentiated better at 22°C than at 12°C.

(J. Chambers and S. Johnson)

Viruses of lily and tulip

Further work on lily symptomless virus showed that, contrary to our earlier findings, it can infect *Tulipa gesneriana* cv. Rose Copland. However, symptoms did not develop until the second year after the virus was inoculated by aphids.

A virus (code-named L45) with filamentous particles about 720 nm long was transmitted by sap inoculation to herbaceous test plants from *Lilium formosanum* bait plants grown for 1 year in a 5 year-old field planting of Asiatic lily hybrids, some of which also contained the virus. L45 induces local lesions in several species of *Chenopodium* and infects *Nicotiana clevelandii* systemically. Infectivity of sap from *N. clevelandii* survives heating for 10 min at 55°C but not 60°C. *Myzus persicae* transmits L45 from *L. formosanum* after short acquisition feeds. The virus infects tulip but differs from tulip

breaking virus—the only potyvirus previously reported in *Lilium* spp.—in its ability to infect dicotyledonous species.

(W. P. Mowat)

Previous observations have shown that the field spread of tulip breaking and lily symptomless viruses by aphids to *Lilium formosanum* plants occurs from June to October, and that in 1972 spread was most rapid in September. During 1973, two possible ways of preventing virus spread were tested. Mulching with aluminium-coated building paper decreased the number of winged aphids alighting (see Zoology Section report), but all the *L. formosanum* plants in treated plots nevertheless became infected with virus. The second method was more effective. *Lilium* plants were surrounded with a barrier row of barley and the infectors and test plants were sprayed weekly from 27 June to 25 September with a 1% emulsion of the mineral oil Albolineum (ICI Ltd). Only two of 50 protected plants became infected compared with 42 of 50 unprotected plants.

(W. P. Mowat with J. A. T. Woodford¹)

RASPBERRY VIRUSES

52V virus

This virus, mentioned in the reports for 1969 and 1970, reaches very low concentrations in infected plants and is difficult to transmit by sap inoculation, but can be grown throughout the year in *Chenopodium quinoa* plants kept in growth chambers if care is taken to prepare highly infective inoculum. *Chenopodium murale* proved to be a satisfactory local lesion assay plant. A reliable purification procedure is to grind systemically infected *C. quinoa* leaves in 0.05M citrate buffer, pH 6.0, and to follow clarification using diethyl ether by two cycles of differential centrifugation. In sucrose density gradients infectivity is associated with a small peak of ultraviolet absorbing material, but there is no visible light scattering zone because of the low concentration of virus particles relative to host components. Fractions from the u.v. absorbing zone contain a few virus particles about 30 nm in diameter, together with many phytoferritin particles. Serum from rabbits injected with infective fractions from density gradients contained antibodies to several non-viral antigens, including two that were detectable rarely in sap from healthy *C. quinoa* plants but readily in plants infected either with 52V or with any of several unrelated viruses.

No success was achieved in attempts to return 52V to *Rubus* but it is heat labile in raspberry, and circumstantial evidence suggests that it causes necrosis of black raspberry (*Rubus occidentalis*) and *Rubus henryi*.

(A. F. Murant, A. T. Jones and R. A. Goold)

Raspberry cultivars resistant to the aphid *Amphorophora rubi* again tended to escape infection by 52V virus. After 3 years in the field all plants of Malling

¹Zoology Section.

Jewel and Lloyd George were infected, whereas less than 10% infection occurred in the cultivars Glen Clova, Malling Orion, Norfolk Giant and selection 888/49.

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

Other sap transmissible viruses found in Rubus

Mechanical inoculations were made to herbaceous test plants using inoculum from *Rubus* spp. growing in the field at SHRI. Cucumber mosaic and raspberry bushy dwarf viruses were found in several plants of *R. phoenicolasius*, and raspberry bushy dwarf virus was also found in *R. idaeus* cv. Fallcrop and Savetskaja, which were not previously known to be hosts. A virus which appears to be related serologically to tobacco streak virus was found in Aurora and Cascade blackberries imported from the USA.

A previously unreported virus from *Rubus* was obtained from *R. phoenicolasius*. It was transmitted to several herbaceous plants and induced necrotic local lesions in many chenopodiaceous species. Sap from infected *Chenopodium quinoa* lost infectivity after diluting to 10^{-3} , heating for 10 min at 60–70°C or storage at 18°C for 10 days. Infectivity was retained after treatment with diethyl ether or chloroform. The virus was precipitated by acidifying sap to pH 4.0. Some partially purified preparations contained very long flexuous threads which appear to be aggregates of the 550–650 nm long particles found in infective *C. quinoa* sap.

(A. T. Jones)

Particles associated with raspberry vein chlorosis and mosaic diseases

Electron microscopy of thin sections of red raspberry leaf tissue infected with raspberry vein chlorosis virus alone, or in combination with other viruses, revealed large bacilliform particles ca. 430 x 65 nm. The particles were found in the cytoplasm and perinuclear space of a small proportion of xylem parenchyma cells of infected but not virus free plants. The particles are probably those of raspberry vein chlorosis virus.

Bacilliform particles ca. 125 x 30 nm were found in the cytoplasm of a small proportion of vascular parenchyma cells of red raspberry showing symptoms of raspberry mosaic (veinbanding), but not in plants free from mosaic. However, it is not known which, if any, of the viruses associated with raspberry mosaic are represented by the particles.

(A. T. Jones, I. M. Roberts and A. F. Murant)

Mosaic in Glen Clova raspberry

Grafting experiments have shown that raspberry leaf spot virus alone can induce mosaic symptoms in cv. Glen Clova. However, all the field infected plants tested contain both raspberry leaf spot and raspberry leaf mottle viruses. *Amphorophora rubi*, fed on Glen Clova plants naturally affected by mosaic, transmitted both these viruses to virus free Glen Clova in which mosaic subsequently developed.

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

Raspberry bushy dwarf virus

In a 5 year field experiment, virus spread to Lloyd George raspberry plants with their flowering canes removed was compared with spread to plants allowed to flower. Transmission of raspberry bushy dwarf virus through pollination apparently appeared to be the only method of spread in the field; most plants near infectors became infected during the first two or three flowering seasons. In another experiment, no transmission occurred on the blades of pruning knives. The virus is transmitted to raspberry seed both through the pollen and through the ovule. Although infected plants show no obvious leaf symptoms, healthy or infected flowers pollinated with infected pollen produced 'crumbly' fruit containing a high proportion of aborted drupelets. Raspberry cultivars that fail to become infected naturally were also immune to infection by grafting. Thus the use of immune cultivars seems the only method of control and, because infected plants may produce crumbly fruit, future cultivars should if possible possess immunity to raspberry bushy dwarf virus.

(A. F. Murant, J. Chambers, A. T. Jones and R. A. Goold)

Elimination of viruses by heat therapy

Plants of the cultivars Hilton, Malling Exploit and Zeva were freed by heat treatment from viruses detectable by grafting to *Rubus henryi*. However the cultivars Canby and Lloyd George were not freed from raspberry bushy dwarf virus after 36 days at 36°C.

(J. Chambers)

OTHER VIRUSES

Tobacco rattle virus in potato

Further tests were made to compare the reaction of field susceptible and field resistant potato cultivars to virus transmitted by mechanical inoculation or by nematode vectors. The leaves of all cultivars developed lesions after inoculation of infective sap. The roots of four field susceptible cultivars were readily infected when exposed to virus-carrying *Trichodorus* nematodes, spraing symptoms were produced in progeny tubers and, when well sprouted 'seed' tubers were used, stem-mottle symptoms developed in several plants. By contrast, the roots of five field resistant cultivars were rarely infected and neither spraing nor stem-mottle developed.

(B. D. Harrison)

A second experiment to test the ability of systemic nematicides to control potato spraing disease caused by tobacco rattle virus was made on land infested with virus-carrying *Trichodorus*. The results are summarized in the Zoology Section report.

(B. D. Harrison, H. Barker, with T. J. W. Alphey¹)

¹Zoology Section.

Viruses from umbelliferous plants

Further studies on the vector relations of parsnip yellow fleck virus (PYFV) and its 'helper' virus, anthriscus yellows (AYV), showed that although the minimum access time required for the aphid *Cavariella aegopodii* to acquire the virus complex is about 15 min, aphids that have previously acquired AYV can acquire PYFV from singly infected plants in minimum access times of 2 min. Thus the apparent minimum time for acquisition of PYFV from doubly infected plants is really the time required for acquisition of the helper component of the complex. Efficiency of transmission of PYFV in these tests is not affected by starving the aphids for 2-3 h after acquiring AYV and before feeding on a source of PYFV. Pre-acquisition starvation also had no effect on acquisition of AYV.

These results suggest that AYV is confined to the deeper-lying tissues of the leaf, perhaps to phloem tissues, whereas PYFV is present in epidermal tissues too. These ideas receive support from experiments in which transmission of AYV from infected chervil leaves was not prevented by irradiating the leaves for up to 20 min with ultraviolet light, a treatment which destroys the infectivity of virus in epidermal cells and possibly in immediately underlying layers. In contrast, ultraviolet irradiation of leaves infected with PYFV alone prevented AYV-carrying aphids from acquiring PYFV from them in 2 min feeds; they did, however, acquire PYFV in feeds of 1 h. It is not possible to conclude from these experiments whether AYV-infected plants contain a 'helper factor' distinct from AYV particles, but results reported previously suggest they do not, and only treatments that enabled *C. aegopodii* to acquire AYV also gave them the ability to transmit PYFV.

The dependence of PYFV on AYV for aphid transmissibility seems to be absolute. No transmission of PYFV has ever been obtained in the absence of AYV. In experiments reported previously, carrot redleaf virus, which assists transmission of carrot mottle virus, was unable to assist PYFV. Further experiments showed that neither celery mosaic, parsnip mosaic nor parsnip mottle viruses assisted transmission of PYFV by *C. aegopodii*, nor did potato virus Y enable PYFV to be transmitted by *Myzus persicae*.

Isolates of PYFV from wild hogweed (*Heracleum spondylium*) plants were identical in serological and host plant reactions to isolates from parsnip and differed from those obtained from wild cow parsley (*Anthriscus sylvestris*) plants. The hogweed plants also contained AYV, and hogweed isolates, like those from the other two sources, depend on AYV for their transmission by *C. aegopodii*.

Aphids receiving intrahaemocoelic injections with haemolymph from aphids transmitting the carrot mottle/carrot redleaf virus complex, themselves transmitted both viruses, but aphids injected with haemolymph from aphids transmitting the PYFV/AYV complex did not transmit, nor did aphids injected with partially purified preparations of carrot mottle virus.

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

Composition of particles of parsnip yellow fleck virus

Purified preparations of a parsnip isolate (P121) and an *Anthriscus sylvestris* isolate (A421) of parsnip yellow fleck virus (PYFV) yielded single stranded RNA which migrated in polyacrylamide gel electrophoresis as a single peak corresponding to a mol. wt. of about 3.7×10^6 . Polyacrylamide gel electrophoresis of protein from either isolate produced three bands corresponding to mol. wt. of about 30,000, 27,000 and 22,000. It is not clear whether the three bands represent distinct polypeptides or derivatives of a single polypeptide. However, the number and sizes of the polypeptides were unchanged when the virus was extracted from leaves in the presence of diethyl pyrocarbonate, or was obtained from leaf extracts which had been kept for 24 h at room temperature. This suggests that if the polypeptides are derived from a single precursor, the degradation process occurs *in vivo*. Purified preparations of PYFV particles contained a single sedimenting component and formed a single precipitin band in gel-diffusion serological tests but the particles migrated heterogeneously when subjected to immunoelectrophoresis, or to electrophoresis in polyacrylamide gels.

(A. F. Murant, M. A. Mayo and R. A. Goold)

Elm mottle virus

This virus was found to be seed borne in elm but infected plants did not develop leaf symptoms when kept in a heated glasshouse. Most virus particles were degraded when centrifuged to equilibrium in caesium chloride solution and formed a non-infective band of density ca. 1.27g/cm^3 . Undergraded virus particles formed a band of density ca. 1.35g/cm^3 and retained infectivity. Both density bands contained virus-like particles, but whereas most of those in the infective band had a diameter of about 28 nm most of those in the non-infective band had diameters of 15-22 nm.

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

Viruses from broad bean in the Sudan

Two viruses were found to be associated with Sudanese broad bean mosaic. One, with filamentous particles ca. 750 nm long, proved to be a strain of pea mosaic virus. The other, with isometric particles ca. 26-28 nm in diameter, was identified as a strain of broad bean mottle virus. Both viruses were seed transmitted in Beladi, a local Sudanese broad bean cultivar; less than 1% of the seeds were infected but the infected seeds contained both viruses. The Sudan isolate of broad bean mottle virus was less virulent than the type isolate, and the two were slightly different antigenically. *Cyamopsis psoraloides* is a useful local lesion indicator for broad bean mottle virus, producing tiny black local lesions in 1-2 days. This is only the third time that this virus has been reported and is its first recorded occurrence outside the UK. The vector is at present unknown but the virus spreads readily in Sudanese broad bean crops.

(A. F. Murant, H. S. Abu Salih and R. A. Goold)

Ultrastructural changes associated with African cassava mosaic disease

Flexuous filamentous particles with obvious helical structure but no characteristic modal length were found in leaf-dip preparations and in exudates of latex from cassava (*Manihot esculenta*), both from healthy plants and from plants infected by the white-fly transmitted African cassava mosaic agent. Electron microscope examination of thin sections showed that in healthy plants the filamentous particles occurred as amorphous and crystalline inclusions in the laticifers and occasionally also in the sieve tubes. In chlorotic areas of diseased cassava leaves, laticifers were rare but sieve tube inclusions were more common. The filamentous particles resemble those reported in other latex-bearing plants and are probably a normal host component. They did not occur in plants of castor bean (*Ricinus communis*) infected with the agent of cassava mosaic disease. Virus-like or mycoplasma-like particles were not found in the cassava or castor bean material examined.

(A. F. Murant, I. M. Roberts with D. L. Jennings¹)

ELECTRON MICROSCOPE TECHNIQUES

The performance of glass ultramicrotome knives was considerably improved by coating their cutting edge with a film of evaporated tungsten. Coating with carbon or other metals was less effective. Tungsten coated knives cut three to ten times as many sections as uncoated knives, produced thinner sections and cut harder tissues, and they caused fewer artefacts. The reason for their improved performance is not apparent.

A technique was devised that allows comparative light and electron microscopy of specimens fixed using glutaraldehyde and osmium tetroxide, treated with uranyl acetate and embedded in epoxy resin. Thin sections for electron microscopy are stained conventionally with lead citrate. Thicker (0.25–1.0 µm) sections for light microscopy are picked up on thin glass strips, then treated with 1% aqueous periodic acid, and stained with aqueous basic fuchsin followed by methylene blue. The stained sections are then mounted in diluted DePeX. The staining is polychromatic and is effective with a wide range of plant, insect, nematode and other animal tissues.

(I. M. Roberts and Aileen M. Hutcheson)

Zoology

D. L. TRUDGILL

During the year a technique for studying the feeding of virus vector nematodes on seedlings growing in agar was developed for use in studies on the action of nematicides on nematode feeding in relation to virus transmission, and on host parasite relationships. Techniques for experimenting with small numbers of nematodes using micro-containers have been improved and several viruses now have been separately transmitted by single nematodes. Ultrastructural studies on *Longidorus* and *Xiphinema* spp. have revealed several adaptations, hitherto unknown and apparently unique to these nematodes, for feeding on cells deep inside plant roots.

In trials testing chemicals to control raspberry mite, vamidothion has given excellent results. When vamidothion was applied in the spring the spawn cane was completely protected and there were worthwhile increases in fruit yield in the year following treatment. Work on the control of raspberry beetle has been largely concluded with fenitrothion, when applied between the green fruit and first pink fruit stage, proving a satisfactory alternative to DDT.

Nematodes and trees*

Results from an initial survey of nematodes associated with forest and woodland trees suggested that Criconematid species have a marked preference for deciduous trees. Using samples collected during a NATO sponsored survey of the distribution of *Xiphinema* and *Longidorus* spp. in the British Isles, over 20 Criconematid species in seven genera have been identified. Of these *Nothocriconema annuliferum* was the most common followed by *Macroposthonia rustica* and *Criconemoides informis*.

Studies over 2 years on the population dynamics of the most abundant plant parasitic nematodes associated with trees have shown Criconematid numbers to be fewest in winter and that numbers of most nematodes increase during the spring and summer.

The growth rate of Sitka spruce seedlings in glasshouse pot studies was decreased by *Rotylenchus robustus*. After 8 months, control seedlings grown in steam sterilised soil were 19 cm high whilst those infected with 10, 100 and 1000 nematodes per seedling were 17, 11 and 9 cm high respectively. In a second experiment the height increase of 15-day old seedlings infested with 1000 *R. robustus*/litre, was only 55% that of the nematode free controls after 21 weeks. As might be expected, older seedlings with more root were

*In conjunction with the Institute of Tree Biology, Edinburgh.

¹Plant Breeding Section.

less affected; the increase in height of 300-day old seedlings was 90% that of the nematode free control over the same period.

(B. Boag)

Chemical control of nematodes

More nematicides are now available and their use by farmers is increasing slowly although still limited by cost or application difficulties. The recently introduced oxime carbamate nematicides (oxamyl and aldicarb) are efficient and easy to apply but their mode of action is not yet fully understood. However, these chemicals seem to be consistently effective in decreasing virus spread when applied to soils containing populations of *Trichodorus* carrying tobacco rattle virus. Oxamyl 5 lb a.i./ac (5.6 kg a.i./ha) and aldicarb 3 lb a.i./ac (3.36 kg a.i./ha) applied as granules and incorporated into the ridge decreased the incidence of spraing in potato tubers (cv. Pentland Dell) from 19% in the untreated control to 4% and 3% respectively. However numbers of nematodes 6 wk after planting were decreased little. A dichloro-propane-dichloropropene mixture (D-D) 200 lb/ac (224 kg/ha) applied 6 wk before planting was much less effective than in previous years. It decreased *Trichodorus* numbers by 83% but did not decrease virus infection. A fourth pesticide, phenamiphos, 13.4 lb a.i./ac (15.0 kg a.i./ha) was largely ineffective. These results support a previous suggestion* that oxime carbamates have limited direct nematicidal action but act by disorganising nematode host finding and feeding behaviour, thus preventing virus transmission.

(T. J. W. Alphey, with H. Barker¹ and B. D. Harrison¹)

Further support for this suggestion comes from a pot test in which 7 days after treatment more *Longidorus elongatus* were recovered from pots drenched with oxamyl (1 mg/560 g soil) than the untreated control. One month after treatment, virus transmission had been largely prevented and significantly fewer *L. elongatus* were recovered from the treated pots than the untreated control. Dipping plant roots in oxamyl at transplanting did not prevent virus transmission, but did eventually decrease soil nematode numbers.

Even a relatively short exposure of nematodes to oxamyl decreased or prevented virus transmission in some tests. In one test virus transmission by *L. elongatus* and *Trichodorus* spp. was greatly decreased when nematodes were immersed in 5 ppm oxamyl for 1 h but virus transmission by *Xiphinema diversicaudatum* was little affected. Following exposure to 50 ppm oxamyl for 1 h all failed to transmit virus to bait plants. Nematode numbers were decreased little after 1 month by the 5 ppm oxamyl treatment but greatly reduced by the 50 ppm treatment.

(T. J. W. Alphey and L. B. Forer)

Oxamyl probably directly affected the nematodes in these tests because when the chemical was used as a diluent for manually inoculated tomato black ring virus (TBRV) there was no decrease in infectivity.

(L. B. Forer)

*Annual Report 1972, p. 76.

¹Virology Section.

Prior to planting raspberries, two field experiments tested oxamyl 7 lb a.i./ac (7.84 kg/ha), aldicarb 7 lb a.i. and 3.5 lb a.i./ac (7.84 and 3.92 kg/ha), D-D and dazomet, both at 300 lb/ac (336 kg/ha), as alternatives to quintozone 80 lb a.i./ac (89.6 kg a.i./ha) for controlling viruliferous *L. elongatus*. Dazomet and D-D gave almost a complete kill of nematodes and largely prevented virus transmission to *Chenopodium quinoa* bait plants in glasshouse tests of the field soil. Nematode populations decreased only slowly in plots which received quintozone, oxamyl or aldicarb, and were decreased to about 20% of the numbers in the untreated control 3 months after treatment. After 12 wk virus transmission was completely prevented by quintozone and aldicarb and largely so by oxamyl. Weeds growing in the plots provided a host and a source of virus for the nematode and after 6 months numbers of *L. elongatus* and the rate of virus transmission had increased in the oxamyl and aldicarb treated plots.

Thus oxamyl and aldicarb gave reasonable short term control of nematodes and virus, but for them to be used with confidence good weed control is essential. Quintozone has several disadvantages. It is phytotoxic to some crops, persistent and selective; also it had little influence on large populations of the lesion nematode, *Pratylenchus* spp.

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

Feeding behaviour of nematodes in relation to virus transmission

Feeding behaviour influences the efficiency of acquisition and transmission of stylet borne viruses by aphids, but little is known about how it affects these processes with nematode transmitted viruses. A preliminary study of host parasite relations and feeding behaviour of *Xiphinema diversicaudatum* feeding on rose seedlings growing on agar in petri dishes showed nematodes started to feed within 6 h of being introduced. Initially feeding was confined to the hypocotyl and root hair region but after 2 or 3 days some nematodes fed close to the tips of the roots which responded by forming small galls. Over a period of a further 2 or 3 days these galls enlarged and became the preferential feeding sites of most of the nematodes in the culture.

(D. L. Trudgill and J. Bloom)

The 'galling' response of plants parasitised by *Longidorus* spp. has been used in pot studies as a measure of nematode feeding. The number of *Petunia hybrida* galled increased little when small open capsules (0.5 ml) each containing a single plant and nematode were left for more than 14 days, but the mean number of galls per plant increased slightly when they were left for a further 14 days. Three strains (Lloyd George, 4B7 and Himalayan) of raspberry ringspot virus (RRV) were transmitted equally well by single nematodes feeding on bait plants for 14 or 28 days, and the proportion of virus-infected plants increased proportionally with three nematodes per plant. In 5 ml tubes, with coarse sieved soil, *L. elongatus* survived better than in the capsules and with five and 20 nematodes per tube, numbers of galls after 30 days exceeded

the initial number of nematodes. With 66 nematodes root growth and mean number of galls per nematode were decreased. Although all the bait plants were extensively galled only 11 with five nematodes, 13 with 20 nematodes and 27 of 30 bait plants with 66 nematodes became infected with TBRV (strain W22). From these results it seems likely that only a small proportion of the nematodes carried virus, but the relative decrease in infectivity with increasing numbers of nematodes is unexplained.

Acquisition of virus by *L. elongatus* and *L. macrosoma* was also related to feeding. *P. hybrida* in 5 ml containers were infected with RRV (strains 4B7 and Himalayan) 2 days after the nematodes had been introduced. After 1 month the infector plants were extensively galled, but although 750 *L. elongatus* and 360 *L. macrosoma* were tested only 6 of 160 *Petunia* bait plants subsequently became infected. Twenty selected well fed nematodes were sectioned for examination using the electron microscope but no virus-like particles were found associated with their feeding apparatus.

(D. L. Trudgill, L. B. Forer and W. M. Robertson)

Feeding of *Trichodorus hooperi* on seedlings in agar was much more vigorous than that of *Trichodorus pachydermus*, which fed little. The preferential feeding site was the region of root elongation where small numbers rapidly stunted root growth. Results suggest that *T. hooperi* exposed to leaves infected with TRV acquired the virus and transmitted it to uninfected leaves buried in the same soil. This technique is being developed as a simple method of testing for TRV infectivity in *Trichodorus* populations.

(T. J. W. Alphey)

In one experiment *Longidorus leptocephalus* failed to transmit to *Petunia hybrida* bait plants RRV (4B7 and Himalayan), TBRV (W22 and potato bouquet strains), Cherry leaf roll virus, and Arabis mosaic virus (AB10 strain), after being exposed for 1 month to *P. hybrida* infected with these viruses. An electron microscope examination of sections through the feeding apparatus of at least five specimens from each treatment failed to reveal any virus-like particles. However, in a second test one bait plant became infected with RRV Himalayan strain.

(L. B. Forer and W. M. Robertson)

Ultrastructure of virus vector nematode

Studies of the ultrastructure of the feeding apparatus of *Longidorus leptocephalus* have revealed several adaptations for feeding on cells deep inside plant roots. The central feeding apparatus is linked to the hypodermal chords by five nerve fibres which have part of their length free in the pseudocoel to allow for stylet protraction and retraction. These fibres possibly provide the connection between the nerve ring and two sets of nerve processes which come together in the region of the odontophore. The first set, comprising four small nerve processes, pass forward along the length of the buccal

capsule, in close association with the support membrane for the stylet protractor muscles, to innervate the stoma (vestibule). The second set of nerve processes pass posteriorly from the three sinuses within the odontophore. In the sinuses these nerves are closely associated with pore-like areas which penetrate almost to the food canal. The location and structure of these innervated areas suggest that they have a gustatory function. This facility is probably necessary for the nematodes to accurately locate feeding sites deep in plant roots.

The three nerve processes from the sinuses, after linking with the other nerves, pass posteriorly, via three ganglia within the central oesophagus, to the oesophageal bulb.

(W. M. Robertson)

Biotypes of potato cyst nematode and effects of resistant potato cultivars

The forms of potato cyst nematode *Heterodera pallida*—pathotype B and E, able to reproduce on the resistant potato Maris Piper seem to be rare or absent in those fields sampled at the SHRI. The non aggressive form *H. rostochiensis*—pathotype A, is present in field plots, but although it can form occasional cysts on Maris Piper, no selection seems to occur of a race able to reproduce on this cultivar if *H. pallida* is absent.

Most of the potato cyst nematode populations in the potato seed growing areas are small and the majority are probably *H. rostochiensis*—pathotype A. It may be possible to eliminate them by growing resistant cultivars and this hypothesis is being tested in a field experiment at the SHRI where a small population of the nematode became undetectable after one crop of Maris Piper. In pots, the same soil (400 g) produced a mean of 101 new cysts on a susceptible cultivar.

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

Control of aphids spreading non-persistent viruses in lilies

Because stylet-borne viruses can be transmitted by aphids probing on the leaf surface for only a few seconds systemic insecticides do not prevent migrating vector aphids from infecting plants, though spread within a field may be decreased by preventing the establishment of aphid colonies. Oil sprays have shown promise in decreasing plant infection with stylet-borne viruses and there is evidence that reflective surfaces which deter aphids from landing may reduce virus spread. Experiments were started to test the efficacy of these methods in preventing the spread of lily symptomless virus and tulip breaking virus.

Healthy *Lilium formosanum* were planted in June in plots of Asiatic lily hybrids. In one experiment two rows of 10 bait plants were grown in each of two adjacent plots (7 m x 7 m). Strips of aluminium coated building paper were laid as a soil mulch round all the plants in one plot. In the other experiment five rows of 20 *L. formosanum* were grown in a plot (11 m x 11 m) and a barrier crop of barley was sown round 10 bait plants in each row in one

half of the planting. These plants and the infector rows next to them were sprayed weekly from 27 June to 25 September with a 1% emulsion of mineral oil, Albolineum (ICI Ltd.), applied to run off. The numbers of winged aphids landing in water filled yellow pans on each plot were recorded.

Considerably fewer aphids were caught in the traps on the aluminium mulch plots than in those on the untreated control, but the *L. formosanum* bait plants became equally infected with virus. Large numbers of apterous *Macrosiphum euphorbiae* were present in both treatments and these, rather than the winged aphids, may have been responsible for much of the virus spread. In the oil spray experiment numbers of aphids trapped were similar in the control and treated plots, but only two of 50 sprayed bait plants became infected, compared with 42 of 50 untreated bait plants.

(J. A. T. Woodford with W. P. Mowat¹)

Ecology of aphids infesting raspberries

Canes of the raspberry cultivars Malling Jewel, Malling Promise and Malling M were examined in January for aphid eggs. Eggs of *Amphorophora rubi* were found mostly on the basal part of the cane but smaller eggs, almost certainly of *Aphis idaei*, were found throughout the length of the cane, often in the upper bud axils. The greatest numbers of *A. rubi* eggs were found on M. Promise whilst eggs of *A. idaei* were most common on M. Jewel, but numbers of eggs per cane differed greatly even within a cultivar. *A. idaei* was scarce on raspberry at the SHRI in 1973, possibly due to a high mortality in overwintering eggs; almost 90% of *A. idaei* eggs were found to be damaged, but the cause remains unknown.

In a field experiment with six raspberry cultivars differing in resistance to *A. rubi* (M. Jewel, M. Promise, M. Admiral, Glen Clova, M. Landmark and M. Orion), the greatest numbers of *A. rubi* occurred on M. Jewel. Very few were found on M. Landmark and M. Orion—two cultivars containing gene A1 for resistance to *A. rubi*. This suggests that the 'resistance breaking strain 2' of this species was absent. *Macrosiphum euphorbiae* occurred on all cultivars, but was less abundant than *A. rubi* except on M. Orion and especially on M. Landmark which had populations six times greater than on any other cultivar. M. Orion also supported quite large numbers of *Myzus ornatus*, a species not previously reported on raspberry in Scotland.

R. D. Hughes's 'twin-sample' method was used to study the population dynamics of *A. rubi* on M. Jewel. There were two peaks in the population, one in late July and one in late August. There seemed to be a close association between the decline in the population and the numbers of predators, mainly syrphid and neuropteran larvae. Hymenopteran parasites and entomophagous fungi did not seem to be important, though the former may have reduced the numbers of the first generation. *Aphidius urticae* (Hymenoptera) was the only primary parasite of *A. rubi* and its effectiveness seemed to be limited by hyperparasites.

(A. T. Dickson)

Aphids and field beans

Heavy infestations of *Aphis fabae* are uncommon in Scotland and there is little information on the extent to which aphids affect bean yields. With the renewed interest in field beans as a protein source and break crop, work was started to assess the severity of aphid attack and the best time for control.

Field beans cv. Herz Freya were sown on 5 March in drills 5 in apart in plots 8.3 x 6 yd (7.7 x 5.5 m). The pesticides tested were phorate (10% granules), oxamyl (10% granules) and demeton-S-methyl (58% e.c.). Phorate and oxamyl were applied at 10 lb/ac (11.2 kg/ha) at late flowering (29 June). Demeton-S-methyl, 6 fl oz/ac (0.4 l/ha), was applied as an eradicant spray after flowering on 6 July when cover was poor, and again on 17 July. In a second treatment demeton-S-methyl was sprayed only on 17 July. Plots were harvested by combine harvester on 25 September.

Aphid populations were assessed every 10 days after the first winged migrants appeared on the crop. By late July 60% of the untreated plants were infested—12% with moderate to heavy infestations. Phorate and both demeton-S-methyl treatments gave a good control of aphids and there were significantly fewer plants with high infestations in these treatments. None of the treatments produced significant differences in yield components measured on 26 July, and fresh weight yields at harvest were not significantly improved. With the exception of oxamyl, all treatments gave a small (4–7%) but significant increase in individual dry seed weight, but it seems likely that in 1973 bean aphids arrived in the crop too late to greatly affect yields.

(J. A. T. Woodford)

Raspberry cane midge distribution

Following the discovery at the SHRI in 1972 of a breeding population of raspberry cane midge (*Thomasiniana theobaldi*) on cv. Glen Clova, a survey of cane midge was started in 1973.

Cane midge was well established in four plantations of Glen Clova at the Institute and in the Carse of Gowrie where larvae were found in more than 60% of the canes examined. In eastern Perthshire 26% of 100 cane samples from three sites contained larvae, and smaller infestations (3–6%) were found in samples from six plantations in northern Angus. No larvae were found in samples from Aberdeenshire and Morayshire (four sites), Berwickshire (one site) or Ayrshire (one site).

Raspberry cultivars in which the epidermis and outer cortical tissue split extensively, such as Glen Clova, are known to be susceptible to cane midge damage. However, a few cane midge larvae were also found on Malling Jewel, Malling Promise, Malling Admiral and Malling Orion.

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

Effects of benomyl on invertebrates

Benomyl was applied at two rates to plants of raspberry cv. Glen Clova grown on stooled and hedgerow systems in a Crops Research section experi-

¹Virology Section.

ment to study bud death and yield (p. 32). Two insects, *Amphorophora rubi* and *Thomasiniana theobaldi* were sufficiently abundant to enable quantitative comparisons to be made of the effects of benomyl on their numbers.

There was a small increase in the number of aphids on fruiting and first year canes treated with benomyl. The chemical had little effect on the number of canes infested by cane midge larvae but larval populations were greater on plots treated with benomyl; compared with unsprayed canes there were significantly more larvae on canes sprayed from April to June. Large differences were found between the populations of midge larvae in stooled and hedgerow canes; larval populations were greater in stooled canes, but fewer stooled canes contained larvae than canes grown on hedgerows.

Numbers of plant parasitic nematodes were increased by benomyl, but the differences were small. The numbers of earthworms, however, were greatly decreased by benomyl. *Allolobophora rosea* was the only species found in hedgerow plots sprayed from April to June, and no earthworms at all were found in stooled plots given this treatment. A few immature *Lumbricus terrestris* were found in plots sprayed with benomyl in June, but adults were found only in untreated plots.

(J. A. T. Woodford and D. L. Trudgill)

Control of raspberry mite

A trial started in spring 1972 tested the effects of three acaricides—endosulfan, vamidothion and tricyclohexyltin hydroxide (Plictran, Dow Chemical Co.). On plots sprayed with vamidothion, yellow blotching of the leaves typical of mite damage was suppressed in the year of application, and overwintering mite populations were decreased by 75%. Fruit yields were not significantly increased.

The same chemicals were re-applied twice in May 1973 at rates of: endosulfan 40 fl oz, vamidothion 20 fl oz/ac and Plictran 12 oz/ac (2.81, 1.40 l/ha and 0.81 kg/ha respectively). The fruiting canes in the vamidothion sprayed plots showed slight mite damage, but the leaves of the new cane were entirely free from symptoms.

In the second year of the trial the mean lateral shoot length of the fruiting canes was increased 31% by vamidothion and 23% by endosulfan compared with the untreated control. The mean weight of fruit per cane increased from 84 g in the untreated control to 141 g in the vamidothion, and 116 g per cane in the endosulfan treated plots.

(S. C. Gordon)

Biology of raspberry beetle

In 1973 emergence of adult beetles at the SHRI started on 21 May, and maximum numbers emerged in the second week of June. Eggs were first found on 20 June when 16% of raspberry laterals had open flowers. Egg hatch reached a maximum between the green and pink fruit stage but continued until the end of July when 50% of the fruits were ripe. Maximum

numbers of larvae were found in the last fortnight in July, immediately after the time found to be optimum for applying fenitrothion in previous trials. Larvae emerging at this time also often fed on the basal drupelets before invading the receptacle, so increasing their exposure to insecticide applied a few days before.

These studies of the biology of raspberry beetle confirm that a short-persistence insecticide such as fenitrothion (approximately 6 days at normal commercial rates) is best applied between the green and first pink fruit stage.

(S. C. Gordon)

Farm and Experimental Crops

W. I. A. JACK

As the meteorological records show 1973 was a year of extreme weather conditions. The main feature was the very low average rainfall, and late frosts from 28 to 30 April, which caused widespread damage to fruit blossom and barley crops.

Farm crops included 2 acres (0.8 ha) field beans, 61 acres (24.6 ha) barley, 26 acres (10.5 ha) grass for hay, 21 acres (8.4 ha) winter wheat, 16 acres (6.4 ha) permanent grass, and 8 acres (3.2 ha) fallow.

Field work progressed well in the spring and field beans sown on 21 February grew well despite the dry conditions in the early part of the year. An attack of bean aphid (*Aphis fabae*) reduced yield and quality a little although when combined on 25 September the crop yielded 40.8 cwt/ac (5.12 t/ha) with a protein value of 27.14%.

Barley sowing was completed by 12 March, 10 days earlier than 1972. This crop suffered most from the year's weather. Loose seedbeds due to drought conditions resulted in delayed germination followed by erratic growth; the crop was then affected by the late April frosts. Heavy rain and wind flattened about 60% of the crop early in July and there were isolated outbreaks of mildew (*Erysiphe graminis*) in some fields. Combining started on 13 August and although lodging created some difficulties the harvest was completed in record time with only moderate losses which were balanced by the good prices obtained. Yields averaged 41.3 cwt/ac (5.18 t/ha) and although less than the previous year they still equalled the 5-year average; moisture and nitrogen content was such that all was sold for malting.

A reasonably good crop of hay was secured. Cutting started on 27 June and baling was completed by 6 July. Yield was down 10.1 cwt/ac (1.26 t/ha) on the previous year.

Winter wheat was an excellent crop. Combined on 22 August in good weather the yield averaged 51.2 cwt/ac (6.42 t/ha) with the best field giving 68 cwt/ac (8.53 t/ha), all of which went for milling.

Field experiments included 34 acres (13.8 ha) raspberries, 6.5 acres (2.6 ha) strawberries, 13.5 acres (5.4 ha) black currants, 1 acre (0.4 ha) blueberries, 14 acres (5.7 ha) vegetables, 9 acres (3.6 ha) potatoes, 3 acres (1.2 ha) nursery crops, 2 acres (0.8 ha) ornamental bulbs, 1 acre (0.4 ha) other crops; this shows a decrease of 10 acres (4 ha) from the previous year.

Soft fruit yields were considerably reduced by frost, and rain falling on 10 out of the 14 critical days from 8–21 July created additional managerial

problems not the least of which was trying to maintain a regular picking squad.

Strawberry picking started on 2 July and yields were down by 30%, grey mould being a particular problem. This was followed by raspberry picking with two small picks on 9 and 17 July with the main picking on 22 July. This crop also was damaged by high winds on 16 July and together with the effects of the spring frost total yield losses were estimated at 30%. Had it not been for the ability of Glen Clova raspberry to produce a second flush of flowers, losses would have been higher. Black currants were picked on 23 July.

The soft fruit crop totalled 18 tons less than 1972 and included 22.5 tons (22.8 t) raspberries, 11 tons (11.1 t) strawberries, 0.5 ton (0.5 t) black currants. Somewhat higher prices, notably for raspberries, helped to redress the income position.

Vegetable trials provided quantities of beetroot, Brussels sprouts, cabbages, calabrese, carrots, cauliflowers, courgettes, French beans, leeks and onions, all of which were marketed locally. The yield of potatoes was less than the previous year, due mainly to reduced tuber size caused by lack of water.

An early August harvest and continuing dry weather enabled the routine programme of stubble hygiene to be practised, using rotary cultivation and paraquat spraying to suppress perennial grass weeds and volunteer corn until ploughing took place. Winter wheat was sown by 2 November and establishment was satisfactory. Winter came early with frosts and four falls of snow between mid November and mid December. Ploughing was done when conditions were suitable and about half was completed by the end of the year.

New equipment includes a spring tine cultivator with crumbler attachment. No intermediate sized equipment exists between the knapsack sprayer and the tractor mounted sprayer and so a compact highly accurate plot sprayer has been designed; this unit has been built by the farm workshop staff.

General estate work included routine maintenance of lawns, fences, dykes, windbreaks and roadways. Other work included laying 250 yards of pavement on the east side of the main drive.

Acknowledgment is made to the estate staff. Despite the many difficulties experienced, they have worked well over the past year to provide the service necessary for the accomplishment of a large and varied programme of work.

Glasshouse Section

J. CANTWELL

Management of the Section was made more difficult this year by a continuing shortage of labour coupled with increased prices and shortage of materials which necessitated time consuming recycling and 'do it yourself' techniques. The need for a permanent body of reliable and skilled workers has been forcibly demonstrated and the Section is fortunate in having a core of such workers ably supervised by the foreman R. Taylor. The problems of manpower made doubly welcome the acquisition of a compost mixing machine and gas powered fork lift truck. Both are key pieces of equipment in the plan for overall mechanisation and efficient manpower usage.

The final touch to a somewhat depressing year was the energy crisis. Savings of 30% on fuel oil and 40% on electricity for supplementary lighting resulted from the co-operation of the research sections in reducing plant requirements and acceptance of a slower throughput of freshly propagated material. The emergency has however vindicated the policy of installing comprehensive environmental control and monitoring equipment in all new glasshouses, and it is clear that capital spent in this way will produce long term economies.

In the last quarter of the year improvements were made in the water supply to the northern part of the glasshouse area which has been used increasingly in recent years for protected cropping. The new water supply system provides a 2-inch ring main from which 40 three-quarter inch standpipes can be supplied, together with 20 sprinklers to irrigate a permanent standing ground for pot grown plants. Over a period of time it is intended that all this area should be made vermin proof.

Owing to changes in the technique for screening virus-tested raspberries for 'crumbly-fruit,' the procedure for growing stock plants has been changed and each plant is now rooted in its own plastic container. The containers have been tested for 2 years, and half the plants were transferred in 1973; the project is scheduled for completion in March 1974.

The experimental work of the Section was confined to investigating specific problems concerned with plant growth and management. It was confirmed that the standard soilless compost used at the Institute was not inferior to John Innes compost when used for propagating lilies or when used for the twin scale propagation of virus-tested narcissus plants. A technique was devised for the production of a specified number of evenly developed cucumber seedlings. The method is based on seed examination and

the rejection of small and deformed and 'suspect' seeds, chitting seed for 12 h before sowing, and pre-warming the potting compost before sowing the seeds into individual pots.

For virological work it has been shown possible to grow suitable plants in large aluminium glasshouses shaded with external slatted blinds, the relative humidity being increased by misting lines installed above the plants. This finding permits much greater flexibility of design in planning new glasshouse facilities for virological work and should remove any doubts about phasing-out labour-intensive and most inefficient chemical shading.

Increased costs of raw materials for soilless compost have necessitated consideration of the possibility of recycling. A preliminary experiment concerned with toxicity created by steam sterilization has shown that steamed compost probably will need to stand for at least 6 weeks before use, and then will be suitable for incorporation with fresh compost. It was found, for example, that once-used steam sterilized soilless compost could safely provide the peat and sand components required in the compost used for plant production associated with the brassica breeding programme.

Investigations were continued on the glasshouse propagation of virus-tested raspberries. It appears that gains may be possible in speed of rooting and number of cuttings rooted by spraying ethephon (2-chloroethylphosphon acid) on the soft wood cuttings immediately after excision from the parent root cutting. There appear to be cultivar differences in response; Glen Clova responding more positively than Malling Jewel which propagates reliably anyway. The investigation is to be continued but a spray of 20 ppm is being applied during the 1973-74 propagation programme.

Information Services

R. J. A. EXLEY

During the year there have been visitors to the Institute from home and abroad with many and varied interests. Of particular interest was a visit for the second consecutive year by a small party of senior staff from the Laboratorium voor Bloembollenderzoek, Lisse, Netherlands. On this occasion, under the leadership of their Director, the bulb specialists included in their itinerary tours of Scottish and English bulb growing areas organised by Scottish College and ADAS advisory officers, as well as engagements at other UK centres of bulb research.

Each year the Institute is an appropriate and convenient venue for meetings of such bodies as the Scottish Nuclear Stock Association and the Scottish Branch of the National Fruit Trials Committee. Other meetings which have been convened in 1973 include those on behalf of the SHRI Association, and on one occasion a meeting for advisers of the three Scottish Colleges to present a review of our current research work.

Early in March a course of lectures organised for all new employees of the Institute also was attended in part by established staff who in the course of their duties are particularly exposed to the potential hazards of some chemicals, or fire. Institute speakers lectured about the organisation and role of the SHRI and the safe handling of chemicals in the field. Specialists from the Scottish Occupational Health Laboratory, Dundee University Department of Occupational Medicine, and Angus Fire Brigade, discussed medical and other safety aspects of field and laboratory chemical usage.

A seminar on visual communication given to research staff by the photographer generated interest and discussion. Also, it produced a marked improvement in the format of drafts submitted to Visual Aids, and resulted in better quality illustrative product. An additional improvement will be possible when the conceptual difference between report and lecture illustration becomes more generally understood and accepted.

Library

Library finances were very constrained during 1973 and only five books were bought and two new journal subscriptions entered. A gift of the Journal of the Royal Horticultural Society, 1922-1972, was gratefully received from Mr Robert L. Scarlett a former member of the Governing Body.

Internal borrowing dropped slightly to 2,450 items, while items borrowed from the British Lending Library remained at approximately 1,500. The number of requests made to other libraries rose to 210.

Reprints distributed throughout the world both to individuals and Institutes numbered 2,300, and the 1972 Annual Report was sent to 42 foreign countries. Bulletin No. 7 of the SHRI Association was distributed to 242 members in April.

(Kathleen J. Harrison)

Visual Aids

The Visual Aids Section has produced some 14,000 negatives and transparencies in the 18 years since its inception and requests for copies of some of the first photographs on file indicate the continuing value of the early work.

Currently about 1,500 photographs are made annually, the majority being required for visual records. However, the past year has seen a change. Photography is being used more as a research 'tool' in both the laboratory and the field, and the provision of information and advice on all aspects of the use of photographic materials and equipment for specialised techniques now is an additional service. The application has been investigated of infra-red recording, ultra-violet fluorescence, time sampling and time lapse photography, as well as simple photogrammetry. These techniques are designed to provide information which would be either difficult or impossible to obtain using conventional methods, and the preliminary of results are encouraging.

Although the increasing use of applied photography has exposed shortcomings in equipment, financial constraints unfortunately will restrict modernisation. However, acknowledgment is given to the Maintenance Section for assisting in the modification and manufacture of specialised equipment.

The printing of electron microscope plates is a continuing requirement and the commissioning of a third instrument will increase this work which currently amounts to some 3,500 prints each year. Existing equipment for this service is poor and it is regrettable that the necessary support facilities were not evaluated when a major purchase of this type was being considered.

Much illustrative work for research papers has to conform strictly to a specification provided by the publishing journals, and rationalisation by them is overdue. Also, simplification of the requirements would greatly assist in the more economical production of high quality art work.

(J. I. Campbell)

Scottish Horticultural Research Institute Association

The Association was formed in August 1967, to promote interchange of information between the Institute and the horticultural industry; membership is on an individual or corporate basis. A Bulletin is published at indefinite intervals and the articles are intended to communicate the results of experimental work, sometimes at an incomplete stage, between research workers and growers; it also publishes papers presented at symposia organised for the Association.

At the fifth Annual General Meeting of the Association in April, Mr James A. Forbes resigned as Chairman after 2 years in office; Mr W. H. Porter was elected Chairman.

On 14 July 80 members of the Association were conducted round many of the fruit and vegetable experiments and members of the Institute staff explained and discussed the work they were doing.

The harvesting of the crop is the greatest problem facing the raspberry grower and it will influence greatly the future of the industry. It was not surprising, therefore, that a symposium in November on the Mechanical Harvesting of Raspberries attracted a large audience to hear about harvesting in America and a progress report about a joint SHRI/NIAE(SS) raspberry mechanical harvester project and its economic implications.

Bulletin No. 7 (March 1973)

Papers presented at a meeting on 'Transport, handling and marketing of raspberries and strawberries' held by the Association on 30 November 1972.

The needs of the wholesale market in fresh strawberries and raspberries *by* Miss Barbara Wallis (Procurement Division, Francis Nicholls Group), pp. 2-8.

Management problems of marketing refrigerated raspberries in South of England markets *by* D. H. Turner (East of Scotland College of Agriculture), pp. 9-15.

Handling, transport and distribution of raspberries and strawberries *by* A. W. Tomalin (ARC Food Research Institute, Norwich), pp. 16-20.

The rapid cooling and storage of raspberry and strawberry fruits *by* A. Farrimond (ARC Food Research Institute, Norwich), pp. 21-28.

Factors affecting postharvest fungi on strawberry and raspberry fruit *by* W. R. Jarvis, pp. 29-31.

The affect of fungicides on the shelf life of raspberries *by* D. T. Mason, pp. 32-38.

Meteorological Records 1973

D. K. L. MACKERRON AND E. SWEENEY

MYLNEFIELD

Wind

Total wind run for the year was near average. The unusually high wind run experienced in April (30% above average) was partly offset by the low values recorded in July (30% below average). The highest gust speeds of 87 km h⁻¹ were recorded in May and November.

Temperature

A mild winter encouraged early plant growth but this received a check during the cold spell in April and May. During the last few days of April, a very severe radiation frost gave the lowest grass minimum temperatures recorded in April at this station since records began in 1954. This frost did extensive damage to raspberry flower buds but there was some recovery.

Rainfall

The dry spell in the second half of 1972 continued through April in 1973. Rainfall in February was the lowest recorded for that month in the Dundee area since 1948. July was the only month of the year with higher than average rainfall with 17 days having more than 0.2 mm of rain. After July until the end of the year, rainfall was again below average by 30 mm per month.

Sunshine and Solar Radiation

For the second year running the number of hours of bright sunshine received in January was the lowest recorded in the Dundee district since 1948. Much brighter weather in February and March more than offset this and over the year the total hours of bright sunshine exceeded the 1954-68 average by almost 10%.

Receipt of total solar radiation was near the average for the preceding 4 years.

MYLNEFIELD 1973

Month	Mean of daily maxima		Mean of daily minima		Deviation from average*		Temperature (Centigrade)		Accumulated Temperature		Highest Max.		Lowest Min.		Soil Temperature at 30cm depth		Ground frost days		Rainfall		Solar Radiation		Wind Run Kilo- metres	
	of maxima	of minima	of maxima	of minima	Above 6°C	Below 6°C	Temp.	Date	Temp.	Date	Temp.	Date	Temp.	Date	Mean	Deviation from average*	Hours	Deviation from average*	Milli- metres	Milli- metres	Hours	Deviation from average*		Mean daily radiation mW h cm ⁻²
January	6.3	1.9	6.3	1.9	19	63	10.9	29	63	19	-6.0	19	4.2	+2.3	19	37.5	27	-12.5	19	37.5	27	-31	42	8218
February	7.3	-0.4	75	-0.4	21	75	15.0	20	21	75	-7.9	15	3.6	+1.4	20	5.6	119	-38.9	20	5.6	119	+44	145	9334
March	10.6	1.3	43	1.3	43	58	14.0	25	43	58	-5.0	15	4.8	+0.7	23	11.1	151	-35.4	23	11.1	151	+51	238	9954
April	10.6	2.9	64	2.9	64	35	18.1	15	64	35	-3.0	29	6.9	0.0	16	24.0	178	-18.7	16	24.0	178	+18	367	13303
May	12.8	6.2	140	6.2	140	7	19.3	27	140	7	0.4	2	9.5	-0.6	8	52.0	160	-2.1	8	52.0	160	-28	384	11470
June	18.5	9.5	266	9.5	266	3	24.1	7	266	3	3.0	1	14.1	+0.5	3	38.0	186	-13.3	3	38.0	186	+10	458	9168
July	19.2	10.7	306	10.7	306	0	23.2	30	306	0	4.4	23	16.1	+1.2	0	85.2	186	+17.6	0	85.2	186	+21	362	5822
August	18.3	10.0	279	10.0	279	0	23.4	13	279	0	6.0	11	15.1	+0.6	0	44.7	180	-34.3	0	44.7	180	+34	352	7264
September	16.0	9.1	223	9.1	223	0	22.5	8	223	0	2.9	21	12.6	+0.1	1	37.9	104	-25.6	1	37.9	104	-13	234	7489
October	11.9	5.2	100	5.2	100	20	22.8	2	100	20	-0.4	12	9.1	-0.6	11	37.9	72	-25.3	11	37.9	72	-21	153	6120
November	7.9	1.0	39	1.0	39	72	15.0	8	39	72	-3.9	30	5.5	0.0	21	17.7	94	-43.3	21	17.7	94	+34	69	10789
December	6.5	0.8	19	0.8	19	91	12.6	3	19	91	-8.5	1	3.0	-0.2	26	49.5	56	-24.2	26	49.5	56	+11	48	11453
Year	12.1	4.8	1519	4.8	1519	424	-	-	424	1519	-	-	8.7	+0.4	148	440.0	1515	-257.0	148	440.0	1515	+132	-	110384

*Recorded at Mylnefield 1954-1968

Month	Temperature (Centigrade)				Soil Temperature at 30 cm depth		Rainfall		Sunshine	
	Mean of daily maxima	Deviation from average*	Highest Max. Temp.	Lowest Min. Temp.	Mean	Deviation from average*	Milli-metres	Deviation from average*	Hours	Deviation from average*
January	6.7	+0.6	10.6	-4.0	5.6	+1.7	82.6	+1.1	41	-15
February	6.2	-0.2	10.1	-9.9	5.2	+1.6	78.9	+30.6	72	-6
March	9.2	+0.4	13.6	-1.8	5.6	+0.7	41.3	-12.3	125	+20
April	9.8	-1.6	12.9	-2.7	7.1	-0.2	56.4	+5.0	160	+7
May	13.4	-0.9	20.9	1.1	9.5	-0.8	66.1	+10.1	156	-38
June	18.3	+1.1	21.1	4.4	13.3	+0.2	40.4	-24.7	197	+15
July	17.7	-0.3	22.0	4.5	14.9	+0.5	70.6	-15.4	161	+2
August	18.0	+0.5	27.4	5.4	14.9	+0.7	63.1	-32.1	134	-15
September	16.0	0.0	22.5	2.6	13.8	+0.9	43.3	-64.7	130	+13
October	11.3	-1.8	15.7	-2.7	10.2	-0.4	52.9	-52.3	96	+13
November	8.3	-0.7	13.6	-6.4	7.6	-0.2	99.2	+18.8	54	-4
December	7.3	+0.3	11.0	-6.2	5.1	-0.2	122.1	+28.1	40	+1
Year	11.9	-0.2	—	—	9.4	+0.4	816.9	-107.8	1366	-7

*Recorded at Weather Station, Department of Plant Pathology, Auchincraive, 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.

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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

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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
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