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The Scottish Horticultural Research Institute

23rd Annual Report for the year 1976

The Scottish Horticultural Research Institute
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West of Scotland Unit
Auchincruive, Ayr *Telephone* ANNBANK 293

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- Professor M. B. Wilkins, B.Sc., Ph.D., D.Sc. A.K.C.

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- R. N. Wilson
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- T. P. Reid
- Judith Thomson
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- C. A. Reid

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Frances Devaney
Mrs Elizabeth J. Lindsay
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Mrs Sheena Strachan
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Virology

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B. Boag, B.SC., PH.D.
D. J. F. Brown
S. C. Gordon
W. M. Robertson
J. A. T. Woodford, M.A., PH.D.

Zoology—continued

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*Honorary Lecturer in the University of Dundee.

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

General Report

C. E. TAYLOR

The unusually dry summer of 1976 was a sharp reminder of the biological variation with which one has to contend in crop production and research. The high soil moisture deficits, as in 1975, resulted in some problems in crop establishment and intensified crop variability, but at the same time the dry conditions provided a useful test of stability of experimental results obtained in previous, more normal and wetter years as well as the opportunity for the assessment of crop responses to irrigation and other cultural practices influencing water availability. The hot dry weather also intensified several pest problems such as aphids on potatoes and other crops, and the raspberry cane midge which devastated some plantations. Fortunately, there were previous indications of such problems arising and investigations were put in train to establish information on the biology of the pests in relation to their control. Such events do, however, illustrate the necessity of maintaining sufficient flexibility in the Institute's research programme to sustain an awareness of local events and to initiate investigations quickly in relation to local needs, as well as responding to the more generally expressed needs identified by the Boards of the Joint Consultative Organisation.

This report summarises the research work undertaken at the Institute during 1976 and commissioned by the Department of Agriculture and Fisheries for Scotland, with projects numbered for the purpose of accounting and classification by the Agricultural Research Council Planning Unit. While it is a somewhat terse account of events it is hoped that it is not without interest and will stimulate readers to read the more extensive accounts of our research in the scientific and commercial press, and in the SHRI Association Bulletins and Occasional Publications.

Governing Body

We regret to report the death of Sir Stephen J. Watson, C.B.E., in July, 1976. Sir Stephen was a former Principal of ESCA and a member of the Governing Body from 1953 to 1968.

Appointments

Mr T. G. Geoghegan was appointed in January as Senior Photographer in the Visual Aids Section. Miss Helen D. McGregor was appointed as Clerical Officer (Accounts).

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

J. N. Dick	Plant Breeding Section
Judith Thomson	Plant Breeding Section
Mrs Elizabeth Lindsay	Mycology Section

Mr A. Davidson was appointed as Painter in the Maintenance Section in September. Mr C. A. Reid was appointed as Experimental Worker at the West of Scotland Unit, Auchincruive, in May, and during the year Mr L. A. McNicoll, Miss Mandy Morris and Mr G. Wilson were appointed as apprentices in the Estate Section.

Resignations

Mrs Sheena Strachan	ASO, Mycology Section
Mrs Frances Turnbull	ASO, Mycology Section
W. B. Taylor	ASO, Plant Breeding Section
Mrs Isobel Ormiston	LA, Mycology Section
J. A. Cochrane	Estate Section
G. Kemp	Estate Section
T. Young	Auchincruive

Promotions

Pauline B. Topham	SSO to PSO
B. Boag	
D. K. L. MacKerron	
B. Williamson	
H. Barker	HSO to SSO
J. B. Cowan	
S. C. Gordon	
A. J. Hargreaves	
Heather A. Ross	SO to HSO
	ASO to SO

Awards

Heather A. Ross	M.I.Biol. by examination
J. R. T. Hodgkin	Ph.D., University of Dundee
G. Wood	Ph.D., University of Hull

Research Students

R. M. Brook continued an ARC Research Studentship studying weather factors controlling yield and yield components in field bean.

A. E. B. Ibrahim continued his studies on seed physiology in relation to effects of the environment and genotype of the mother plant, financed by a British Government Technical Assistance Training Award.

C. J. Wright continued an ARC Research Studentship studying the nature and effects of the competition which exists within the raspberry plant between its vegetative cane and its fruiting cane. (Crops Research Section).

F. Bem, supported by the Greek Ministry of Agriculture, L. F. Salazar, supported by the International Potato Center, Peru, and Lesley Torrance, a DAFS postgraduate student, continued their researches on viruses of umbelliferous plants, potatoes and grasses, respectively. (Virology Section).

C. S. Aveyard commenced studies on the control of potato aphids in relation to the spread of viruses, financed by a grant from the Potato Marketing Board. (Zoology Section).

Sandwich Course Students

Kathleen Bell (Dundee College of Technology) assisted from April to September with investigation of the relationships between time of emergence of crop seeds and weed seeds. (Crops Research Section).

Deirdre MacLellan (West of Scotland Agricultural College) assisted with the strawberry breeding programme at Auchincruive from February to July 1976. (Plant Breeding Section).

R. Farnan (Dundee College of Technology) assisted from April to September on work assessing the damage caused, to a number of crops, by *Longidorus elongatus*. He returned during the winter of 1976 to complete a project on the effects of oxamyl on *L. elongatus*. (Zoology Section).

Sabbatical Leave

Dr M. C. M. Pérombelon returned to the Institute in June after 9 months sabbatical leave in the Department of Plant Pathology, University of Wisconsin, Madison, where he worked with Professor A. Kelman on population dynamics of pectolytic bacteria in rotting potatoes.

Visits Abroad

R. A. Fox attended at Wageningen during 17-21 May a Planning Conference of the European Association for Potato Research, a meeting of the EAPR Disease Assessment Methods Committee, and a meeting of the Editors of 'Potato Research.' Also in Sri Lanka from 6-21 December he attended the Centenary Rubber Conference held to mark the 100th year of the introduction of *Hevea* rubber to the Far East and made working visits to the Institutes for Rubber Research, Tea Research and Coconut Research.

D. L. Jennings visited the International Institute of Tropical Agriculture, Ibadan, Nigeria, between 1-28 February to complete the work he started during his 1975 sabbatical leave.

A. T. Jones and A. F. Murant attended the 1st International Symposium on Small Fruit Virus Diseases and the 10th International Symposium on Fruit Tree Virus Diseases in Heidelberg, BRD, on 1-7 September. Murant served as Chairman of the Symposium on Small Fruit Virus Diseases and received a DAFS travel grant. Jones received travel grants from the W. German government and the British Council.

M. A. Mayo and D. J. Robinson attended the NATO/FEBS/EMBO Advanced Course and CNRS Colloquium on 'Nucleic Acids and Protein Synthesis in Plants' in Strasbourg, France, on 15-24 July. Robinson received a DAFS travel grant. After the meeting Mayo visited IBMC, Strasbourg, to discuss a collaborative project on translation of virus RNA.

Isabel G. Montgomerie from 3-10 May visited Paris, Dr Baker EPPO and Avignon, Dr Molot *et al* for discussions on red core of strawberry and visits to fruit plantations.

W. P. Mowat took part in the 4th International Symposium on Virus Diseases of Ornamental Plants held at Noordwijkerhout, The Netherlands, on 3-8 May.

C. North spoke at the 1st Symposium organised by ISHS on Floriculture, Plant Breeding and Genetics at East Lansing and then travelled to Oregon to see commercial production of lilies at Oregon Bulb Farms, Portland, and to discuss maintenance of healthy lily stocks at the University of Corvallis.

M. C. M. Pérombelon visited Chicago from 17-19 February and attended a meeting of the Plant Pathology and Certification Sections of the Potato Association of America. Also he visited at Versailles from 12-16 December the Laboratoire de Genetique des Microorganismes (INRA) to discuss co-operative research on the genetics of *Erwinia carotovora*.

D. A. Perry attended the International Seed Testing Association Inter-convention Meeting in Stockholm from 17-21 May.

D. L. Trudgill visited The Netherlands during 13-16 July to discuss research on nematology. Also he visited the Technischen Universität in Hannover during 7-11 December to give a lecture on the 'Mechanisms of potato cyst nematode damage to potato plants' and to discuss research on nematode feeding behaviour with Dr U. Wyss.

P. D. Waister visited centres engaged in soft fruit research in Poland, Hungary, Bulgaria, and Yugoslavia between 27 June and 10 July.

C. E. Taylor attended three meetings of the Consiglio Scientifico del Laboratorio di Nematologia agraria, Bari, Italy, on 23-25 March, 30 June-2 July and 8-11 November.

Courses Attended

R. M. Brook attended a Genstat course at ERCC in December.

R. J. McNicol attended a course on meristem culture at John Innes Institute 26-27 October.

M. A. Mayo attended a safety course organised by the Royal Society for the Prevention of Accidents at Rothamsted Experimental Station on 29-30 March and a basic course for middle management at the Civil Service College, Edinburgh, on 10-21 May.

M. C. M. Pérombelon attended a Graduate School of the Department of Bacteriology, University of Wisconsin, for a semester course in Bacterial Genetics.

J. A. T. Woodford attended University of Dundee Department of Biological Sciences Terrestrial Ecology Field Course (as joint tutor) on 17-23 June.

R. W. Reid and R. D. Taylor attended short courses on work planning arranged by the Agricultural Training Board. Six members of the Estate Staff attended short courses arranged by the ATB on various aspects of the use and maintenance of farm implements and two of the staff at the West of Scotland Unit, Auchincruive, attended an ATB tractor maintenance course.

Conferences at which papers were given

6 January	Society for General Microbiology Virus Group, Reading. B. D. Harrison	Defective plant virus particles.
2 February	Federation of British Plant Pathologists, London. A. J. Hargreaves	Effect of cane blight on yield in mechanically harvested red raspberries.
25 March	Association of Applied Biologists (Weed Group), Warwick. H. M. Lawson	Programmed weed control for vegetable crops.
2 April	ARS Conference on Electron Microscopy, Edinburgh. I. M. Roberts	Practical EM serology.
5 April	Society for General Microbiology Virus Group, Cambridge. H. Barker	Interaction of plant viruses in doubly infected tobacco protoplasts.
	A. F. Murant	Association of virus-like particles with the foregut of aphids (<i>Cavariella aegopodii</i>) carrying two semi-persistent viruses.
3-5 May	4th International Symposium on Virus Diseases of Ornamental Plants, Noordwijkerhout, The Netherlands. W. P. Mowat	Control of the spread of two non-persistent aphid-borne viruses in lilies.
	W. P. Mowat	Narcissus tip necrosis virus.
6-9 July	Association of Applied Biologists, Edinburgh. R. A. Fox	The incidence and breaking of latency in potato gangrene in relation to the time of harvesting.
	M. C. M. Pérombelon	Population dynamics of <i>Erwinia carotovora</i> in relation to tuber soft rot.

- 7-9 July British Mycological Society, Birmingham.
 J. M. Duncan Population studies of *Phytophthora fragariae* in soil.
 A. J. Hargreaves Populations of *Phytophthora* species in soil
- 14-22 July Eucarpia/ISHS Symposium on *Rubus* and *Ribes* breeding and machine harvesting, Dundee.
 M. M. Anderson Black currant breeding at the Scottish Horticultural Research Institute.
 M. R. Cormack Sources of yield loss in machine harvested raspberry crops.
 A. Dale Prospects for breeding high-yielding raspberries.
 D. T. Mason Changes in the fruit retention strength of the red raspberry (*Rubus idaeus* L.) during ripening, and their relevance to the selection of raspberry clones suitable for mechanical harvesting.
 Pauline B. Topham Prediction of harvest efficiency in raspberry crops of differing maturity characteristics.
 P. D. Waister Review of raspberry harvesters and prototypes used in Britain.
 P. D. Waister Biennial cropping of raspberries for machine harvesting.
 B. Williamson Control of cane blight (*Leptosphaeria coniothyrium*) in red raspberry following mechanical harvesting.
 J. A. T. Woodford The effect of mechanical harvesting on the raspberry cane midge.
- 20 July CNRS Colloquium on Nucleic Acids and Protein Synthesis in Plants, Strasbourg, France.
 M. A. Mayo Uptake behaviour of tobacco leaf protoplasts in culture.
- 5-6 August Symposium on floriculture, plant breeding and genetics organised by International Society for Horticultural Science, Michigan State University, East Lansing.
 C. North *In vitro* culture of plant material as an aid to hybridization.
 C. North Artificial chromosome doubling in Narcissus and its implications for breeding *N. tazetta* hybrids.

- 1 September International Symposium on Small Fruit Virus Diseases, Heidelberg, W. Germany.
 A. T. Jones Small bacilliform particles associated with infection by rubus yellow net virus in black raspberry (*Rubus occidentalis*).
 A. F. Murant The development of our knowledge of *Rubus* viruses.
 A. F. Murant Recent research on 52V virus of raspberry.
 A. F. Murant Comparison of isolates of raspberry bushy dwarf virus from red and black raspberries.
- 5-11 September Society of European Nematologists XIII International Symposium of Nematology, Dublin, Ireland.
 B. Boag Nematodes in Scottish forest nurseries.
 B. Boag The criconematidae of the British Isles.
 W. M. Robertson Possible chemoreceptors in the oesophageal region of *Longidorus leptcephalus*.
 C. E. Taylor Control of spraing in potatoes by foliar applications of oxamyl.
 D. L. Trudgill Effects of potato cyst nematodes on potatoes.
 D. L. Trudgill Feeding of *Xiphinema diversicaudatum* on *Petunia hybrida* roots.
 D. L. Trudgill Effect of potato cyst nematode (*Heterodera rostochiensis*) on the growth and nutrient content of potatoes at three sites.
 D. L. Trudgill *Pratylenchus* spp. as pests of raspberries in Scotland.
- 8-9 September British Crop Protection Council Symposium, Stirling.
 R. J. McNicol A personal evaluation of the crop protection course at Aberdeen University 1969-74.
 C. North What we want.
- 12 September Association of Agriculture, Edinburgh.
 P. D. Waister The development of the Scottish horticultural industry.

- 16 September Society for General Microbiology Virus Group, Glasgow.
 B. D. Harrison Pseudo-recombinant isolates of tomato black ring virus.
 D. J. Robinson Evidence for a second gene on RNA-2 of tobacco rattle virus.
- 6 October Royal Entomological Society, London.
 A. F. Murant Association of plant viruses with their vectors.
- 18 November North and East of Scotland Colleges of Agriculture Conference on Narcissus Production Developments, Stonehaven.
 W. P. Mowat Progress with the propagation of virus-tested clones of narcissus.
- 24 November Fourth ARC Data Logging Symposium, Silsoe.
 D. K. L. MacKerron Semi-automatic processing of chart records.
- 13-17 December Centenary Rubber Conference, Colombo, Sri Lanka.
 R. A. Fox The impact of ecological, cultural and biological factors on the costs of controlling root disease in tropical plantation crops as exemplified by *Hevea brasiliensis*.

Conferences Organised

A meeting on 'Viruses and Plant Breeding' was organised by B. D. Harrison and M. A. Mayo, and held at SHRI on 8-9 July. About 30 people with research interests in this topic attended, mostly from the ARS. Sessions were devoted to genetic variation in viruses and in plants, mechanisms of response of plants to viruses, resistance to vectors, methods of testing, the situation in selected crops, and strategy and tactics.

D. L. Jennings organised a symposium on *Rubus* and *Ribes* breeding and machine harvesting held at East Malling and Dundee from 14-22 July. The first 3 days were spent at East Malling and after a free weekend, delegates travelled to Dundee for a further 4 days. Altogether 63 participants attended some or all the meetings. The topics covered included problems arising from the machine harvesting of *Rubus* and *Ribes* fruits, aspects of *Rubus* culture, *Rubus* diseases and pests, *Rubus* and *Ribes* breeding and cultivar evaluation. Visits to field experiments and to growers were made during both parts of the meeting.

D. T. Mason organised an AAB Post-Harvest Biology Group meeting on 9 July at the Institute. Following discussion of post-harvest problems in soft fruit, visits were made to local fruit processors and to a growers' production group.

I. M. Roberts organised the Fourth Scottish Symposium on Electron Microscope Techniques, held in Dundee on 17 November. Invited speakers dealt with photography in electron microscopy, recent advances in biological electron microscopy, and studies of the outflow apparatus of the eye. Other contributions covered metallurgy, analytical techniques and radiation sensitive materials. More than 100 people attended and 14 trade firms prepared exhibits.

Editorial Duties

- C. E. Taylor Editor of *Nematologia Mediterranea*.
 Associate Editor of *Journal of Horticultural Science*.
 Member of the Board of Editors of *Horticultural Research*.
- R. A. Fox Editor of *Potato Research*.
- H. J. Gooding Member of Board of Editors of *Horticultural Research*.
- B. D. Harrison Editor of *Journal of General Virology*.
 Editor of *Commonwealth Mycological Institute/ Association of Applied Biologists Descriptions of Plant Viruses*.
 Member of Editorial Board of *Intervirology*.
- M. A. Mayo Member of Editorial Board of *Journal of General Virology*.
- A. F. Murant Member of Board of Editors of *Annals of Applied Biology*.
 Editor of *Commonwealth Mycological Institute/ Association of Applied Biologists Descriptions of Plant Viruses*.
- Pauline B. Topham Editor of *Horticultural Research*.
- P. D. Waister Associate Editor of *Journal of Horticultural Science*.

Service on Committees

- C. E. Taylor Journal of Horticultural Science Publications Committee.
 University of Strathclyde/West of Scotland Degree Advisory Board.
 West of Scotland Agricultural College Glasshouse Advisory Committee.
 ARC Management Advisory Committee.
 ARS Whitley Council.
 Joint ARC/IPCS Working Party on Promotion Procedure.
 NFT Advisory Committee.
 NFU Soft Fruit Working Group Committee.
 SNSA-Adviser to Committee.
 SNSA (Flower Bulbs)-Adviser to Committee.

C. E. Taylor	NSDO Advisory Committee. Member of Scientific Council of the Laboratorio di Nematologia Agraria, University of Bari, Italy. SHRI/Scottish Colleges Liaison Group. ACAS Advisory Committee. HEA Scottish Branch.	R. Thompson	NIAB Vegetable Trials Advisory Committee. SHRI/Scottish Colleges Liaison Group.
C. North	Dundee University Botanic Garden Committee. RHS Lily Group Committee. Eucarpia Vegetable Crops Section Committee.	Pauline B. Topham	ERCC Research Council Users Committee.
B. Boag	European Invertebrate Survey Committee— Nematology representative.	P. D. Waister	JCO, Member of Fruit Committee. Scottish Council/DAFS Joint Committee on Food Processing.
R. A. Fox	Chairman, Pathology Section, European Association for Potato Research. Chairman, EAPR Disease Assessment Committee.	<i>Exhibitions</i>	
H. J. Gooding	NFT Strawberry Variety Assessment Panel. NFU Soft Fruit Working Group Committee. City and Guilds of London Institute Advisory Panel on Tropical Agriculture. NFT Scottish Sub-Committee.	11 March-3 April	Exhibition of electron microscope work at ARS institutes, Edinburgh. I. M. Roberts displayed electron micrographs illustrating electron microscope serology, virus in plant protoplasts, and the association of virus particles with the foregut of an aphid vector. In addition, he set out demonstrations of the preparation of lattice test grids, the making of silicon rubber embedding moulds, and a method of handling and staining epoxy resin sections for light microscopy.
B. D. Harrison	British National Committee for Biology, Member of Microbiology Sub-Committee. International Society for Plant Pathology, Member of Council. JCO, Member of Plant Science Committee. Section of Virology, International Association of Microbiological Societies, Member of Advisory Council.	22-25 June	Royal Highland Show, Edinburgh. Gerberas bred at the SHRI West of Scotland Unit.
D. L. Jennings	NFT Raspberry Sub-Committee. NFT Scottish Sub-Committee. SNSA—Adviser to Committee.	10-12 August	Ayr Flower Show. An exhibit was staged demonstrating research findings from the Institute which concerned problems associated with the production of calabrese. Gerberas bred at the SHRI, West of Scotland Unit.
A. T. Jones	Association of Applied Biologists, Member of Council. Virology Group of Federation of British Plant Pathologists, Member of Committee.	21-27 September	European Botrytis Group Meeting, Bordeaux. Demonstration of computerised information retrieval applied to a bibliography, prepared by W. R. Jarvis (Canada Department of Agriculture), P. B. Topham and R. J. Clark.
H. M. Lawson	ISHS Working Group on Weed Control in Vegetables. British Crop Protection Council Sub-Committees— weed control meetings and publications. JCO, Technical Secretary of Field Vegetables Committee.	5 October	ERCC 2980 Open Day. Pauline B. Topham and D. T. Mason contributed an exhibit on the application of computers in determining the relationship between raspberry fruit ripeness, removal force, and titratable acidity.
W. P. Mowat	Scottish Bulb Technical Committee.	<i>Radio and Television</i>	
A. F. Murant	Society for General Microbiology, Virus Group Committee. International Society for Horticultural Science, Chairman of Working Group on Small Fruit Viruses.	Radio:	Dr H. J. Gooding answered questions on fruit on the BBC 'Scottish Garden' programme on 20 March. D. A. Perry was interviewed on seed vigour in cereals in BBC Radio Scotland's 'Farm Journal' on 20 April.
D. A. Perry	Chairman, Vigour Test Committee, International Seed Testing Association.	Television:	Film was made of mechanical harvesting of strawberries and MSU/CML de-capper at work on the West of Scotland Unit, Auchincruive, on 12 July. R. J. McNicol was interviewed. P. D. Waister discussed the implications of experiments on biennial cropping of raspberries on the Grampian Television programme 'Grampian Today' on 5 February.

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Crops Research

P. D. WAISTER

This year, calculated maximum soil moisture deficits* reached the same high level as in 1975, at about 130 mm. In this respect, these have been the two driest years out of the past 17 for which deficit estimates are available at Mylnefield, and compare with the mean of 80 mm.

Such seasons are a mixed blessing for field experimentation. On the debit side, crop establishment is made difficult and crop variability is intensified, resulting in high experimental error. However, on the credit side, the dry conditions provide a useful test of the stability of experimental results obtained in previous more 'normal' years, and a good opportunity to gain further insight into crop responses to irrigation treatments or to other cultural practices that influence water availability. Of particular interest this year have been the negligible yield responses to irrigation in perennial soft fruit crops, contrasting with the marked response in an annual vegetable crop, calabrese.

Deep-rooted perennial crops, and annual crops established before deficits build up, are buffered against drought by the extent to which their roots exploit the soil water reservoir. On the other hand, seeds sown at intervals throughout a season such as this last one, are exposed to violently fluctuating stresses both of moisture and temperature, acting directly or via effects on soil structure, with the net results that there is very considerable variation in establishment percentage and in uniformity of establishment. This means loss to the grower because yields *per se* are poor, or because lack of uniformity causes yield loss in once-over harvest, or directly because of the waste of expensive seed.

The research programme on germination and establishment has already shown the complexity of the problems which involve the interaction of genotype, seed quality, weather, soil conditions, and sowing techniques. There is no simple panacea for these problems. Successful solutions will only come from a painstaking assessment of the quantitative contribution of each factor and interaction, across the wide range of conditions experienced in commercial horticulture.

*See footnote to meteorological records, p. 107.

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

Crop response to shelter

Sheltered blocks of Cambridge Favourite strawberry outyielded exposed by 11%, the increase being attributable mainly to higher numbers of trusses per plant. There is considerable year-to-year variability in the magnitude of the response which appears to be related to the wind conditions at the time of truss initiation. Potted plants have now been set out in the shelter experiment for destructive investigation of truss initiation and development.

Field measurements of soil moisture depletion and of leaf water potentials have confirmed previous observations that exposed and sheltered plots do not differ in these respects, any tendency for greater evaporation rates from the exposed plants being offset by the larger evaporating surface of the sheltered plants.

Mechanical damage to leaf surfaces is suspected as a cause of at least some of the growth and yield depression in exposed plants. In co-operation with Dr J. Grace¹ a start was made on characterising the air flow patterns which produce damage. The relation of wind speed and turbulence to the shear or drag force exerted on a strawberry plant and to the amount of leaf flutter was examined in a wind tunnel. The data obtained will allow a preliminary estimate to be made of the degree of self sheltering of leaves by strawberry plants. Attempts to correlate eddies and drag force were thwarted on this occasion by instrumentation difficulties.

(D. K. L. MacKerron).

Irrigation and water use

Though 1976 was again a dry year compared with the long-term average, there were no significant yield responses in irrigation experiments on strawberry and raspberry. In part this may reflect the high water-holding capacity of Institute soils (23% on a volume basis), but there was evidence this year that the control non-irrigated plants did suffer appreciably greater stresses than those irrigated at 30 cm Hg tension in the root zone. Leaf water potentials were lower in the controls and, particularly in strawberry, there was a marked divergence in water use between the two treatments, indicating that stomatal resistance was higher in the controls. Measurements of stomatal resistance were made using a diffusion porometer and, though there were difficulties with instability of the instrument, there appeared to be marked differences between watered and control plants.

¹University of Edinburgh.

Interpretation of yield responses (or lack of them) in soft fruit crops is made more difficult because of the potential competition between the fruiting and vegetative phases. This is particularly true in raspberries where any effects of the 1976 soil moisture conditions on growth will not be measurable in yield until 1977.

Leaf water potentials and stomatal resistances were compared on primocanes and fruiting canes. Potentials in the primocane were higher and stomatal resistances usually lower. A lower resistance would mean a higher rate of transpiration for a given set of environmental conditions. For the primocanes to sustain this and have a higher leaf potential they must be better supplied with water than the leaves on the fruiting canes. This condition could arise either from a better connection to the root system or from the conducting system in the cane itself being in better condition in the primocane.

(D. K. L. MacKerron).

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

Irrigation

The calabrese cv. Corvet was sown on 1 April, 27 April and 25 May and irrigated to maintain soil moisture tensiometer readings below 20 cm Hg. The excess of potential transpiration over rainfall was 138 mm, 148 mm and 226 mm respectively for the three sowings. These indications of different levels of water stress in the control plots were reflected in the differences in yield between the irrigated and unirrigated plots. For the first sowing, yields were 7.3 and 6.2 t/ha for the irrigated and unirrigated plots respectively and corresponding values for the second and third sowings were 6.0 and 4.8 t/ha and 7.7 and 4.3 t/ha. The amount of leaf to be removed from the spear stem to give a marketable product was unaffected by irrigation on the first sowing but was reduced for the second and third sowings by about 50% and 90% respectively.

(R. Thompson, H. Taylor).

Light interception by peas

One of the mutant forms of pea produced by the John Innes Institute (hybrid No. 4) has well-developed tendrils but no leaves. The pattern of light interception in this genotype was examined at three plant densities, using tube solarimeters, and compared with that in a conventional leafy pea, cv. Scout.

An increase in density of the mutant from 64 to 141 plants/m² produced more rapid attainment of maximum light interception but did not affect its final value (~90%). Comparing equivalent densities of the two types (90 plants/m²), the conventional leafy cultivar showed earlier light extinction than the mutant and greater attenuation in the upper part of the canopy. It produced the same maximum total interception 13 weeks after sowing but thereafter senescence of the middle and lower leaves reduced light interception. This did not occur in the mutant.

For further assessment of the potential of the leafless form for dried pea or vining pea production, it will be necessary to relate these light profiles to the position and growth rates of pods in the different layers of the canopy.

(D. K. L. MacKerron).

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

Continuous sowing experiment

Calabrese, carrot, onion and red beet seeds were sown on 10 occasions between 9 March and 1 July, with 0, 125 and 250 kg/ha inorganic N fertilizer incorporated into the seedbed. The species differed in their range of emergence percentages, onions being most consistent (65%–85%) and beet least so (21%–89%). Species differed too in their emergence on each sowing occasion, reflecting differential susceptibilities to specific environmental complexes. For example, emergence of carrot, red beet and calabrese was worst from the first sowing which encountered cold wet conditions producing soil slumping, whereas onion emergence was worst at later sowings made in hot dry conditions.

Only the calabrese sowings showed a depression in emergence percentage attributable to fertilizer concentration, but the rate of emergence of all crops was reduced on some occasions by it. Again species response differed in its magnitude, ranging from a maximum of 2 days delay in onions to 14 days delay in red beet.

(T. W. Hegarty, K. Bell).

Seed activation and germination under moisture stress

Seeds of calabrese and carrot were held at 10°C or 20°C for periods of up to 21 days in water or polyethylene glycol solutions of approximately -5, -10, -15 and -20 bars. Seeds were subsequently placed to germinate in a favourable environment or, along with any germinated seeds, were first dehydrated before being allowed to re-hydrate in this environment. The seeds' ability to germinate was virtually unaffected by any of the temperature, water stress or duration treatments, and carrot seeds in particular were to some extent tolerant of dehydration after germination had occurred. The levels of water content and oxygen uptake rates after initial imbibition were lower at each increasing level of water stress and the onset of germination was progressively delayed. At -15 and -20 bars no germination occurred, water content remained approximately constant after imbibition throughout the duration of the experiment but oxygen uptake rates fell after about 6 days.

(T. W. Hegarty).

Seed and seedling susceptibility to phased moisture stress in soil

In a laboratory experiment seeds of calabrese and carrot were sown in soils at -10, -5.5 and -4 bars. After periods of up to 3 weeks at 15°C the soil was

either re-hydrated directly, or re-hydrated after a short period of severe dehydration (<-50 bars). Seed and seedling losses appeared to be almost entirely due to seedling death after germination under conditions of severe dehydration but not all germinated seeds were killed by the dehydration. Deterioration or death of seeds rather than seedlings was implicated only in carrot when seeds were dehydrated and then re-hydrated after being held for from 1 to 3 weeks in soil at -10 bars.

(T. W. Hegarty).

Seedling emergence and crop uniformity

Seeds of carrot were sown on 30 April to give a stand of 350 plants m⁻² and red beet on 10 May to give a stand of 150 plants m⁻². Samples were taken at fortnightly intervals from 7 June (beet) and 14 June (carrot) and at first tops and later roots were weighed. In both crops self thinning was negligible at least until October. The weight distribution of individuals within each crop was expressed relative to the mean at each harvest, thus allowing comparison across harvests using a X² test. On this basis the root population structure of each crop remained constant on a relative basis throughout the period of measurement as did the tops structure over the same period, but alterations were noted in the tops population structure at the first two population sampling dates when root weights were not recorded. It appears that in both crops at these densities, root size uniformity is determined at or shortly after seedling establishment.

(T. W. Hegarty).

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

Seed vigour in field bean

Seed samples of cv. Maris Bead were obtained from 59 crops from different locations in Britain. Seed weights ranged from 0.26 to 0.37g, germination from 73 to 99%, conductivity from 13 to 28 µmho/g and field emergence from 32 to 95%. The conductivity test was a better indicator of potential emergence than was the germination test, even when considered only in relation to those samples above the minimum permitted germination percentage of 85% for commercial seed.

Observation plots of Maris Bead were grown with and without free access for bees, the main pollinating agents. Yield from the plot with enforced self-pollination was less than half that of the control plot, as a result of reduction both in number of productive plants and in number of seeds per pod. The seed produced from the self-pollinated plot gave a lower germination percentage and a higher figure for seed leachate conductivity.

(T. W. Hegarty).

Genetic and environmental components of seed vigour in Brassicas

Thirty-two stocks of open pollinated, and 17 stocks of hybrid Brussels sprout seeds were germinated in optimal or in stress conditions in the laboratory and were sown in the field on four occasions. There was a significant seed stock x germination stress interaction in percentage germination, with seed stocks responding differently to moisture stress (-7.5 bars, 20°C) and temperature stress (0 bars, 7.5°C) compared to the control (0 bars, 20°C). There was also a significant seed stock x sowing date interaction in field emergence, indicating vigour differences within the seed stocks. Although some F₁ seed stocks had low germination and emergence percentages it seems significant that of the 10 seed stocks with mean emergence levels > 70%, 9 were hybrids. While this may reflect aspects of seed production it may also indicate genetic superiority (see Annual Report for 1975). Germination at 20°C correlated well with field emergence but it was useful more as a ranking indicator than a predictor of emergence. High germinating stocks (>90%), especially amongst the hybrids, gave the most consistent emergence levels.

Sixty-seven stocks of a kale cultivar, produced at a diversity of sites within the UK, with germination ranging from 60 to 95% were sown in the field on three occasions. There was a significant seed stock x sowing date interaction but, in contrast to the Brussels sprouts, there was much less variability in the response of the seed stocks. This difference could represent an effect of more diverse environments of seed production and storage of the Brussels sprouts, but indicates that the genetic component must also be considered.

(A. E. B. Ibrahim, T. W. Hegarty, J. R. T. Hodgkin).

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

Soil impedance and field emergence of calabrese

Seeds of calabrese were sown by hand on four occasions. Plots contained unrolled control drills and drills which were rolled with the press wheel of a hand seed drill weighted to deliver pressures of 3.2 and 6.1 N cm⁻², to simulate respectively a correctly and badly set drill press wheel. Five millimetres of water was then applied to half of the plots to induce surface crusting. Plots were protected from natural rainfall with clear corrugated plastic screens. Measurements of soil impedance were made on replicate drills without seeds, using a force transducer penetrometer fitted with a 2 mm diameter flat-ended probe, driven into the soil to a depth of 15 mm.

Emergence from the unrolled, unwatered control plots was high at each sowing (mean 93%). Watering caused an overall reduction in final emergence level from 86% to 51%. Heavy rolling significantly reduced emergence on all sowings from a mean 78% to 58%. Emergence was significantly reduced by light rolling only on the two sowing occasions with highest soil moisture contents.

Final emergence percent correlated well with the integral of the force-distance curve from the penetrometer output ($r=0.96^{***}$). Mathematical models which incorporated soil surface moisture content at sowing, level of compaction, and level of applied water, explained 96% and 95% respectively of the variation in emergence and penetrometer integrals.

Both the watering and heavy rolling treatments significantly increased time to 50% emergence and caused a reduction in mean seedling weight at the 1½-2½ true leaf stage. There were also small but significant increases in the coefficients of variation of seedling weight with watering and rolling treatments and a significant increase in the time interval between 25 and 75% emergence with watering, indicating effects on seedling size uniformity due to soil impedance.

Apart from the risks associated with a poorly set press wheel, the data suggest that even when correctly set, pressure from the press wheel may result in soil impedance problems if the surface soil is too moist at sowing or if heavy rainfall occurs after sowing.

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

WEED INVESTIGATIONS

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

Weed competition

When residual herbicide treatments fail because of adverse soil and weather conditions, spring planted raspberries and strawberries can suffer severe setbacks in establishment. Selective removal of the weeds is not at present possible by chemical methods, but non-selective removal of the foliage of both crops and weeds is being examined in experiments commenced in 1976 for assessment in 1977. Previous work has indicated that the perennial nature of these crops may allow regrowth and give better establishment than would be possible with unrestricted weed competition.

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

Herbicide evaluation

For many years, simazine has been the only residual herbicide in general use for the field bean crop. In 1976 several of the newer pea herbicides were evaluated for phototoxicity following pre-emergence application to field beans drilled to a depth of 7.5 cm. No evidence of adverse effects on either seedling growth or yield of harvested beans followed treatment with simazine or with cyanazine, trietazine/simazine or terbutryne/terbuthylazine applied at rates recommended for peas. The last three treatments all gave better control of weeds, particularly *Polygonum aviculare*, than did simazine. Bentazone was compared with the standard dinoseb acetate as a post-emergence treatment. Both caused a certain amount of foliage scorch, but bentazone caused less long-term check to the crop.

Of a number of soil-applied herbicides recently developed for the sugar beet crop, cycloate and ethofumesate proved useful in mixtures with low rates of lenacil for weed control, and did not damage red beet; normal rates of lenacil caused crop injury, particularly after incorporation, when a week of very wet weather followed drilling. Metamitron also proved safe and effective as a pre-emergence treatment, but did not control *Chenopodium album* and *Urtica urens* up to 10 cm tall when applied at the two true leaf stage of crop growth. Phenmedipham achieved reasonable but by no means complete control of these weeds. Ethofumesate showed promise in a mixture with phenmedipham under these circumstances, but a mixture of lenacil and phenmedipham severely injured the crop. The addition of activating oil to phenmedipham increased weed control but caused slight crop scorch.

Of a range of herbicides evaluated as immediate post-planting treatments in strawberries, propachlor, penoxalin and ethofumesate showed sufficient margin of safety to the crop to be worth further development. A trietazine/simazine mixture was however, no safer than simazine alone, which killed a substantial proportion of the planted runners when applied at rates of 2.2 kg a.i./ha or above.

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

VEGETABLES, FIELD CROPS AND FLOWER BULBS

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

Dried peas

Successful dried pea production in Scotland is unpredictable because the weather is often too wet during the time the crop is drying-off. A mutant (No. 4) from the John Innes Institute, with additional tendrils, no leaflets and reduced stipules, resists lodging compared with commercial cultivars. Air movement within the crop and hence drying are likely to be promoted by these characteristics and the potential of this type of pea for Scotland was therefore examined. The crop was sown on 1 April to give population densities of 44, 93 and 163 plants/m² to find whether plant density affected either yield or the standing ability of the crop. No lodging occurred at any of the population densities but yield increased as population density was increased with 2.2, 2.9 and 3.5 t/ha (15% moisture content) respectively.

(R. Thompson, H. Taylor).

Vining peas

The cultivar Scout is very high yielding but is classed as early main crop in maturity, and is therefore generally used for only a limited part of a pea production schedule. Its performance was assessed when sown for harvesting over the whole pea production season between 11 July–13 August. Six sowings were made between 19 March and 4 June and gave an average population density at harvest of 53 plants/m². Harvests made at T100 on

11, 18, 25 July, 3, 8 and 13 August gave corresponding yields of 7.5, 4.7, 3.1, 4.0, 4.5 and 4.4 t/ha. The similarity of yield over much of the harvest period justifies further investigation. In this abnormally dry year it may indicate that only the early sowing was adequately supplied with water. These yields are well below those usually obtained at the Institute.

(R. Thompson, H. Taylor).

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

Field bean yield potential

Yields of field bean at SHRI over the past 4 years have been good, showing little of the variation that is often associated with this crop elsewhere. However it was not known how nearly the yields obtained approached the potential for our climate. To explore this an attempt was made to grow a crop of field beans with non-limiting levels of all factors affecting growth apart from light, CO₂ and temperature. This was compared with a crop grown in the usual way. For the 'non-limiting' treatment a specially made compost was used, irrigation was applied on the basis of tensiometer values, and an additional 125 kg/ha N, 43 kg/ha P and 43 kg/ha K were given in solution.

Yields at 15% moisture content were 5.8 and 4.8 t/ha for the non-limiting and control plots respectively. It is surprising that in 1976 the effects of soil moisture deficit were not big enough to give a larger difference in yield than this. Plant growth was clearly more vigorous in the 'non-limiting' plot than in the control; plants were 34% taller from the former, and although not measured objectively, leaf area duration was also greater for plants from the 'non-limiting' plot. Compared with plants from the control plot, those from the 'non-limiting' treatment had a greater average bean weight (38%), a greater number of pod-bearing nodes (19%), similar numbers of beans per pod and fewer pods/node (27%).

(R. Thompson, H. Taylor).

By decreasing incident light on a field crop, using increasing intensity of shading, progressive reductions in haulm weight and seed yield were obtained. The yield reduction occurred primarily as a result of decrease in the number of pod-bearing nodes, while other yield components remained relatively constant.

In leaf removal experiments in the glasshouse, a similar result was obtained. In particular, the weight per seed showed remarkable stability. However when sinks were limited by removal of varying proportions of flowers, both seeds per pod and seed weight were increased, the latter by as much as 100%.

(R. M. Brook, R. Thompson).

Winter and spring sowing of field bean

Eight spring bean and three winter bean cultivars were sown both in the autumn and in the spring. In contrast to last year there were no yield differences between averages for spring cultivars sown on the two occasions (4.6 t/ha). Nevertheless, components of yield contributed to final yield in a similar way to that reported last year. Average bean weight and number of pod-bearing nodes/plant of the spring-sown spring cultivars were 13% and 42% lower than from the winter-sown. These reductions were balanced by 10% more beans/pod and 43% more pods/pod-bearing node.

Yields for the spring and winter sowings averaged over the winter cultivars were also similar (4.4 t/ha), but again the relative contribution to yield of the several yield components differed between the two sowings. Unlike the spring bean cultivars the number of pod-bearing nodes/plant was similar for the two sowings but mean bean weight was 39% greater for the earlier sowing. This was balanced by 37% fewer pods/pod-bearing node.

(R. Thompson, H. Taylor).

Lupin

In a particularly favourable season for lupins, growth and yield of the species *L. albus* (Kievsky mutant), *L. luteus* (cv. Gyulatanyai), *L. angustifolius* (cv. Unicrop and cv. Uniharvest) were good compared with results reported elsewhere in Britain. Plants were ready for harvesting about mid-September but rain delayed harvest until the end of September. Such late maturation in an exceptionally warm dry year must cast doubt on the performance of the crop in a more normal year.

Maximum yield equivalent to 4.0 t/ha (10% moisture content) was obtained from Kievsky mutant, with 2.5 t/ha from Gyulatanyai and 2 t/ha from both Unicrop and Uniharvest.

Delay in sowing Gyulatanyai from 30 March until 15 April depressed yield by 40% and delay until 30 April by 50%.

(R. Thompson, H. Taylor).

Linseed

Neither sowing date (15 April, 3 May and 24 May) nor sowing rate (25, 50 and 100 kg/ha \approx approx. 280, 510 and 1020 plants/m²) affected the yield of cultivars Antares and Noralta, which gave averaged yields of 4.5 and 3.5 t/ha respectively. Compensation for changing population was, as last year, largely through numbers of capsules/plant.

Earlier sowing resulted in earlier maturity, the first two sowings being ready for harvest by end August, whilst the third sowing was not dry enough until mid September.

(R. Thompson, H. Taylor).

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

Tulip yield potential

Yields of cv. Apeldoorn at SHRI were only half those recorded at Lisse (Holland) in recent experiments. This could not be accounted for by differences in radiation or temperature between the two sites, nor was there evidence of differential pest and disease attack. This suggested that some soil property was involved and so comparison has been made between the growth of cv. Apeldoorn grown in the usual way with that in an artificial compost with a plentiful supply of nutrients and water. For the non-limiting treatment the artificial compost consisted of five parts loam, two parts peat, one part coarse sand and fertilizer providing 90 kg/ha N, 144 kg/ha P and 175 kg/ha K together with a complete range of trace elements.

Although net assimilation rate (NAR) was slightly higher for the control than for the 'non-limiting' treatment during the time of peak leaf area index (195–220 days after planting), daughter bulb relative growth rates (RGR) were higher throughout for the 'non-limiting' treatment than for the control by about 0.005 g g⁻¹ day⁻¹. Of greater significance than either NAR or RGR in relation to final yield was leaf area duration which was 23% greater for the 'non-limiting' treatment than for the control plot.

Final daughter bulb yields equivalent to 57 and 35 t/ha were obtained from the 'non-limiting' and control treatments respectively.

(R. Thompson, H. Taylor).

Biennial lifting

The present programme of experiments to compare annual and biennial lifting has now been completed. Season-to-season differences in bulking rates of tulips, whichever system is used, inevitably complicates any attempts at accurate prediction of either bulb yield or size grading. However, enough is now known to give guidance on the likely outcome of the many alternative strategies for producing forcing-size bulbs from either system.

One interesting application of biennial lifting is in the utilisation of the smaller size grades as planting stock. Bulbs of grade 6–7 cm of the cvs. Apeldoorn and Merry Widow were planted in 1974 and 1975 on annually-lifted plots, and in 1974 in plots to be left down for 2 years.

At a planting rate of 1.5 millions/ha the yields of bulbs >10 cm for cv. Apeldoorn were 27,000 and 65,000 for annual treatments lifted in 1975 and 1976 respectively, compared with 638,000 in the biennial plots in 1976.

The corresponding figures for cv. Merry Widow were 17,000 and 210,000 for the annual liftings and 510,000 for the biennial.

Tulip forcing

In collaboration with the University of Bath a study was made of the relationship between forcing performance and carbohydrate changes during

storage at 5°, 9° or 13°C. Although regressions of stem length and time from housing to flowering on total soluble sugars, reducing sugars and % dry matter were significant and the relationships very good for each storage temperature, preliminary analysis has failed to reveal any relationship between chemical composition and forcing performance that holds good across all three temperatures.

(R. Thompson, H. Taylor).

FRUIT CROPS

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

National Fruit Trial 1975

Despite the dry summer, yields were high in the first cropping year of this trial. Out of 16 cultivars and seedlings only one yielded less than cv. Malling Jewel, and the highest yielding (M32) produced 19 t/ha, nearly three times the yield of Malling Jewel. It is already apparent that the majority of the new seedlings will present the same problems of excessive vigour as was found in the previous trial. Chemical control of cane vigour will be practised in two of the four replicates in 1977.

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

Control of cane vigour

The technique developed for the control of excessive cane vigour depends for its success on the fact that most raspberry cultivars produce a second flush of young canes if the first one is removed. With correct timing of removal, the growth of these young canes will be sufficient to provide adequate fruiting cane for the following year. Removal by cutting is impracticable on a large scale and the technique depends on effective knock-down of young canes by a contact herbicide.

A very wide range of herbicides has been evaluated in the glasshouse over the last 2 years for efficacy of knock-down or stunting of raspberry shoots. The performance of a 9% w/v oil formulation of dinoseb was used as a standard. Herbicides showing sufficient activity to merit examination in the field included paraquat, diquat, propyzamide, chlorpropham, dimexan, nitrofen, sodium monochloracetate, tar oil, TVO and sulphuric acid. The oil formulation of dinoseb was much more active than either the acetate or amine formulations at equivalent rates of active ingredient. No benefits were found from adding the activating oils 'Actipron' or 'Sun oil' to the dinoseb-in-oil formulation.

In field examination most of the alternative herbicides have proved insufficiently effective at economic rates of application, but a few merit further evaluation as less toxic alternatives to dinoseb.

Applications of dinoseb-in-oil in field trials covering a wide range of cultivars, seasonal conditions, growth stages and dose rates has produced no evidence of injury by translocation to the fruiting canes or to subsequent young cane growth, despite repeated treatment and intentional overdosing. Thorough spray coverage was found to be very important in the attainment of rapid and effective knock-down. The volume of water required varied greatly according to the height and density of the young canes and it proved more effective to apply a standard concentration of chemical in water to run-off point than to develop a range of herbicide rates and water volumes for different circumstances. Consistently good results have been obtained using a concentration of 3 l of 9% dinoseb-in-oil formulation per 100 l water. Samples of fruit from treated plots have shown no evidence of taint or taste abnormalities in tests at CFPRA. Analyses carried out by Messrs. A. H. Marks have also demonstrated that fruit from treated plots contains no unacceptable chemical residues.

Experiments on time of application of dinoseb-in-oil have shown that the herbicide is best applied when young canes of cv. Glen Clova are between 10 cm and 20 cm high. Young canes have taken only 8-12 days to span this growth interval in our trials, so that timely application is most important.

While Glen Clova has recovered quickly from removal of the first flush of young canes in SHRI experiments, cv. Malling Jewel has in most cases failed to produce adequate secondary cane growth. The response of other cultivars is being examined in a trial which commenced in 1976.

It is very difficult to avoid spraying lower laterals on fruiting canes when young canes are treated with dinoseb-in-oil. The importance of these laterals for fruit production was examined by comparing the development of untreated fruiting canes with those from which laterals below the bottom wire (60 cm) were removed by hand in mid April. Mean number of cropping laterals per cane was 13, of which 2 were removed on treated canes. Yield of fruit per cane was identical, the reduction in cropping laterals being compensated for by increases in both number and size of berries on remaining laterals on treated canes.

Other treatments included spray application when young canes were 10 cm or 30 cm high. Any adverse effect of herbicide treatment on lower laterals was more than made up by increases of 15% and 50% respectively in yield per fruiting cane as a result of the removal of competition by young canes. Accidental treatment of basal laterals is therefore unlikely to produce adverse effects on yield and may be beneficial in concentrating fruit production further up the cane.

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

If vigour of the newer cultivars is not controlled, canes become very tall and a large number of potentially productive buds are removed in the tipping operation. The consequent loss was measured by bowing-over canes of cv. Glen Isla and comparing yields with a tipped control. The increase was 40%, confirming the results of a previous experiment on this cultivar.

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

Biennial cropping

Young cane was removed regularly by application of dinoseb-in-oil to plots of six cultivars which had hitherto been grown normally. The results were compared with controls grown on the annual crop system. The sprayed biennial plots were, therefore, in their part-biennial year. On average, the six cultivars produced 45% more crop in the part-biennial plots than in the annual, the increase varying from 26% more in cv. Malling Jewel to 68% more in cv. Malling Orion. Average fruit size was 11% higher in the part-biennial plots.

An experiment on biennial cropping of cv. Glen Clova reached its first full fruiting year, in which comparisons were possible between conventionally grown fruiting cane, cane freed from competition from vegetative cane in the current year (part-biennial) and cane produced in the previous year in the absence of fruiting cane and maintained free of competition on its current fruiting year (fully-biennial). The fully biennial gave a 51% yield increase over the annual control, compared with 31% for the part-biennial. Yield increase in the former resulted from more fruiting laterals and a greater number of canes per stool, and in the latter from increased yield per lateral. Mean berry weight was highest in the part-biennial treatment. Yield potential for each lateral position on the canes was estimated from the sum of numbers of fruit, flowers and buds, and showed a fall from tip to base of annual canes but an increase in biennial canes. (All canes had been tipped at a standard height of 1.45 m). Yields in this experiment were low because of a severe attack of midge blight.

An experiment on timing and rate of nitrogen application to the biennial system was started, with the object of defining the relative nitrogen demands of the fruiting and vegetative phases.

(M. R. Cormack, C. J. Wright, P. D. Waister).

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

Raspberry

There is evidence that damage caused by the vibrating fingers of the mechanical harvester is an important contributor to yield depression in the following year. In collaboration with the SIAE two settings of the machine were used in 1976 for harvesting plots of cv. Malling Jewel, one giving a long stroke at low frequency and the other a short stroke at high frequency. Fruit removal by the two settings was similar, and their effects on cane damage and subsequent yield will be assessed in 1977.

The use of two alternative catching devices this year will similarly permit comparison of damage from this source in 1977.

Investigation of cultivar and seedling suitability for machine harvesting again showed differences both in proportion of green fruit removed and in the overall recovery of ripe fruit. On the basis of this screening seven cultivars and seedlings have been selected for detailed examination in a replicated

experiment. One of these, cv. Meeker, is mechanically harvested in Oregon, and its performance in Scotland will aid understanding of the relative importance of genotype and environment in determining ease of mechanical harvesting.

In co-operative work with ESCA, a plot of cv. Glen Isla was used for comparison of two different types of raspberry harvester. Assessment of their relative performance awaits the results of damage measurements in the 1977 crop.

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

Fruit retention strengths measured with a Correx tension gauge on 16 raspberry cultivars and seedlings were compared with the percentage of edible fruit removed from the same clones using an Agricultural Sciences Harvester on one occasion during the middle of the fruiting period. High harvester efficiency, the amount of edible fruit removed by the machine as a percentage of the amount present, was significantly correlated with a low retention strength of the ripe fruit indicating that this is an important attribute when selecting for cultivars suitable for mechanical harvesting. The correlation coefficient for ripe berries was higher than that for either slightly overripe or overripe berries. However, the regression only accounted for 60% of the variance which suggested that other factors such as the length and strength of the fruiting laterals must also be taken into account.

The raspberry crop ripens over a period of 3 to 5 weeks, depending upon cultivar and season. The shape of the ripening curve is one of the factors which will determine the timing of mechanical harvesting operations. In 1976 the daily flowering curves for cv. Malling Jewel and cv. Glen Isla were mirrored approximately 40 days later by the fruiting curves which suggested that the period of maximum fruiting could be predicted from the period of maximum flowering. The curve for the standard cultivar Malling Jewel showed an appreciably more concentrated ripening pattern than that for Glen Isla, a cultivar with otherwise desirable machine harvesting characteristics. During a 16-day period centred on the point of maximum daily yield, 66% and 76% of the crop of Glen Isla and 85% and 90% of the crop of Malling Jewel were produced in 1975 and 1976 respectively.

Although machine efficiency can be improved by timing harvests to coincide with the period of maximum fruit ripening the total yield of fruit is always less than that achieved by hand picking because the machine does not remove all the ripe fruit available at each pass, and may remove some of the green berries by breaking the fruit pedicels. In order to achieve maximum efficiency at each harvest it is necessary to operate the machine so that it removes the highest percentage of the ripe fruit compatible with an acceptable level of removal of green fruit. The effect of finger frequency on harvester efficiency was examined on the cultivar Malling Jewel by comparing three finger frequencies, low (5.0 hz), medium (8.3 hz) and high (11.7 hz) at a standard forward speed (1.6 km/hr) and finger stroke (6.5 cm). The low, medium and high frequencies removed approximately 5%, 11% and 37% respectively of the green berries, 17%, 52% and 87% respectively of the ripe berries and 37%, 66% and 90% respectively of the slightly overripe berries.

Knowing the shape of the ripening curve, and the effect of machine settings on the percentage removal of fruit of each age group it is possible to predict the effect of various harvesting strategies on fruit recovery and on the quality of the harvested sample.

(D. T. Mason).

A numerical representation of the day-to-day ripening of a raspberry crop was combined with estimates of the rate of loss of overripe fruit and of the efficiency of hand and machine picking in relation to fruit in different ripeness categories. From this was calculated the effect on the proportion of the potential crop harvested at different simulated harvesting intervals. Hand-picking regimes, based on a recovery rate of 95% of available ripe fruit at each harvest, were highly efficient, and even regimes with only three picks collected over 79% of the potential crop. With machine harvesting, the loss of green fruit caused by mechanical damage to the pedicels was greatest in early harvests when most of the crop was unripe and vulnerable. Four successive harvests, each causing only a 10% loss of the green fruits exposed to them, could reduce the potential crop by 25%.

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

01008 Physiological disorders of soft fruit

Strawberry crown death

The results of a survey of the incidence of crown death in eastern Scotland were re-analysed using fitting constants. This analysis showed that the percentage of dead crowns increased with the age of the plantation, and that the only factor significantly associated with crown death in plantations of all ages was the parent material of the soil. Plantations growing on soils derived from Old Red Sandstone contained a higher percentage of dead crowns than plantations on soils derived from other parent materials. An examination of the literature on strawberry nutrition and the differences between soil types combined with the results of the survey suggested that sulphur deficiency may be involved in the crown death syndrome. Field and pot experiments have been commenced to test this theory.

(D. T. Mason).

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

National Fruit Trial 1975

In its first main cropping year this trial produced high yields. The control cultivar, Cambridge Favourite, gave 19 t/ha, and the two highest yielding entries, 66G52 and cv. Jurica, 34 t and 26 t respectively. Jurica's yield superiority came mainly from higher numbers of trusses per plant, while that of 66G52 was attributable largely to its fruit size which was more than 40% greater than in Cambridge Favourite.

A new experiment was planted whose object is to identify the interactions between cultivar, de-running and defoliation treatments.

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

01012 Ecology of new fruit crops for Scotland

Blackberry

When vegetative cane was removed as it developed in the cultivar Ashton Cross, the yield of the fruiting cane was only enhanced by about 10%, contrasting with the large responses obtained in many raspberry cultivars. Other plots were maintained in the vegetative phase only, by cutting out the fruiting cane, with the object of measuring the yield response in the fully biennial fruiting phase in 1977.

Blackberries and hybrid berries cropped well, particularly cv. Bedford Giant (11.5 t/ha) and the SHRI hybrids 102/51 and 102/84 (each nearly 10 t/ha). It remains to be seen whether their good performance in recent years is closely linked with the unusually warm and dry summers.

Vaccinium species

Highbush blueberry yields reached 9 t/ha in 1976. Though the fruiting framework has been slow to develop it is now capable of supporting good crops but, as in the case of blackberries, regularity of fruiting has yet to be tested in an adverse season. Observation plots receiving irrigation showed no measurable benefit, despite the dry conditions prior to and during fruiting.

(M. R. Cormack).

STATISTICS AND COMPUTING

01044 Statistics (Service)

In several experiments involving field bean and raspberry, records have been taken on an individual plant or cane basis. For instance, from one raspberry experiment over 5000 canes were recorded for 9 characteristics and in another instance involving about 360 field bean plants, five pieces of information were collected from every cropping node. The gathering of data on this scale is not a guarantee of successful results, but it is gratifying that if the experimenter considers the step to be justified, the information can be summarized and analysed almost as readily as plot values.

An improved method of estimating from dilution series the concentrations of infective particles in soil from field experiments on red core has been brought into use. The previous method used weighted analysis of variance following individual point estimates of the 'most probable number.' This has been replaced by direct maximum likelihood estimation of treatment effects using the GLIM package.

The first two lectures in a series of eight have been given as an internal service course in elementary statistics. The initial consumer response has been favourable.

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

01045 *Use of computing facilities*

The equipment for a remote job entry terminal to the ERCC network was purchased during the year and at the time of writing is being tested in Edinburgh. Our thanks are due to the many people at the ERCC who have helped us. It will be interesting to see the effect of the new communications system on the computing pattern. In 1976 the average 'time-to-completion' of a job, that is the time from first submitting cards to the computer to the arrival in the scientists' hands of usable output, has been 7.6 working days representing 2.8 submissions of each job and a turn-round time of 2.7 working days. This turn-round time has been achieved by thoroughly revising the job-handling facilities on EMAS to simplify and speed their usage and by constant attention to returning work to its originator and correcting it as early in the day as possible.

	1975		1976	
	Jobs	%	Jobs	%
Crops Research	503	67.9	620	67.0
Plant Breeding	97	13.1	145	15.7
Mycology	34	4.6	80	8.6
Zoology	88	11.9	69	7.5
Virology	19	2.5	11	1.1
	<hr/>		<hr/>	
	741		925	

The number of computing jobs rose to 925, an increase of 25%. This increase was spread over all the programs used; in particular, however, the interactive use of GLIM, the General Linear Interactive Modelling package, increased considerably and users are increasingly self-sufficient in this activity.

The Rothamsted Multijob system is used occasionally and provides useful facilities for urgent jobs on Genstat or MLP, especially if part of the ERCC system is down. Occasionally a package such as TAXIR is available at Rothamsted which is not supported at Edinburgh and it is convenient to experiment with its use.

Usage of the Wang programmable desk calculator increased considerably. About 45 programs are now available of which seven were used for over 100 runs each. The use of paper tape input and output from the teletype interface has made for new uses in the field of data processing rather than statistical analyses.

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

Information retrieval

An exhibit featuring *BOTBIB*, the *Botrytis* bibliography maintained in conjunction with Dr W. R. Jarvis of the Canadian Department of Agriculture, Harrow, Ontario, was displayed at the European Botrytis Group meeting in France in September and since then a number of requests for retrievals have been received from scientists in the UK and overseas, showing that a small specialist bibliography of under 2000 entries can still be very worthwhile in making information available quickly and cheaply.

The Institute's retrieval system for photographic records attracted interest at a meeting of the Scottish Region Institute of Incorporated Photographers. After a year in service about 1000 entries are included. Support for the TRIAL computer package which was used for these projects has been withdrawn at the ERCC and it has been replaced by FAMULUS, which is more flexible. The Program Library Unit of the ERCC is developing a program to convert TRIAL records into a form suitable for input to FAMULUS and we are grateful for their support in maintaining our projects in this field. The use of TAXIR to maintain a file of virus descriptions is being explored in conjunction with the Rothamsted Computing Department.

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

Plant Breeding

C. NORTH

Many of the Section's projects are at a very productive period.

The new *Rubus* hybrid has been named 'Tayberry' and is being propagated for release. It resembles the 'Loganberry' in many respects but is earlier fruiting, more productive and easier to propagate.

Four strawberries have been passed on for propagation and entered for Plant Breeders' Rights. The names chosen are 'Silver Jubilee' (65G95) primarily a garden cultivar, 'Troubador' (65R70) is late-maturing and 'Saladin' (65G52) and 'Tantallon' (65G48) are very productive and have firm fruits; all have field resistance to red core disease.

Another six lily cultivars have been released. Three are Asiatic hybrids with upright-facing flowers; 'Pandora' is very early, 'Phoebus' midseason and 'Achilles' late. The other three—'Eros,' 'Pegasus' and 'Theseus'—are vigorous, scented *L. lankongense* hybrids. There are also some very promising clones among the triploid lily clones which will be finally selected in 1978.

In addition to new cultivars released during the last year, there are a number of advanced selections under trial, some of which will be introduced in the near future. These include promising late-flowering black currant clones, one especially interesting, and some blackberry and raspberry clones having useful properties not seen in existing cultivars.

03001 *Strawberry: breeding and associated genetic studies*

Screening for disease resistance

A high incidence of mildew *Sphaerotheca macularis* was obtained on the foliage of plants grown in walk-in polythene tunnels by increasing ventilation and thus reducing relative humidity following fruiting. This technique provided a good screen for selecting resistant seedlings. The susceptibility of fruit to mildew is also being scored under glasshouse conditions. Five selections which showed combined resistance to *S. macularis* and *Botrytis cinerea* included CH34, a cv. Tioga derivative, which is also easily decapped and has a short period to fruit maturity—the latter an important character for late frost avoidance.

Four techniques have been compared in screening for resistance to crown rot caused by *Phytophthora cactorum*—inoculation of young seedlings, whole plants, detached leaves, and planting in infected soil. Successful procedures involving taking runners from the field in February, potting and keeping under long days for one month and then inoculating by placing disks of mycelium between the inner surfaces of split petioles: and the inoculation of young leaves taken from the plants described above. Both these techniques ranked cv. Templar and Silver Jubilee (65G95) as the most resistant of the tested cultivars.

Fruit quality testing

Gardner Color Difference Meter readings made on thawed pulp and skin of cv. Cambridge Favourite and a range of selections have given highly significant differences both between selections and the control cultivar for darkness and redness ratings. These objective tests have provided a valuable supplement to subjective colour scoring on fresh and canned fruit. A recent canning test report has indicated that Tantallon (65G48) is promising both with and without artificial colouring matter, which is encouraging because red-fleshed selections often tend to become too brownish with artificial colour. Assessment of canned samples with artificial dye added showed no significant differences in cultivar ranking between five judges, and 63AF86 and 65G67 proved the best on appearance. No significant overall differences were obtained with flavour. Fresh fruit assessments for general preference made by visitors on replicated samples indicated that only one seedling was significantly inferior to Cambridge Favourite. Since the fruits in these tests varied greatly in colour and glossiness, the results suggest that assessors differ markedly in their opinions of a good strawberry. However, the Cambridge Favourite type apparently tends to be regarded as the best, possibly because it is the most widely encountered. Saladin (65G52), which is slightly darker than Cambridge Favourite, scored highly for appearance and flavour in contrast to Troubador (65R70), which was rated lower probably due to slight malformation.

Mechanical harvesting

We were fortunate in having the NIAE/Smallford strawberry harvester plus an MSU/CML capper for trials at Auchincruive. The harvester demonstrated the need for flat stone-free strawberry beds; most readily produced with non-cultivation techniques. Several selections were harvested and it was concluded that, although selections with stiff peduncles could easily be elevated, so could traditional cultivars when given suitable ground conditions. Selection 66R115 proved the easiest to decap using rollers. The more difficult to decap, as assessed by hand, were successfully decapped by a band knife provided pedicel length was sufficiently long to allow the fruit to be 'singulated,' that is, cut from the peduncle leaving a long pedicel to be held by the rollers. Pedicel length, a character usually measured only for taxo-

onomic purposes, therefore seems to be important for mechanical decapping efficiency. Previous records indicate there is variation in this character, not only between cultivars but between seasons, and further checks on this will be made in 1977. Auchincruive selections with and without strong peduncles and concentrated ripening were grown at Luddington EHS expressly for the purpose of mechanical harvesting tests but unfortunately the harvester was not available there.

Advanced selections

The NFT Multi-Centre Trial, grown at six sites and containing six Auchincruive selections, produced first main crops this summer. Most of these selections have already been cropped twice at Brogdale and several times at Auchincruive, with the result that considerable information is now available on yield and quality of fresh and processed fruit. Tantallon (65G48) and Saladin (65G52) have both exceeded the marketable yield of the standard cultivar Cambridge Favourite by more than 30%, when averaged over all centres. Results of tests on fruit blast frozen at WSAC indicate that Tantallon (65G48), Saladin (65G52) and Silver Jubilee (65G95) are superior to Cambridge Favourite in having better colour, less 'collapse,' lower 'drip loss' and even retaining a degree of glossiness on thawing. All these selections, plus Troubador (65R70), have a high field resistance to red core disease. In anticipation of their naming and release, NSA and NSDO are propagating them for extensive growers' observation plots in different regions. Silver Jubilee (65G95), which is early and produces very attractive glossy fruit, but is often lower yielding than the above-mentioned selections, will be released as a cultivar for amateurs.

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

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

Fragaria vesca programme

Three hexaploids bred from tetraploid *Fragaria vesca*, by crossing with the cultivars Gorella, Redgauntlet and Hood, have now been crossed, or open-pollinated, with octoploid seedling selections, some derived from red core field resistant *Fragaria virginiana* I. Many of the resultant 360 seedlings died of red core or were highly infertile and failed to set fruit. Twelve of the most fertile seedlings were examined cytologically, eight were octoploid and four decaploid. The former may have originated from sib matings of octoploids and the latter were presumably the result of non-reduced hexaploid female gametes mating with tetraploid pollen from octoploids. These decaploids are moderately fertile and have survived in heavily red core infected land as single plants, whereas both diploid and tetraploid *F. vesca*s have died. The hexaploid progeny of tetraploid *F. vesca* crossed with Hood showed good field resistance to red core, as does Hood itself, indicating that this character is effectively transmitted by half the chromosome complement of that cultivar.

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

03006 *Raspberry breeding and associated genetic studies*

Cv. Glen Esk

A further attempt to select a stable stock of the new cultivar Glen Esk was unsuccessful because of the continued instability of gene L_1 , which contributes to the large fruit size of this cultivar. It was therefore decided to discontinue further propagation. There remains the possibility of propagating the reverted form of the cultivar, which is also satisfactory for yield and fruit size, but it was decided to submit it first to commercial appraisal, largely because the cultivar has shown high susceptibility to *Botrytis* infection of the fruit. This experience with Glen Esk casts doubt on the value of gene L_1 for breeding purposes: though its beneficial effects are considerable, it seems that its instability may prevent it being utilised.

Breeding for improved yield and growth habit

Considerable attention in breeding is now being placed on selection for improved yield potential. In some material this improvement is being sought in combination with an erect, compact growth habit, like that of cv. Malling Jewel, where vegetative vigour is moderate and easily managed. In other material high plant vigour is favoured, provided that it is directed into higher yield by reducing the competition of young primocanes in the spring: cv. Glen Clova is an example of this. Both types of material have potential disadvantages: in the first, it is possible that plant vigour may prove inadequate where soil fertility is marginal, while in the second, success depends on the efficacy of an additional cultural treatment.

To obtain more accurate assessments of yield potential at an early stage of selection, data on fruit weight were collected from 26 single-plant selections and compared with similar data from M31, one of our highest yielding genotypes. Fruit weights were taken throughout the season and data on fruit numbers and certain morphological characteristics which affect yield were recorded for all lateral positions on the canes. The results suggest that considerable potential for advance in yield exists among the present breeding material. Similar potential for improvement in the numbers of fruiting laterals per cane was indicated by derivatives of cv. Carnival. An interesting feature of the results was that the tendency for the number of fruits per lateral to decrease progressively towards the bases of the canes was most marked in selections with the highest fruit numbers. This reduction in fruit number occurred even though lateral length and the number of lateral nodes tended to increase. It seems likely that a reduction in this tendency would give an even higher yield potential: variations in the relationship are therefore being studied closely.

Yield components and raspberry management

Data from seven cultivars in the 1971 NFT showed that when competition from primocanes was reduced the laterals of fruiting canes tended to be larger and more productive. For example, in M32 the fruiting laterals were

thicker, more of the lateral nodes bore fruit and a higher proportion of them bore two fruits instead of one. In some instances, reduction of primocane competition changed the relationships between aspects of lateral morphology and the position of the lateral on the fruiting cane. Thus, in M32, when young primocanes were not removed the fruit numbers per lateral were lowest towards the bases of the canes, but when primocane competition was reduced they were lowest in the middle regions. (A. Dale, H. M. Lawson).

Disease and pest resistance

Further experiments were done to find sources of resistance to *Leptosphaeria coniothyrium*. Up to 30 mycelial inoculations were made on canes of each of 22 genotypes and the size of the resultant lesions recorded after 4 weeks. No genotype proved immune from infection but lesion size was smallest on canes of *Rubus pileatus*, raspberry cv. Latham and possibly *R. coreanus*, though the result for the last named was equivocal. The development of fruiting laterals on the inoculated canes in 1977 will provide a more appropriate assessment of resistance.

Breeding for resistance to raspberry beetle (*Byturus tomentosus*) has previously been based upon derivatives of *R. phoenicolasius* or *R. coreanus*, but in tests of feeding on young leaves the black raspberry *R. occidentalis* cv. Munger proved as unacceptable to adult beetles as *R. phoenicolasius* itself or three of its most resistant derivatives. An attempt to evaluate a range of genotypes for resistance at the flowering stage failed because of technical difficulties and a further attempt will be made in 1977.

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

Raspberry leaf spot virus (RLSV), induces symptoms in plants of cv. Glen Clova but infects plants of the cultivars Carnival, Lloyd George or Malling Landmark without inducing symptoms: similarly, raspberry leaf mottle virus (RLMV) induces symptoms in plants of Malling Landmark but not in Glen Clova, Carnival or Lloyd George though it infects them. To study the inheritance of these different reactions, selfs and crosses among these four cultivars were made and twenty-plant samples from the progenies were graft-tested to determine their reaction to one or other of the viruses. Results are available from only six of these samples; they show that the selfed progeny of Glen Clova but not those of Carnival or Malling Landmark segregated for the ability to react to RLSV, and that neither of these three progenies segregated for the ability to react to RLMS. Other families from this series will be tested in 1977 and larger numbers of seedlings tested from families shown to be segregating. However, this first result suggests that Glen Clova is heterozygous for a dominant gene which confers the ability to produce symptoms of infection with RLSV. (A. T. Jones¹, D. L. Jennings).

¹Virology Section.

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

The hexaploid raspberry-blackberry hybrid mentioned in the last report aroused considerable interest in 1976, exceeding the 'Loganberry' in both yield and fruit quality. It was decided to release the hybrid as a new cultivar and a virus-free stock of it, produced by heat therapy, is being increased prior to its release for propagation in 1978. A minor failing of this selection is a somewhat inadequate development of the abscission layers of the fruit. Three F₁ hybrids of the family were therefore intercrossed in 1973 to seek improvement of this characteristic. The resultant families fruited in 1976 and selections from them showed good fruit abscission; several were also notable for their very large fruits. Two new F₁ families genetically similar to the above material, but from crosses with different raspberry parents, also fruited in 1976. Both showed interesting segregation of erect, compact forms with short internodes and short petioles. Some of these bore good fruits and are being studied further. Unfortunately, the compaction of the internodes has increased the density of spines.

The warm weather of 1976 caused blackberries to ripen 7 to 14 days earlier than in recent years. Data from early ripening families showed that a tetraploid parent derived from the hexaploid cv. Chehalem conferred earliness to its progenies through early flowering rather than through quick ripening, whereas a tetraploid parent derived from another early hexaploid conferred earliness through quick ripening rather than through early flowering. Analyses showed that both components of earliness were determined largely by additive gene action, so there should be little difficulty in combining them. Progress was made in selecting for early ripening and for spinefree, erect habit, but while selections with excellent fruits were obtained from both groups, there were no outstanding selections combining earliness with improved habit. A further series of crosses will be required to achieve this.

A factor which influences the quality of frozen blackberries is their ability to remain black during freezing and not to turn red. Chemical analyses of samples of three cultivars suggested that this tendency was partly but not entirely due to inadequate ripening of the fruit. Increases in colour intensity, loss of blackness, and reduction in acidity occurred in all samples after a short period of freezing, possibly due to a breakdown of cell membranes and a consequent mixing of cell plasma and vacuolar contents during freezing and thawing. However, small samples of some selections showed little loss of blackness, suggesting that it may be possible to take account of this factor in breeding.

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

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

The cultivars Ben Nevis and Ben Lomond maintained a high level of cropping in trials at Luddington EHS and Brogdale NFT, but only Ben Lomond has been reported upon favourably for juice processing and canning. The fruit of Ben Nevis is generally considered to be more acid, weaker in flavour and

slightly lower in ascorbic acid content. Juice of both cultivars is darker in colour than that of cv. Baldwin.

At Luddington, 18 selections cropped for the first time in 1976. Although berry size and yield were affected by the unusually dry season, four derivatives of Goliath × Öjebyn, a cv. Anger von Oeffelt × cv. Sztahanovka hybrid and a *R. dikuscha* second backcross hybrid, gave particularly high yields.

One late-flowering Goliath × Öjebyn selection (238/36/14) began flowering 18 days later than Baldwin and required only 11 weeks to ripen its fruit, whereas Baldwin required 13 weeks.

Productivity, disease resistance and plant habit

Four groups of progenies of particular interest fruited for the first time in 1976. In three progenies of N43/6 (*R. nigrum* × *R. dikuscha* × *R. hudsonianum* - a hybrid outstanding for its freedom from running-off) selections were noted for uniformity of berry size along the strig combined with freedom from running-off. Berries ranged in size from small to medium and contained the normal complement of seeds. These features were also prominent in a Westra-type plant selected from an American gooseberry mildew-resistant progeny of one of three open-pollinated seed accessions of *R. hudsonianum*.

Three disease-resistant progenies of Westra (a West German, X-ray induced fastigiata mutant of cv. Westwick Choice) crossed with hybrids of *R. dikuscha* and Goliath × Öjebyn, showed large variation both in plant and productivity. Not unexpectedly, none of the Westra-type plants (scored 5 for habit) approached the high productivity of the more spreading types (scored 3 or less for habit). Nevertheless, certain erect types (scored 4 for habit) were distinguished by considerable improvement in berry size, contrary to all previous experience with progenies segregating for these characteristics, and showed good potential for further breeding. This was especially true of progenies of Westra × ND12/26 (*R. dikuscha* second backcross hybrid) and Westra × 238/36 (Goliath × Öjebyn hybrid). Larger and genetically more diverse Westra progenies, which have been subjected to stringent selection for disease resistance and for erect habit, will crop for the first time in 1977.

Finally, a number of useful selections were made in three progenies of ND17/7 (an early-maturing *R. dikuscha* second backcross hybrid) crossed with three extremely late-flowering selections, designed to combine late flowering with rapid fruit development and earlier ripening. Selections from all four groups of progenies have been propagated for more intensive trials.

Fruit quality

Experience gained with Ben Nevis, Ben Lomond and other selections submitted for processing tests has drawn attention to important deficiencies of certain aspects of fruit quality in some of our breeding material. More attention is therefore being devoted to assessments of flavour, ascorbic acid content, juice colour and specific gravity.

The most important quality criterion—a characteristic black currant flavour—is particularly elusive in Nordic and Russian black currant cultivars and their hybrids, and even more so in *R. bracteosum* and *R. ussuriense* hybrids. Frequently the flavour of processed juice of Nordic and Russian hybrids, though not objectionable and sometimes pleasant, is not typical of the black currant. The cultivars Merveille de la Gironde (French Black) and Edina are currently being used in breeding as sources of good flavour.

None of the 180 genotypes assessed in 1975 for ascorbic acid content was superior to Baldwin, but the relative order of merit changed in 1976 and several selections with high assessments in 1975, including Ben Lomond and Westra, gave higher values than Baldwin. A number of clones have been selected to study the relative stability of high ascorbic acid content over a period of several years under uniform cultural conditions.

Within-progeny values for ascorbic acid in 1975 were intermediate between the two parents, but in at least one progeny in 1976 there was a suggestion of positive transgressive segregation. Very high ascorbic acid values were also confirmed in 1976 in a *R. nigrum* × *R. dikuscha* × *R. bracteosum* progeny outstanding for large berry size.

In 1975 ascorbic acid content was positively correlated with juice colour and specific gravity, and negatively correlated with mean berry weight and juice yield per 100 g fruit.

(M. M. Anderson).

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

Allele analyses and estimates of partial self-compatibility were carried out on breeding materials and are noted under the appropriate projects.

(T. Hodgkin).

03011 *Brussels sprout: breeding hybrid cultivars*

Improvement of glossy inbred lines

A programme was started in 1973 to breed improved glossy lines by a cyclic single cross selection system which would allow for the maximum rate of inbreeding coupled with selection based almost entirely on the characteristics of hybrid progenies.

During the 1975/76 season plants of the first generation of 37 combinations were grown in a replicated trial. Once-over harvesting was done at three dates and yield and quality characters were recorded. A selection index based on yield and quality factors was used to rank the progenies, seven of which were selected for high performance. The mean yield of the selected types grown at 64 × 91 cm was 17.7 t/ha with 78.5% in the freezer grade (19–38 mm).

Progenies derived by selfing the parents of the seven selected hybrid combinations were tested to determine their S-allele status. Only three S-alleles were found in the 13 lines examined and therefore it was necessary to arrange pairing of the parent plants so that each member of a pair possessed at least one different S-allele from the other. Of the S-alleles found two were identified as S₂ and S₄₅. Progeny tests were also made to ensure that only heterozygous glossy foliage plants were used to produce a second generation of combinations. As a result of poor plant survival over the prolonged period involved in the first cycle, it has been found necessary to resow some of the selfed progenies and the second generation of combinations is now expected to be grown in 1979.

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

Glossy marker genes

Two experimental hybrids incorporating glossy foliage markers were multiplied following satisfactory trials in 1975 in which sibs were successfully eliminated from both transplanted and direct-drilled plots by unskilled labour. Hybrid A1278 had markers in each parent line but contained a very high proportion of sib seeds; however hybrid A1337, with a glossy marker in only one parent line, gave 2% sibs. Seeds of the latter hybrid have been supplied to three interested organizations for further trials on the recognition and elimination of sibs.

(A. J. Redfern, C. North).

Yield components

Results of the experiment grown in 1975 to determine the importance of different yield components of Brussels sprouts showed that sprout development early in the season, and node number, were of key importance in accounting for differences in final yields. The same cultivars were grown in 1976 to measure early growth as well as final performance. Drought caused uneven growth responses over the trial area and final yields of the cultivars were markedly lower (8.1–16.2 t/ha) than in the previous season. Preliminary results indicate that individual cultivars behaved differently relative to one another in the two seasons and a further experiment is considered necessary.

In the progenies of a half diallel between the cultivars used in yield component analysis, final node number, sprout number and weight, plant height and plant fresh weight were measured. Seasonal peculiarities are likely to affect these results also; in addition the siting of the experiment on a slight slope, has led to highly significant differences between replicates.

(J. R. T. Hodgkin).

03012 *Cabbage: breeding hybrid cultivars*

Successive years of producing and assessing hybrids between inbreeding lines of various savoy cabbage cultivars and the 'DK' and 'S' parents of cv. Celtic Cross reveal that the 'S' parent has tended to give superior hybrids to those from the 'DK' line. Further inbreeding and selection for seed production was continued on a number of lines yielding the best combinations.

Inbreeding of white cabbage cultivars was also carried out to enable assessment of the breeding potential of Celtic Cross parent lines in combination with them.

Pollen from cabbage inbred lines was exchanged between Asmer Seeds Ltd. and ourselves on the basis of the formal agreement drawn up between the ARC and the BAPB. Hybrid seed from a range of inbred lines has already been produced from pollen received here. (A. J. Redfern, A. B. Wills).

03013 *Brassicac: isoenzyme analysis in Brassica oleracea*

Discrimination of sibs by location of acid phosphatase isoenzymes present either in seeds or cotyledons was demonstrated for approximately 80% of commercial and experimental hybrid cultivars examined. The unit cost of sampling was considerably reduced by the purchase of further electrophoresis equipment which was operated simultaneously without needing to increase technical staff. With these two developments it was considered that the advantage gained by the rapid testing of hybrid seed lots might be attractive to seedsmen. Consequently, to allow commercial assessment, a pilot testing scheme was offered to BAPB members for a limited period and at an economic fee. The response was encouraging; 14 cultivars were received for testing, some of which were represented by more than one sample, of these three could not be tested because both parent lines were homozygous at all loci and a fourth had one parent line segregating.

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

03015 *Brassicac: genetics and cytology of Brassica oleracea*

Investigations of linkage relationships were continued by growing-out progenies segregating for 20 seedling genes in 32 combinations in backcross and F₂. Linkage was detected between a hairy-leaf gene of unknown origin (Hr^y) and a pale-green-leaf gene (pg-2). Genes Hr-1 and Hr-2 were known already to be linked to pg-2. There were deficiencies of hairy-leaf plants in some progenies, associated in particular with Hr-1 and Hr^y: such deficiencies of hairy phenotypes are common.

Phenotypically identical mutants obtained from different sources were tested for identity. A recessive glossy gene from red cabbage (gl^{re}) proved to be non-allelic to three genes from Brussels sprout (gl^{e2}, gl^{e3} and gl^y); pale-green from cabbage was allelic to pg-3 and a chlorotic form of Brussels sprout received from NVRS was allelic to pg-1.

In flowering progenies crinkly-petal (cp-1) was linked to a strong anthocyanin gene (A^{kr}) and linkage of cp-1 to anther spot (An) was confirmed. White petal (Wh) and persistent sepal (ps) also segregated. No further linkages were found between these genes or with other markers in the material. Backcross families produced to measure linkage of abortive pollen (ap) and the S-gene, were scored. Analyses of the results obtained are not yet available.

Triploid calabrese plants were obtained by crossing induced tetraploids with diploids, they proved to be chromosomally unstable and by the time of flowering only tetraploid or diploid shoots could be found. Further attempts will be made to produce stable triploids in order to obtain trisomics for cytogenetic analysis.

(A. B. Wills, P. Smith).

03019 Calabrese breeding

Hybrids between initial selection from open-pollinated cultivars were grown in demonstration plots. Growth was seriously affected by drought but observations were made on maturity period and variation of maturity within lines. Partial self-compatibility was measured in the material by recording seed set from bagged (self-pollinated) and unbagged (cross-pollinated) inflorescences. Results from the trial have yet to be fully assessed but some problems have been identified. Many buds aborted on both bagged and unbagged inflorescences, making counting of the number of flowering sites difficult; the bagged inflorescences frequently suffered fungal infections and poor weather towards the end of the season damaged the bags used.

Six hybrid cultivars were selected for spear conformation and maturity period. Plants of these cultivars have been self-pollinated to produce segregating populations for incorporation in the breeding programme.

(A. J. Redfern, T. Hodgkin).

03018 Bulbs: breeding disease-resistant lily cultivars

New cultivars

Six new cultivars have been named and 500-1,500 bulbs of each passed on for commercial propagation. They will probably be available to the public for the first time in autumn 1979. The names, which have been accepted for inclusion in the International Lily Register, are Eros, Pegasus, Theseus, Achilles, Pandora and Phoebus. The first three of these cultivars are triploid *L. lankongense* hybrids with downward-facing scented flowers; the others are diploid hybrids of other Asiatic species and have upright-facing flowers.

Seventy-four new selections were propagated vegetatively for final selection in 1978. They include 54 *L. lankongense* 'back-cross' hybrids most of which are triploids, each with one genome from *L. lankongense* and two from other Asiatic species, and selected in preference to diploids because of their superior vigour. They have scented flowers of a wide range of unusual colours from clear yellow to dark red and including white and pale mauve, orange and pink, and represent a considerable advance on the five cultivars of this type already released. When pollinated extensively amongst themselves and with Asiatic cultivars, none produced seeds and it seems that they must be considered female sterile. The other 20 selections include those of fertile

crosses between Asiatic cultivars selected primarily for unusual-coloured flowers or potential for early pot culture. Some of these 74 selections will be named and probably become available to the public as new cultivars in 1981-83.

L. henryi crosses

The *L. henryi* × Asiatic cultivar described in the Annual Report grew extremely vigorously, producing three flowering-sized bulbs by August 1976 from an embryo excised in July 1975. Two of these bulbs have been used for vegetative propagation and the remaining one was grown on for flowering in the glasshouse. It produced seven outward-facing flowers with orange-coloured reflexed petals and long pedicels. One secondary bud was produced on the inflorescence and a few stem bulbils developed in the axils of the upper leaves. An attempt was made to repeat the *L. henryi* × Asiatic type cross and pollen of various Asiatic hybrids and species was applied to 407 flowers of *L. henryi*. Eighty-seven small near-spherical embryos were found and cultured *in vitro*. About 10% only grew in the tubes and four survived transfer to soil medium. All those which survived were derived from *L. henryi* pollinated with *L. davidii*. One of them has narrower leaves than typical *L. henryi* and may be hybrid but it has not been confirmed cytologically.

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

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

This project suffered a major setback when all the flowering-size bulbs of chromosome-doubled 'Poetaz' cultivars died, apparently as a result of *Fusarium* attack. Material which had not had colchicine treatment was also killed. However, some of the smaller bulbs of chromosome-doubled material which had been kept in an unheated frame were not visibly affected, and it is expected that they will flower in 1978 and can then be tested for fertility.

Mycology

R. A. FOX

The cause of cavity spot has been sought here and elsewhere for many years. It was noted in last year's Report, that a heat sensitive factor which caused characteristic lesions on carrot roots in anaerobic conditions was present in soil where there had been an outbreak of cavity spot. Following this discovery an anaerobic, pectolytic species of the genus *Clostridium* was isolated. In anoxic conditions, the bacteria were cultured and inoculated to carrots on which they caused lesions and from which they were subsequently recovered. This is the first known record of an anaerobic, pectolytic bacterium causing specific disease symptoms in the field in contrast to non-specific rots in storage.

Work done in co-operation with the Virology Section has shown for the first time that a phytoalexin, rishitin, may directly effect cell membrane function and, at sufficient concentration, cause plant protoplasts to lyse. In part of the same project on latency, *Botrytis cinerea* has been shown to produce a thermostable phytotoxin.

Investigations into the contamination of VTSC seed potato stocks by *Erwinia carotovora* have shown that the bacteria may survive long enough to be carried several kilometres by the wind in aerosols generated when stems are pulverized. Potato Marketing Board surveys have shown that mechanical haulm destruction, either alone or followed by chemical treatment to prevent regeneration, is now practised on over 70% of the Scottish potato acreage.

SOIL MICROBIOLOGY AND ROOT DISEASES

02017 *Biology of potato gangrene*

Continuing histological studies, supported by isolations made from the tissues examined, showed that *Phoma exigua* var *foveata* spreads only slowly into sprouts from lesions in the eye region whether these be natural or artificially induced. Areas of superficial necrosis on sprouts, growing from parts of tuber free from gangrene lesions, appeared mostly to be associated with or caused by *Colletotrichum* spp and to a lesser extent by species of *Rhizoctonia* and *Fusarium* and of *Phoma* spp other than var *foveata*. Only 2% of these necrosed sprouts yielded the var *foveata*, a percentage similar to that obtained from apparently healthy sprouts associated with gangrene lesions. In nine of the ten cultivars the var *foveata* was detected only in the

basal region of the sprout within the inner parenchyma. Penetration within the pith parenchyma was greatest in cv. King Edward, confirming previous observation that this cultivar is less resistant to subterranean spread within the stem, and it was effected—as in the other cultivars—by mass penetration from pycnospores. Within sprout tissue thin hyphae invaded the cells of the pith parenchyma disintegrating their contents and producing within them micropycnidia five to six times smaller than those normally found in senescent stem or tuber tissue. Penetration of adjacent cells occurred in successive cycles as pycnospores were released from the micropycnidia. Limited wound barrier formation adjacent to, and five to six cells distal from, infected cells was evident by cell division and slight wall thickening which gave positive reactions for both suberin and lignin. However, these limited wound barriers were ineffective in preventing penetration from the mass of germinating pycnospores. Observations on the distribution of micropycnidia within sprouts following eye inoculation with pycnospore suspensions also suggested that the fungus might slowly spread within the parenchyma of sprouts. However, the results from isolations were irregular and no assertion can yet be made about the potential importance in the field of spread from a tuber within the stem to form lesions above ground.

Previous experiments have shown that a number of crop plants as well as some common weeds may be able to act as alternative hosts for the var *foveata* which has been isolated from field grown barley plants. The importance of alternative hosts is difficult to evaluate because in past experiments no specific symptoms could be associated with infection which, indeed, was apparently symptomless. Plants of barley, which may readily be infected, were grown in inoculated compost in 64 pots set in temperature controlled root boxes in two growth cabinets to give two air and two root temperature regimes, 15° and 20°C and 10° and 15°C respectively. All plants were grown to the mature ear stage, those growing in the coldest environments producing somewhat taller and denser stands than the others. At the time of harvest some brown elongate lesions were observed at the base of a few tillers but the pathogen could not be isolated from them nor from pycnidia which developed on two plants in one pot. As in other experiments, the number of propagules of var *foveata* detectable in the compost declined rapidly to similar levels in all treatments although they could still be detected at the end of the experiment (6 months). Isolations were made from the root crowns after surface sterilising them by immersion for 2 minutes in 0.1% HgCl immediately or after 7 or 56 days storage at 3°C. The number of plants yielding the var *foveata* was similar with all growth regimes but increased with time of storage at low temperature. The increase might be ascribed to the development of resistant mycelium with time and/or further penetration and colonisation of the root crown tissue by the fungus analogous with that which might occur in the field with the onset of winter. Although the experiment failed in its objective of inducing symptoms that might be associated with the pathogen, it nevertheless again demonstrated the potential role of a crop plant as an alternative host.

The effects of temperature on the survival of the var *foveata* were again examined in glasshouse experiments primarily designed to test the effects of soil temperatures on the incidence of disease in progeny tubers using the temperature regimes previously described (Annual Report 1975 p. 50). Although mean survival rate was initially greatest at the lowest temperature there was great variation between replicates (pots) and by 12 weeks the detectable propagule densities had fallen to 1% or less of that at the commencement of the experiment. Evidence from other experiments shows that the techniques for amending, sampling, and determining propagule levels in the soil give consistent results. The variability in these experiments and the apparent absence of temperature effects seem more likely to be attributable to variations in soil moisture, which could not be adequately controlled, caused by differences in evaporation and transpiration rates induced by the different temperatures.

The number of positive isolations obtained from mother tubers, stems, stolons, and roots showed no consistent effects of temperature. At the time of harvesting, tuber tissue susceptibility determined by inoculation was lowest following the low temperature regime but subsequent incidence in the daughter tubers after storage varied from nearly double up to more than eight times the incidence following the other temperature regimes.

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

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

The fungus survived for 2 years at 3°C and 15°C but not at 30°C in stored soil. Maximum Likelihood (ML) estimates of infection levels were highest in samples with initial moisture contents of 17% and 26% and lowest in samples initially at 4%. Similar results were obtained in a second experiment in which estimates have also been obtained from soil stored in sections of drainpipe in the field. Infectivity levels remained high in the samples stored at low temperatures but in the field stored soil they declined during spring and summer and rose again in the autumn. The lowest estimates were obtained whenever the soil moisture decreased.

ML estimates on field plot samples taken with an auger to a depth of 200 mm, also decreased in summer and this may, in part, be attributed to high temperatures in the glasshouse decreasing the sensitivity of the baiting procedure (a similar decrease was recorded in 1975). However, the decrease may also in part result from a real reduction of infectivity of soil from the field. These hypotheses are being tested by comparing seasonal changes of ML estimates obtained by baiting in the glasshouse and in the temperature controlled quarantine area. The results may help to determine the best sampling/storage regimes and, in turn, improve the pilot scheme for the routine detection of red core in soil samples being developed at the NOSCA.

In April when the depth distribution of infectivity in the field was determined from 125 mm long core sections taken to a total depth of 500 mm, the ML estimates decreased with increasing depth. In August, when samples were taken in 100 mm sections, infectivity was greatest in the section at 300–400 mm below the surface and lowest in that from 0–100 mm where the soil was drier than at any other depth.

A technique has been developed for obtaining from infected root material substantial quantities of aseptic oospores for studies on their germination. Infected root systems of *F. vesca* VS1 were blended and wet-sieved, the 20 and 38 µ fractions, rich in oospores, were treated with 0.001% aqueous mercuric chloride and then washed 10–15 times in sterile water. The oospores were finally transferred to 1% distilled water agar in petri dishes.

Some oospores usually germinated within 7 days and although the percentage varied greatly it could be as high as 60%. Cultures established from hyphal tips of germinating oospores are typical of *P. fragariae* and zoospores from them have produced typical symptoms of red core disease in plants of *F. vesca* VS1. Initial studies of factors affecting germination suggest that the variation in washing/sterilization cycle may be important as is the temperature at which the oospores are initially held after sterilization. In one experiment a significant increase in germination levels was obtained when the mercuric chloride treated debris was incubated in a sterile water at 25°C for 48 h before the oospores were plated onto distilled water agar. Treatment at 5°C was not stimulatory, whereas treatment at 35°C significantly increased the numbers of non-viable oospores.

(J. M. Duncan).

02013 *Biology of root diseases in field pea and bean*

Biology of Botrytis fabae in bean

Pieces of cellophane, alone or bearing inocula of varying potential produced by growing *B. fabae* on distilled water agar, 0.02, 0.2 and 2.0% malt extract agar were placed on plumules of bean seedlings and after 7 days at room temperature 0, 8, 44, 100 and 76% respectively had developed spreading lesions. When 5 µl drops of water containing ca. 0, 25, 250 or 2500 conidia were placed on plumules 0, 0, 0 and 90% respectively developed spreading lesions after 14 days at 100% r.h. at room temperature. Aggressive lesions developed therefore only when the inoculum potential was high. The results also suggest that the high proportion of apparently healthy seedlings which developed from seeds deliberately infected with *B. fabae* may be attributed to insufficient inoculum on the seeds. Thus no diseased seedlings were seen in the field after sowing stocks in which 0, 2, 5, 10 and 20% of seeds were infected and throughout the summer leaf lesions remained slight and there were no significant differences between lots. Similarly, no diseased seedlings were seen in two farm crops sown with infected stocks, although *B. fabae* was frequently isolated from leaf lesions during the summer.

The effects of a fixed inoculum level of *B. fabae* (4×10^4 conidia per ml) on possible alternative hosts was examined by spraying it to run off on leaves of *Vicia hirsuta*, *V. sativa*, *Trifolium repens* and *T. pratense* and the plants kept at 15°C in the glasshouse. After 48 h light brown leaf and stem lesions were present on *V. sativa* and after 96 h conidiophores bearing conidia, subsequently shown to be *B. fabae*, were also present. Lesions were absent from the other three species. In growth cabinets, it was found that at 15°C and 85% r.h. lesions of *B. fabae* on field bean did not spread, at 90% r.h. they became aggressive but the fungus did not sporulate whereas at 95% r.h. lesions spread rapidly and conidia were produced abundantly.

Overwintering of *B. fabae* was examined by investigating soil 6 and 7 wk after harvest, overwintered dead bean stems, lesions on leaves of groundkeepers, and by exposing cultures in the open. Seven kg of soil taken from the top 20 mm of a field 6 wk after harvest was wet sieved and all material which passed through a 2000 but not a 500 micron sieve was examined. One sclerotium was found which gave rise to a colony of *B. fabae* when placed on agar but none was detected from a further 7 kg soil from a second field 7 wk after harvest.

Dead bean stems which had overwintered in the field were scattered over the surface of soil in a wooden box containing bean seedlings and the box kept in a glasshouse at 15°C and watered daily. Sclerotia embedded in the stems became covered with conidia of *B. fabae* after 4 days. After dislodging the conidia by blowing and spraying the leaves with water characteristic lesions developed.

Isolations were made in November from 50 leaf lesions on groundkeepers growing in two fields where *B. fabae* had been isolated frequently during the summer. The pathogen was isolated from 10 lesions from one field but none from the other. The examination of groundkeepers is being continued.

Cultures of *B. fabae* growing on sucrose-supplemented Last and Hamley's medium X in petri dishes were exposed out of doors from 2 November. Germination of conidia in dilute nutrient broth fell from 82% to zero after 65 days. However, some macroconidia produced spherical microconidia which after 65 and 90 days did not germinate in water or nutrient broth, but 5% of those harvested after 112 days germinated after 24 h in nutrient broth but not in water.

(J. G. Harrison).

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

Cereal crops

Seeds of barley cv. Golden Promise were stored in polyethylene bags at 30°C after adjusting their moisture content to 20%. Samples of increasing levels of deterioration were withdrawn at intervals and dried to ca. 10% m.c. Two seed lots of 89 and 82% germination were selected and together with seeds

which had not been deteriorated, were treated with dust formulations of phenyl mercury acetate (Murganic RPB, Murphy Chemical Company); methoxy ethyl mercuric chloride (Plant Protection Ltd.); carbendazim plus maneb (Granosan, DuPont Chemical Company Ltd.), all at the rate of 2 g/kg; and thiophanate-methyl plus imazalil (Muridal, Murphy Chemical Company) in liquid formulation at the rate of 8 ml/kg. Seeds were sown on 2 April in single row plots of 100 seeds in seed beds maintained at field capacity by trickle irrigation until emergence was complete, and into seed beds exposed to ambient conditions. The results, expressed as the percentage emergence of the number of viable seeds sown, showed that emergence of the most deteriorated lot when not treated with fungicide was reduced from 88 to 28% by the wet seed bed, and that it was improved to 52% by Granosan which was the most effective chemical tested. Non-deteriorated seed was not affected by the wet soil conditions, nor did it respond to fungicide treatment. The results indicate the possibility that fungi may be partly responsible for the emergence failure of deteriorated barley seeds in wet soil conditions.

Investigations into the effects of seed deterioration on seedling growth revealed that the observed slower root growth of seedlings from deteriorated seeds was associated with a slower rate of cell division in the root meristem compared with seedlings from non-deteriorated seed, and that the delay in leaf and tiller appearance was associated with a rate of primordia initiation approximately half of that found in seedlings from non-deteriorated seeds. The shorter length of the first leaf from deteriorated seeds (60 mm cf. 86 mm) was not related to differences in cell number but to smaller cells. Differences in leaf growth from deteriorated and non-deteriorated seeds were greater after soaking seeds in solutions of gibberellic acid because those from deteriorated seeds were less responsive, supporting the hypothesis that slower growth was due to an impairment of cell extension mechanisms.

In continuing the studies on the effects of deteriorating seed at supra optimum moisture content and temperature on yield of cereals, seeds of barley Golden Promise, winter wheat cv. Mega and spring wheat cv. Sappo were stored in polyethylene bags at 30°C and 20% m.c. Two samples of slight and moderate levels of deterioration, both above 85% germination were selected for each cultivar and were sown, together with non-deteriorated seeds, in field plots of 10 rows 125 mm apart and 5 m long for wheat, and 10 m long for barley. Non-deteriorated seeds were sown at four rates equivalent to 250, 125, 60, 30 kg/ha for barley and winter wheat, and 250, 185, 125 and 62 kg/ha for spring wheat, while deteriorated seeds were sown at rates proportionately higher to provide populations similar to those of the non-deteriorated seeds.

Barley was sown on 3 March and analysis of the yield components showed that the lower population density of 55 plants/m², grain yield per plant from plots sown with moderately deteriorated seed were significantly less than those from plots sown with slightly deteriorated and non-deteriorated seeds

(3.38, 4.03, 5.75 g \pm 0.66 respectively). The lower yield was associated with fewer ears per plant while numbers of grain per ear and grain weight were similar. At the highest density of 356 plants/m² no differences in yield components in the plots sown with the different seed lots were recorded.

Winter wheat was sown on 6 November and yields were similar over a range of established populations from 50 to 329/m². However, analysis of the yield components showed that plants from non-deteriorated seeds at low populations produced significantly more ears per plant, but fewer grains per ear than plants from moderately deteriorated seed. Grain size was affected by plant population but not by seed lot.

Spring wheat was sown on 5 April and no significant differences associated with seed lots were found in grain yield, yield per plant or in any of the yield components over the range of established populations.

These experiments demonstrated that of the three cereals examined the effects of seed deterioration on the grain yield of individual plants were detected only in barley where plants from deteriorated seed at low populations produced fewer tillers.

Carrots

Eight seed lots of carrot cv. Chantenay produced in different countries, treated or not with either captan or benlate plus thiram, at a rate equivalent to 3 g/kg were sown in single row plots of 100 seeds on 8 April, 4 May and 7 June. Emergence was best from sowings on 4 May and least from sowings on 7 June. There was an increase in the mean relative field emergence from 73 to 78% following treatment with captan and a lesser response from benlate plus thiram. However, within lots and sowing dates, responses to fungicide treatment were variable with unexplained reductions in emergence at the last sowing in dry soil conditions. (D. A. Perry, J. G. Harrison).

02025 Rhizosphere and allied phenomena affecting plant health

Potato gangrene

Following the failure of heat treatment to eradicate gangrene from potatoes, it had been found that heat *per se* increased tuber susceptibility to infection by *P. exigua* var *foveata*. Moreover, propagules of the fungus, if slowly dried, were found to withstand temperatures regimes far more rigorous (90°C for 30 min) than those which killed vegetative mycelium (43°C for 2 hr). Since the heat treatment would also partially disinfect the tuber surface, surviving propagules would be less affected by tuberplane antagonists. To test this hypothesis, unwashed tubers sampled from a main ware crop soon after storage, or at the extreme end of the ware storage season, were either heat treated or not and their surface then abraded. The material so obtained was used to amend suspensions of var *foveata* spores or water controls which

were then inoculated to surface sterilised tubers. In both experiments, very few lesions developed in check tubers inoculated without the addition of var *foveata* spores. The lesion indices for tubers where the inoculum was amended with non-heat treated material were markedly reduced compared to those from inocula with heated amendments, indicating that the tuber-sphere microflora which survived heat treatment was markedly less antagonistic to the var *foveata* than that which had not been heated.

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

PLANT AND PATHOGEN PHYSIOLOGY

02026 The nature and implication of quiescent fungal and bacterial infections

Phytoalexins

Protoplasts from palisade mesophyll of *Nicotiana tabacum* cv. Xanthi, *N. benthamiana*, *Lycopersicon esculentum* cv. Eurocross BB, and *Chenopodium amaranticolor* were obtained by two-step sequential digestion with macerozyme and cellulase. When rishitin was added to give a concentration of 300 ppm to a suspension of $1-2 \times 10^5$ protoplasts/ml in 0.7 M mannitol, they lysed within 30 minutes. Rishitin at about 0.2 of this level did not cause lysis but the use of fluorescein diacetate showed that protoplasts were affected and loss of electrolytes from *N. tabacum* protoplasts, detected by an increase in conductivity of the suspending medium, suggested that rishitin had a direct effect on membrane function. (G. D. Lyon, M. Mayo¹).

02015 Disorders of vegetables

Cavity spot of carrots

Abundant characteristic lesions developed when field soil from a cavity spot outbreak was added to roots in U.C. compost contained in pots which were later sealed with wax and stood in water for 5 days at 20°C. Fewer lesions occurred after the soil was autoclaved. Isolations from lesions were made under hydrogen in anaerobic jars using a reducing medium with a pectate layer. Pectolytic bacteria were isolated which were repeatedly sub-cultured from single colonies and grown in a liquid basal medium anaerobically. When inoculated to carrots they caused lesions identical to those found after the addition of field soil and the bacteria were recovered by anaerobic culture. Similar bacteria were obtained from several carrot fields by inoculating carrot discs with ca. 1 g soil, and they were also recovered from some natural lesions incubated under anaerobic conditions.

¹Virology Section.

Two colony types were observed. The predominant form was creamy coloured and the bacteria grew rapidly in anaerobic conditions at 25°C producing a plaque in the pectate layer of up to 20 mm diameter in 2 days. Pectolysis on media and on carrot discs were still evident at 10°C and no growth occurred on agar or on carrot discs in air. The bacteria were gram negative rods, 2.8–5.2 × 0.6–0.8 nm, which produced sub-terminal ovoid, gram positive spores, 1.4–2.4 × 0.8–1.0 nm and have been tentatively identified as belonging to the genus *Clostridium*. The second colony type had a similar pectolytic activity on carrot roots but a substantially slower growth rate on the pectate medium, did not produce endospores under the cultural conditions used and exhibited slight growth in air on malt extract. It has not been characterised taxonomically.

In a field experiment, seeds of cv. Royal Chantenay were sown at a rate equivalent to 6.5 kg/ha in 12 rows on beds measuring 2 × 40 m on 22 April. The beds were rolled immediately after sowing and the resulting plant population averaged 675/m². Each bed was divided into four equal lengths and one quarter was trickle irrigated continuously for 2 wk to provide saturated soil conditions on 28 July, 30 August, or 14 October. Plots of 1 m² were harvested from the centre of each treatment on 10 January and the percentage of roots with moderate and severe lesions from the plots irrigated in July, August, October and from control plots which had not been irrigated were 23.0, 18.3, 1.0 and 1.0 (SED = ±5.08) respectively.

(D. A. Perry).

02027 *Studies of plant pathogens*

Phytophthora spp.

During 1975 many plants in a trial of raspberry selections in the original field of the Institute's West of Scotland Unit suffered from a severe root and crown rot. Isolations from necrotic tissue and from soil gave three *Phytophthora* spp.; the first (IMI 195178) was identified by the CMI as *P. megasperma* var *megasperma*, the second (IMI 195177) produced non-papillate sporangia and was described by CMI as being similar to *P. erythroseptica*; the third (IMI 202518) was a slow growing isolate producing papillate sporangia and CMI as yet are unable to classify it to species level.

This field at Auchincruive is known to be infested with *P. fragariae*, the fungus causing red core in strawberry, and spasmodic outbreaks of crown death of strawberry caused by *P. cactorum* also have been recorded. It thus affords a good site for testing the efficiency of baiting techniques for the recovery of these species and for examining various aspects of their biology.

During four experiments six baits were used, pine needles and lupin seedlings, both at 16 and 22°C, and, at room temperature (ca. 22°C), green apples, green pears, culms of red fescue and *Fragariae vesca* seedlings, the last being specific for *P. fragariae*. Results varied for the two sampling times, autumn 1975 and spring 1976. Individually, apple and pear baits were the

most efficient but the number of positive sites was increased when pine needles at 20°C and lupins at 16°C were also used. *P. fragariae*, as expected, was recovered only from seedlings of *F. vesca*. *P. cactorum* was not recovered by any of the baits tested, and culms of red fescue failed to detect any of the fungi. The results allowed preliminary mapping of the distribution of four of the five species in the field.

Isolates IMI 195177 and IMI 202518 were also obtained in December 1976 from apples used to bait water in the ditches draining both the original and new fields at Auchincruive.

(A. J. Hargreaves, J. M. Duncan).

Cane spot (Elsinoe veneta)

Screening raspberries for resistance to cane spot (*Elsinoe veneta*) would be improved by a simple inoculation technique, but the fungus grows slowly and sporulates poorly when grown by conventional procedures. It propagated rapidly, as a uniform crop of microcolonies, when a suspension of homogenised mycelium was spread across agar in petri dishes. When agar bearing microcolonies was further homogenised and the resultant suspension was pipetted on to slopes of oatmeal agar, the best medium of four tested, maximum spore production was obtained in darkness after 7 days at 22°C, at which temperature spores germinated best when at high concentrations (4 × 10⁵ spores/ml) in water.

(B. Williamson).

Botrytis cinerea phytotoxin

A partially purified thermostable phytotoxin has been obtained from culture filtrates of *Botrytis cinerea*. The toxin was not precipitated when 2 volumes of ethanol were added to culture filtrates and some other impurities were removed from the remaining solution by adsorption onto Dowex 50W ion exchange resin. The active principle was further purified when it remained at the origin where the residual filtrate had been spotted onto paper chromatograms developed in isopropanol/water (120:80, v/v). The toxicity of the aqueous eluate obtained from the origin, as assessed by injection into tomato leaves, was not destroyed by autoclaving.

(G. D. Lyon).

Developing of a mating system in E. carotovora

A study of virulence in *E. carotovora* using genetic analysis was initiated during a stay at the University of Wisconsin and a mating system is being developed for the mobilization of genes by conjugation. Transfer of F lac sex factor from *E. coli* failed, but both RP4 and R68.45 plasmids were freely acquired by both var *carotovora* and var *atroseptica* when conjugation was done on membrane filters for 24 h. Evidence for the acquisition of the plasmids was obtained by testing for acquired multiple resistance to antibiotics and the deletion of the plasmids by treatment with ethidium bromide. Presence of the R plasmids does not apparently affect virulence of the isolates on tuber tissue or stems, but their growth rate is slightly lower

in vitro than that of wild type isolates. Preliminary results suggest that R68.45 is promising for the mobilization of genes from wild to auxotroph strains of var *carotovora*. *R. carotovora* is normally resistant to infection by bacteriophage Mu but following the introduction of plasmid RP4::Mu-lcs 62 to the var *carotovora*, heat induction of the phage has been obtained, a step towards the construction of an Hfr-like strain.

This work is being done in co-operation with the Laboratoire de Genetique des Microorganismes (INRA), Versailles, France. (M. C. M. Pérombelon).

EPIDEMIOLOGY AND ETIOLOGY

02003 Shoot disorders of cane and bush fruit

Cane diseases of raspberry

Midge blight

Midge blight, induced by the raspberry cane midge (*Resseliella theobaldi*) and associated fungi, caused substantial losses in 1976 in the highly susceptible cultivar Glen Clova. The fungus isolated most frequently from vascular lesions beneath second and third generation midge feeding areas in overwintering canes is *Fusarium avenaceum*. Less frequently isolated were two other weak pathogens, *Phoma macrostoma* var *macrostoma* and *Phoma exigua* var *exigua* and, rarely, *Didymella applanata* which was more often found colonising the surface of midge feeding areas.

Many canes were also affected by another type of vascular lesion extending both from midge feeding areas and from wounds caused by abrasion with old cane stubs. The lesions are identical to those produced at mechanical harvester wounds and likewise yielded *Leptosphaeria coniothyrium*. Because many midge infested canes also become physically wounded at the base, the relationship between cane midge and *L. coniothyrium* cannot yet be defined.

In July 1976 plots of Glen Clova were destructively sampled and examined for midge blight lesions excluding those canes affected by *L. coniothyrium*. The basal 30 cm of individual canes were scraped and assigned to infection classes derived from a mapping technique. The potential yield (total number of green berries plus flowers) of each cane was not reduced until lesions covered more than 20% of the vascular cylinder.

Spur blight and cane botrytis

The percentage of buds at infected nodes in the cropping region of canes inhibited by *D. applanata* (spur blight) and *Botrytis cinerea* (cane botrytis) was recorded in four cultivars at a range of established plantations in late May. Bud failure was severe in cv. Malling Orion (spur blight, 72%; botrytis, 70%) and cv. Malling Jewel (spur blight, 55%; botrytis, 65%) but much lower in Glen Clova (spur blight, 18%; botrytis, 17%) and cv. Malling

Delight (spur blight, 27%; botrytis, 19%). The results suggest that these last two cultivars are tolerant of infection and may explain the high yields obtained for Glen Clova, which visually appears as highly susceptible to both diseases.

(B. Williamson, A. J. Hargreaves).

Cane spot

Screening raspberries for resistance to cane spot (*Elsinoe veneta*) would be improved by a simple inoculation technique, but the fungus grows slowly and sporulates poorly when grown by conventional procedures. It propagated rapidly, as a uniform crop of microcolonies, when a suspension of homogenised mycelium was spread across agar in petri dishes. When agar bearing microcolonies was further homogenised and the resultant suspension was pipetted on to slopes of oatmeal agar, the best medium of four tested, maximum spore production was obtained in darkness after 7 days at 22°C, at which temperature spores germinated best when at high concentrations (4×10^5 spores/ml) in water.

(B. Williamson).

Cane death and root rot of raspberry

Phytophthora megasperma var *megasperma* and two other *Phytophthora* spp. were isolated from diseased stems, roots, or associated soil and included with the species *P. cactorum*, *P. cambivora*, *P. cinnamomi*, *P. citricola*, *P. erythro-septica* and *P. fragariae* in a glasshouse experiment to determine their pathogenicity to the cv. Malling Jewel. Under the conditions of this experiment, only *P. erythro-septica* caused a significant check to growth or resulted in death of young primocanes although varying amounts of root rotting were caused by some of the other species.

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

Bacterial galls of raspberry

Biological control of crown gall has been demonstrated in several countries on a variety of crops inoculated with a protective isolate of *Agrobacterium radiobacter* var *radiobacter* (K84). Stem inoculations of *Datura stramonium* in the glasshouse with mixtures of K84 and a virulent isolate obtained from root galls of raspberry showed a marked reduction in gall size only when the ratio of cell numbers of K84 to the virulent isolate was 100:1. Large scale field and glasshouse experiments are in progress to explore the potential of isolate K84 to control galling in raspberry.

(M. C. M. Pérombelon, R. Lowe).

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

Potato gangrene

Much stress has been given to the importance of wounding at the time of harvesting or at grading during storage, in relation to the development of

gangrene in otherwise apparently healthy stocks. Practically no consideration has been given to the effects of handling and damaging cold and therefore damage susceptible tubers, by planting them into cold and therefore lesion conducive soils and on the subsequent development of lesions on seed tubers derived from apparently healthy stocks. As previously reported (Annual Report 1975) lesions will develop and continue to spread after planting and their size and spore production from them will clearly be affected by soil conditions. The effect of soil on pycnidial development in both the var *foveata* and var *exigua* was followed in laboratory experiments. Surprisingly, because it is difficult to isolate from soils, pycnidial production of var *foveata* was stimulated by the addition of both sterile and unsterile soil to young cultures and more by the latter than the former, effects which must result from complex interplay between physical factors (soil/fungus interface), nutritional and microbial interactions. Equally surprisingly, the var *exigua*, which can readily be isolated from soils and which is regarded as a widespread weak soil-borne pathogen which can also colonise aerial plant parts, was little affected by the sterile soil but showed much reduced levels of pycnidial production following the addition of unsterile field soil.

Field soil, potting compost and sterile sand were inoculated with spore suspensions to give constant numbers of spores per unit of dry weight when corrected to 20% moisture capacity and the mixtures used to inoculate 20 surface sterilised tubers. The rots which were induced were measured after 8 wk incubation at 5°C. The sand inocula induced extensive rots in all the tubers compared with only five equivalent rots caused by the compost inocula, but only one of the field soil inocula induced rot. In contrast, in a previous experiment, antagonists in the compost inhibited rots more than did those in the field soil suggesting marked variations in the antagonist populations of both composts and soils. In this experiment the inoculated soil formed dense plugs which in part may have acted as a physical barrier as well as forming a biological buffer to the spread of the inocula.

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

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

The trend for decreasing levels of tuber contamination in VTSC stocks in the process of bulking, noted in annual surveys commenced in 1973-4, continued in 1976-7. There is some evidence to suggest that the decrease is related in part to the succession of dry summers because both the extent and rate of rotting of mother tubers and transmission of the bacteria to the progeny tubers is less in moisture deficient soils. Varietal identification showed that *E. carotovora* var *carotovora* again predominated in stocks of all ages.

Contamination of foliage by E. carotovora

Once again, probably because of the near drought conditions which prevailed until late summer, blackleg incidence was very low even where heavily inoculated tubers had been planted. Little or no contamination by

E. carotovora could be detected on leaves while the weather remained dry but when it became wet in late September, large numbers were present on both leaves and stems. Over 90% of the isolates were var *carotovora* and bacteriocin typing showed that these were of several types randomly distributed in essentially monotypic populations in small areas within the field. Tuber and leaf isolates usually differed and although some leaf types were detected on tubers the reverse did not occur.

Numbers of E. carotovora present in aerosols produced by haulm pulverization

Mechanical haulm destruction generates aerosols containing *E. carotovora* (Annual Report 1972 *et seq*) and this technique, often followed by chemical treatment, is practised on over 70% of the potato acreage in Scotland. Numbers of *E. carotovora* in aerosols, generated in the laboratory by a hammer mill adapted to simulate commercial haulm pulverization, have been estimated using a wind tunnel (loaned by the DAFS) which allows isokinetic sampling. Extrapolating to field conditions suggests that ca. 10^8 cells would be released per hectare from healthy plants and a further 10^8 from diseased stems assuming a 1% incidence of blackleg. In addition ca. 10^{10} bacteria per m² were present in the haulm debris left in the field from which aerosols may be generated by rain. Aerosol particle size distribution determined by an Anderson air sampler showed that ca. 50% of the particles were 2-3 microns in diameter, ca. 30% >5 microns and the remainder <2 microns.

(M. C. M. Pérombelon, R. Lowe).

Aerosols of the var *atroseptica* were produced from a suspension of the bacterium in fresh potato stem sap using a Mobile Henderson Aerosol Generator. Between 1 and 5% of the bacteria, captured on microthreads, survived 1 h at 80% r.h. and 20°C.

(M. C. M. Pérombelon, R. Lowe, in co-operation with DAFS).

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

Red core of strawberry

Reference values were established for the susceptibility of cultivars, breeders' selections, and *Fragaria virginiana* clones to infection by physiological races singly and in a mixture. In general, susceptibility to the mixture was equal to the highest degree of susceptibility to any single race. One third of the hosts were completely protected by race specific resistance from some races but not all were resistant to others. The susceptibility of about half the material was similar to, and the remainder less than, that of cv. Cambridge Favourite included in each experiment as a standard. The susceptibility of about one quarter of the hosts was similar to that of the other standard 53Q13, representing the lowest level of susceptibility so far identified, the remainder being more susceptible.

The results of mass inoculation methods for screening large numbers of plants were compared with the reference values obtained with the mixture of races. When motile zoospores were introduced into an automatic watering system many encysted within 2 h and the majority of cultivars had lower susceptibility ratings. Some plants escaped infection but their distribution was random and infection occurred at the greatest distance (several metres) from the source of the inoculum. Plants inoculated by dipping the roots in a zoospore suspension were infected to the same extent whether the spores were motile or encysted but when plants in compost were inoculated by drenching, encysted zoospores caused significantly fewer infections. It thus seemed possible that encystment in the automatic watering system decreased the effective inoculum. In an attempt to compensate for encystment by increasing the quantity of zoospores, a method of stimulating sporulation using a solution of chlorides (reported from the USA) was compared with the standard $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ method in use here. The mean number of sporangia/disc produced by a good sporulating isolate was 199 in a solution of Mg Cl_2 and Ca Cl_2 whereas it was 240 by the normal method; with a poor sporulating isolate, the means were 21 and 122 respectively. The other method of screening (developed in the USA) which was evaluated, was by dipping roots in comminuted mycelium of *Phytophthora fragariae* prior to planting. Three out of the seven cultivars had lower susceptibility ratings and disease escapes occurred.

Many experiments require a continuous supply of young runners in the glasshouse but dormant plants lifted from the field and forced in January provide the earliest batch of rooted plants in April. The feasibility of obtaining plants in February or March was examined by inducing dormancy in Cambridge Favourite lifted at the beginning of November, storing at -1°C for 1 month and forcing in January. Runners from treated plants were initially greater in number but did not provide rooted plants any earlier.

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

Stamen blight of raspberry

Experimental procedures which previously resulted in large numbers of infections gave poor results in the past 2 years. One factor common to both years was the maturation of the primocanes which was more advanced than usual at the time of inoculation. There is as yet no experimental evidence that this factor adversely affects fungal penetration of the axillary buds.

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

02007 *Biology of diseases of ornamental bulbs*

Narcissus smoulder

A field trial with narcissus cv. Verger to study the effect of controlling bulb scale mite (*Steneotarsonemus laticeps*) on the incidence of smoulder caused by *Sclerotinia narcissicola* is continuing. The percentage of plants showing

symptoms of smoulder following the treatments (a) bulbs hot-water dipped (b) plants sprayed with oxamyl (c) hot water dip plus oxamyl spray (d) no treatment, was 1.2, 3.6, 2.0 and 2.9 respectively. A comparison of mite populations with incidence of smoulder will not be possible until next year.

Studies on the infection of detached narcissus leaves by *S. narcissicola* showed that spore suspensions alone could not cause aggressive lesions to develop but they did so when pollen was added to them. (G. D. Lyon).

Virus-tested narcissus twin-scales

All isolates of *Penicillium simplicissium*, *P. verrucosum* var *cyclopium*, *P. multicolor*, *P. oxalicum*, *P. paxilli*, *Botrytis cinerea* and of a *Gliocladium* sp. obtained from necrotic virus-tested narcissus twin-scales previously dipped in benomyl were tolerant to 1000 ppm of this fungicide in agar. The first two species were the most frequently isolated but there were no significant differences in the range of species infecting different narcissus clones or different cultivars. Every necrotic twin-scale examined was infected with at least one fungal species. These results suggest that it is essential to change the fungicide treatment used in twin-scaling. (G. D. Lyon).

Tulips

Five bulbs cv. Crimson Rambler selected at random from a large number previously grown at SHRI were all found to be infected with benomyl-tolerant *Penicillium corymbiferum*. (G. D. Lyon).

Narcissus basal rot

Valuable breeding material of Narcissus 'Poetaz' (*N. poeticus* (P) × *N. tazetta* (T)), (Annual Report 1975 p. 45), produced from twin-scales and grown in potting compost in the glasshouse was lost due to severe rotting of the basal plate and feeder roots. Isolates of two species of *Fusarium*, *F. avenaceum* (IMI 212202) and *F. oxysporum* (IMI 212203) were obtained from the necrotic tissue. None of the isolates were tolerant to the fungicide benomyl, which had been used during twin-scaling, unlike the many isolates of other genera obtained from necrotic narcissus tissue (this Report p. 53).

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

PLANT PROTECTION

02001 *Chemical and cultural techniques for control of raspberry cane diseases*

The final pre- and post-harvest sprays of a 3-year fungicide trial in cv. Malling Jewel were applied in summer 1975 and disease assessments made in spring 1976. In the unsprayed plots only 4% of canes were affected by spur blight (*Didymella appianata*) in the cropping region whereas 61% were affected in

the non-cropping region at the base. The latter figure was reduced to 19% by thiram and to 27, 28, 29, 31, 38 and 36% by thiophanate-methyl, dichlofluanid, captafol, captan, dodine, and carbendazim respectively. Lime sulphur and dithane were phytotoxic.

A trial at another site was started in 1975 to compare alone, or combined, pre- and post-harvest sprays of thiophanate-methyl or dodine. In spring 1976 only 10% of canes in the check plots were affected by spur blight in the cropping region whereas 71% were affected in the non-cropping region. Pre-harvest sprays of thiophanate-methyl were as successful as the pre-harvest plus post-harvest programme but post-harvest sprays alone gave poor control. In summer the potential yield (number of green fruits plus flowers) was measured in all canes and their vascular cylinders scored for cane blight (*Leptosphaeria coniothyrium*). Yield was increased by 54% by pre-harvest plus post-harvest sprays with thiophanate-methyl and by 45% and 40% in plots sprayed only pre-harvest, or post-harvest, respectively. Corresponding increases in the number of live canes suggest that the results are due to good control of cane blight at wounds caused by abrasion against old cane stubs rather than control of spur blight and cane botrytis. Dodine performed poorly and there were indications of phytotoxicity.

The frequency and distribution of wounds on young canes caused by the mechanical harvester and their level of infection by cane blight was determined in cultivars Malling Jewel, Malling M, Glen Clova and Glen Isla in 1975. In all cultivars the vibrating fingers wounded more canes than did the catching plates. Although more infection occurred at plate wounds, more canes per plot were infected at finger wounds suggesting that a greater proportion of the 30% reduction in yield observed in the year following a mechanical harvest may be attributed to infection of finger rather than plate wounds. Both dichlofluanid and thiophanate-methyl, sprayed after each of four harvests, substantially reduced the incidence of vascular lesions arising from either type of wound.

Cane diseases were assessed on replacement canes of Glen Clova produced after the removal, at different stages of growth, of the first flush of canes by dinoseb-in-oil. Forty per cent of the canes in the unsprayed plots were affected by spur blight but in the sprayed plots the incidence was reduced to 28% in those sprayed once on 2 May or to 17% in plots sprayed twice (25 April and 21 May). Cane botrytis (*Botrytis cinerea*) was reduced from 14% to 7% only by the double spray treatment. In unsprayed plots, *D. applanata* infected 79% and 11% of the canes in the non-cropping and cropping regions, respectively whereas, conversely, *B. cinerea* infected 17% in the cropping region and only 10% at the base. *D. applanata* and *B. cinerea* both preferentially infect senescing leaves and the apparent control of these diseases may derive from the relative juvenility and hence the lowered susceptibility of the replacement canes.

Midge blight was progressively reduced on replacement canes in plots sprayed with dinoseb to control cane vigour once at intervals of 3 days from

22 April to 5 May and more so in plots sprayed twice where the last spray was applied on 13 or 21 May. The incidence of cankers from the first generation midge attack was reduced from 40% of canes in unsprayed plots to 1% in plots sprayed on 25 April and to zero on all plots receiving later sprays. The incidence of infected feeding areas of second and third generation larvae was reduced from 73% to 40% in plots sprayed once on 5 May and to 24% in plots sprayed twice (25 April and 21 May). The extent of control was more successful than the presence/absence results suggest because the size and number of lesions per cane was also progressively reduced. Moreover, in plots where the first generation of midge had been effectively controlled, the presence of second and third generations must have been due to migration from adjacent infected areas.

(B. Williamson, A. J. Hargreaves).

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

Chemical and cultural control

In a field trial, planted in April 1973 with the cv. Merton Princess and terminated in 1976, etridiazole and dichlofluanid treatments significantly increased yields by 102% and 94% respectively. However, the magnitude of these improvements reflected the very low productivity of untreated plants rather than the maintenance of economic yields from treated ones. An estimated yield of 7.1 t/ha from untreated plants in 1974 had decreased in the second and third years by 56% and 82% respectively. The comparable decreases in yield from treated plants were 44% and 64% respectively (etridiazole) and 30% and 67% respectively (dichlofluanid). Although the amount of disease was decreased in the second year, neither fungicide controlled red core in the establishment year and the results suggest that unless this is achieved yields are likely to decrease to uneconomic levels. The failure of etridiazole (2000 ppm) to control the disease during establishment could be attributed to irrigation followed by heavy rain, equivalent to 861 mm, following application because good control was achieved in the second year by a drench of 1000 ppm followed by 248 mm of rain whereas none resulted from a similar drench in the third year when followed by 370 mm of rain. The same concentration of fungicide nevertheless decreased the amount of disease in the same year on a different site of similar soil type but with a lower per cent organic matter. Dichlofluanid was effective only in the second year when the concentration was increased from 3000 to 6000 ppm. There was no evidence that either fungicide was persistent which indicated that correct timing of application would be essential and that annual drenches would be necessary.

A new trial planted in April 1975 with the cv. Cambridge Favourite, compared the systemic fungicides pyroxychlor and prothiocarb with etridiazole applied as a pre-plant soil treatment or as a drench 3 months after planting. The per cent diseased roots in untreated check plants examined in

April 1976 varied from 93–100. Most control followed three drenches of etridiazole applied in July and November 1975 and February 1976 but the difference between this treatment and a single drench applied in July or the prothiocarb (5600 ppm) drench was non-significant. Pyroxychlor (250 ppm) was ineffective. Etridiazole incorporated into soil before planting was phytotoxic but replacement runners planted 10 weeks later were not affected. All treatments, except the pre-plant etridiazole, resulted in higher yields but only that following prothiocarb was significant.

In a pot experiment symptoms of red core did not develop in plants dipped in LS 73 1038 (Nina) before planting and subsequently inoculated with mycelial discs and zoospore suspensions of *Phytophthora fragariae*. The decrease in the per cent number of diseased roots was significant when the fungicide was applied as a foliar spray 3 days before inoculation or as a soil drench either 31 days before, or 18 days after, inoculation.

Thirteen antibiotics were tested *in vitro* for activity against *P. fragariae* at 1, 10 and 100 ppm. At 100 ppm, triethylenethiophosphoramidate prevented, and amphotericin B and cephaloridine significantly decreased hyphal growth. The only consistent effect on sporulation was the abnormal release of zoospores from sporangia growing on agar amended with amphotericin B at all concentrations.

Agar discs of a *Penicillium* sp. and *Chaetomium* sp. isolated from a suppressive soil decreased or prevented sporulation of *P. fragariae* on agar discs in autoclaved leachates from field soil or soil-less compost containing attached strawberry roots. Infection of roots was decreased by the *Penicillium* sp. and prevented by the *Chaetomium* sp. Release from sporangia, encystment and germination of zoospores were adversely affected when mycelial discs of *P. fragariae* were placed in filtrates of these fungi. Suspensions of two bacteria (obtained from the same suppressive soil) used as root dips before planting or incorporated into soil at planting did not decrease infections by *P. fragariae* applied to the compost as zoospores or as mycelial discs. Mycelial mats of *P. fragariae* cultured in liquid nutrient were unsatisfactory as inocula for evaluating the activity of antagonists in soil as they failed to cause infection in a susceptible host. (I. G. Montgomerie, D. M. Kennedy).

02016 *Chemical and cultural control of potato gangrene*

The rationale for examining the interactions between storage temperatures and cultural practices for their effects of gangrene incidence was explained previously (Annual Report 1975 p. 63). The effects of storage in a bale store compared with a refrigerated store were again compared following three dates of haulm destruction each followed by four intervals to harvest.

In contrast to previous results, the overall incidence in the cold store decreased with each successive date of haulm kill. Furthermore, after the first two dates of kill the incidence decreased instead of increasing with each successive interval to harvest; only following the last harvest date after the

last kill did the incidence increase. In the bale store, however, the overall incidence between the first two dates of kill differed little but rose markedly after the last date. After the first kill date the incidence tended to decrease with successive harvest intervals but it increased after both the second and third kills, the last harvest after the last kill date giving the highest incidence. The overall averages showed decreasing incidences with later dates of haulm destruction in contrast with many previous years' results; moreover, whereas last year the date of haulm kill was the most important factor, this year storage temperature was most important, the low temperature increasing incidence by a factor of nearly ten. Subsamples taken at the time of some of the harvests and variously wounded and inoculated had very little predictive value for the amount of disease which subsequently developed in storage, whether assessed by incidence or tissue susceptibility.

Variations in tissue susceptibility, physiological activity, the amount of surface inoculum and its survival were shown to interact, as might be expected, with the date of grading during storage. Haulm was destroyed on two dates and tubers harvested immediately or at two intervals thereafter. The samples from each replicate were divided into four and scored in November for gangrene incidence due to the harvesting operations. Three sub-samples were then graded and two were rescored in March of which one was graded again; at the same time the fourth ungraded sample was scored and graded. All samples were then rescored at the beginning of May. The overall effects of the date of haulm destruction and interval to harvest could be related to those of the experiment described in the previous paragraph, in that incidence decreased with increasing interval between haulm destruction and harvesting after the first date and increased after the second date. At the time of scoring in November there was a simple overall relationship reflecting the time which had lapsed since harvesting during which wounds might develop visible symptoms. Surprisingly, the effect of grading twice had little effect on the final incidence, most disease that could be induced having been initiated by the first grading in November. Only the single late grading showed any noticeable effect on incidence—again a simple expression of the short time interval in which lesions might develop between grading and scoring.

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

PHYTOPATHOLOGICAL METHODS

02020 *Development of histological and histochemical techniques*

Cytochemistry

Experiments to define the role of rishitin in latent infections of *Botrytis cinerea* on tomato stems have been hampered by the lack of a specific cytochemical stain. None of the reagents normally used to locate rishitin on thin-layer chromatograms were regarded as useful when tested as cytochemical stains and more work is required on phytoalexin cytochemistry.

(G. D. Lyon).

Virology

B. D. HARRISON

Progress in work directed towards solving problems posed by virus infections in specific crops has included the first release of virus-tested clones of narcissus for the second stage of propagation and the finding that some twin-scales cut from virus-infected narcissus bulbs can produce virus-free plants, the initial indications on the occurrence of viruses in pasture grasses in eastern Scotland, and confirmation that this area is suitable for growing seed crops of field bean free from two viruses that are carried in seed and spread by weevils.

Our more basic research has started to reveal the pattern of synthesis of the RNA of tobacco rattle virus, given evidence of a third gene in this virus, shown that protoplasts from plants infected by one virus can be super-infected by another, and confirmed an unexpected relationship between viruses from potato and apple.

An increasingly significant proportion of our activities has involved co-operation and collaboration with other Sections and with workers in other laboratories in Britain or overseas.

TOBRAVIRUSES

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

Inoculation and uptake of tobacco rattle virus (TRV)

It was previously found that virus inocula prepared using phosphate buffer infect a larger proportion of inoculated tobacco leaf protoplasts than inocula prepared using citrate buffer. The results of further experiments indicated that when phosphate was used the concentrations of protoplasts and of poly-L-ornithine during inoculation were more critical than when using citrate, and that the decrease in infection resulting from inoculation at more than 10^5 protoplasts/ml using phosphate could be minimized by increasing the poly-L-ornithine concentration.

Infection of protoplasts by TRV appears to depend on a reaction occurring between virus particles, poly-L-ornithine and buffer anions before the inoculum is added to protoplasts. It was suggested previously that the aggregates formed in this reaction play an essential role in infection, and moreover that the greater effectiveness of phosphate compared to citrate may

be caused by a difference in size of the aggregates formed. Centrifugation of the inoculum to remove structures of 1,200–3,000 S caused partial to near complete loss of infectivity, and infectivity could be recovered from the sedimented fraction, provided it was collected on a sucrose cushion. There was, however, no evidence that the sedimenting structures formed in phosphate buffer differ in size from those formed in citrate. Aggregates containing about 20–50 virus particles were found when inocula, made using either buffer, were examined in the electron microscope using antiserum-coated grids.

(M. A. Mayo).

Electron microscope grids coated with antiserum to TRV were used to recover virus particles from protoplasts immediately following inoculation and careful washing. Irrespective of whether long particles or short particles predominated in the inoculum, the ratio of particle types recovered from protoplast extracts was the same as that of particles recovered from the inoculum by the same method. The two particle types thus seem to have equal probabilities of uptake by protoplasts.

(M. A. Mayo, I. M. Roberts).

The metabolism of protoplasts and studies of tobacco rattle virus replication

As discussed in last year's Report, knowledge of the rates of uptake of radioactive precursors by protoplasts is necessary for the rational design of labelling experiments. Further work has shown that not only ^3H -leucine and ^{32}P -phosphate but also ^3H -uracil, ^3H -uridine triphosphate and ^{14}C -glucose are taken up at rates which vary in a qualitatively similar way during culture of the protoplasts at 22°C. The rate increased several-fold during the first 8 h, remained at this higher level for about 12 h, and then declined slowly until after 45 h in culture it was at or below the initial rate. The increase in rate was observed not only with protoplasts in various physiological conditions but also with isolated cells, and was due neither to recovery from the trauma of centrifugation nor to depletion of a nutrient or accumulation of an inhibitor in the medium. It was prevented by cycloheximide (1 µg/ml) or puromycin (0.3 mg/ml) but not by chloramphenicol (100 µg/ml) or sodium azide (0.1 mM). 2,4-dinitrophenol (0.1 mM) killed the protoplasts.

The quantity of leucine taken up by protoplasts in a 2 h pulse at any time was proportional to the concentration supplied between 0.02 µM and 0.1 mM; similarly, increasing the phosphate concentration in the medium from 0.014 µM to 2 mM increased the amount of phosphate taken up about 10^5 -fold.

Although uptake rates can be measured, their use to interpret data on the incorporation of precursors into macromolecules involves unjustifiable assumptions about the number and properties of internal pools, so that direct measurement of the kinetics of virus RNA synthesis is still not possible. An additional problem is that in polyacrylamide gel electrophoresis, TRV RNA-2 co-migrates with the smaller RNA from host ribosomes, and RNA-1

co-migrates with another host RNA, probably a ribosomal RNA precursor, which is heavily labelled by short pulses of ^{32}P -phosphate. However, actinomycin D (25 $\mu\text{g}/\text{ml}$) efficiently suppressed incorporation into these host RNA species, and had no significant effect on phosphate uptake. Virus RNA and nucleoprotein synthesis were unaffected when the inhibitor was added 3 h after inoculation, or later.

When ^{32}P -phosphate was supplied to actinomycin D-treated protoplasts during virus multiplication, autoradiography of polyacrylamide gel analyses of RNA labelled by these pulses showed that proportionately more RNA-1 than RNA-2 was synthesized at early stages of infection whereas labelled RNA extracted at later stages was predominantly RNA-2. This result compares with the previous finding that long virus particles (containing RNA-1) predominate over short at early stages of multiplication and shows that the different rates of synthesis of the two virus particles reported previously is at least in part a result of different rates of synthesis of the two RNA species. These experiments also showed that RNA-1 and RNA-2 both were synthesized at a time when no net increase in RNA infectivity was detectable, which indicates turnover of RNA-1.

In addition to RNA-1 and RNA-2 a number of minor RNA species were detected in infected protoplasts, including two which have properties expected for the replicative forms of the genome RNAs, such as resistance to ribonuclease digestion and solubility in 2 M LiCl.

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

YS, a variant of tobacco rattle virus

This variant, mentioned in the Report for 1973, arose spontaneously from the CAM strain of TRV and produces yellow symptoms in several species of host plant. This character was shown to be controlled by RNA-2. However, the coat proteins of YS and CAM were indistinguishable by serology, by electrophoresis in polyacrylamide gels or by tryptic peptide mapping. It is concluded that the mutation responsible for the yellow symptoms is not in the coat protein gene, but in a second gene in RNA-2.

(D. J. Robinson).

To study the role of this second gene in induction of disease symptoms, a start was made on the comparison of the physiology and biochemistry of White Burley tobacco leaves infected with YS and with CAM. The content of reducing sugars was lower in both kinds of infected leaves than in healthy leaves, and chloroplasts in the yellow areas of YS-infected leaves appeared normal in electron micrographs of thin sections. Carbon dioxide assimilation under light-limited conditions was similar (on a leaf area basis) in healthy, or symptom-bearing YS-infected or symptomless CAM-infected leaves, and responded similarly to changes in illumination. This implies that the quantum efficiencies of the photo-systems in these three types of leaf are similar. However, at saturating light intensities, YS-infected leaves had a lower rate of net photosynthesis than either sort of symptomless leaf, indicating a

greater resistance to diffusion of CO_2 to the photosynthesis sites. Simultaneous measurements of transpiration showed that the symptom-bearing leaves had a higher stomatal resistance to diffusion. This indicates that at least part of the effect on photosynthesis is a consequence of changes in the leaf surface that involve the stomata.

(D. J. Robinson, D. K. L. MacKerron¹).

NEPOVIRUSES

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

Interaction of raspberry ringspot (RRV) and tobacco rattle (TRV) viruses in protoplasts

Last year we reported a novel interaction between RRV and TRV (CAM strain) in tobacco protoplasts, in which RRV antigen occurred in small aggregates instead of being generally distributed in the cytoplasm, as in singly infected protoplasts. Further studies showed that the aggregates of RRV antigen do not result from enhanced accumulation of RRV, assessed by the yields of infective or serologically active virus. The phenomenon was observed with serologically distinct strains of RRV but did not occur when tobacco mosaic virus, or two other strains of TRV, were substituted for strain CAM.

Experiments with *Nicotiana benthamiana* plants inoculated singly with either RRV or TRV showed that over 90% of the protoplasts from systemically infected leaves contained virus. Up to 50% of these protoplasts could be superinfected with the other virus of the pair, to produce RRV antigen aggregates. Similar antigen aggregates occurred in about half the protoplasts prepared from doubly infected leaves, and electron microscopy of ultra-thin sections of these protoplasts revealed particles of RRV lying in close association with TRV particles, particularly the long particles attached to mitochondria.

Mixing purified preparations of RRV and TRV in a wide range of conditions resulted in the formation of aggregates containing particles of both viruses. The production of aggregates *in vitro* had the same virus and strain specificity as the formation of RRV antigen aggregates *in vivo*. The aggregates were produced in conditions in which the particles of both viruses are negatively charged but not in distilled water. Aggregation seems to result from a reaction that increases hydrophobicity and not from electrostatic attraction of particles of opposite charge.

We conclude that the production of RRV antigen aggregates *in vivo* results from a redistribution of RRV particles in the protoplast or cell, and that this occurs because of the affinity between RRV and TRV (CAM strain) particles, the longer of which accumulate predominantly on the surface of mitochondria.

(H. Barker, B. D. Harrison, Aileen M. Hutchison).

¹Crops Research Section.

Nematode transmissibility of pseudo-recombinant isolates of tomato black ring virus (TBRV)

Pseudo-recombinant isolates of TBRV, containing RNA-1 of the potato bouquet serotype and RNA-2 of the beet ringspot serotype, were transmitted by the nematode *Longidorus elongatus*, which also transmits the beet ringspot serotype but not the potato bouquet serotype. Transmissibility by *L. elongatus* was correlated with antigenic specificity of the virus particles, providing further evidence that nematode transmissibility depends on the structure of the virus coat protein. The distribution of the genetic determinants for biological properties between RNA-1 and RNA-2 of TBRV resembles that found previously for RRV.

Transmissibility of the beet ringspot serotype by *L. elongatus* was unaffected by the presence in the culture of the 'satellite' RNA, RNA-3.

(B. D. Harrison, A. F. Murant).

Translation of TBRV RNA in vitro

Work was started in collaboration with Dr Christiane Fritsch¹, to investigate the possible function of the three RNA species found in TBRV particles. In preliminary experiments using preparations of mixed RNA species, the highest molecular weight products were of about 2×10^5 daltons and possibly result from complete translation of RNA-1. The coat protein was not found among the products.

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

Pseudo-recombinant isolates of cherry leaf roll virus (CLRV)

CLRV strains from elderberry (G) and rhubarb (R), and tomato ringspot virus (W) have similar *in vitro* properties and sedimentation behaviour in sucrose density gradients, but the two viruses appear to be unrelated serologically. The two separated nucleoprotein components of each isolate had little or no infectivity alone but mixtures of homologous components were very infective. However, whereas mixtures of the heterologous components of G and R were also highly infective, little or no infectivity resulted from mixing the heterologous components of R and W.

Pseudo-recombinant isolates, obtained by inoculating mixtures of the heterologous components of G and R, had *in vitro* properties similar to those of G and R but in most hosts the pseudo-recombinants were less virulent than the parent strains. Serological specificity was determined by the slower sedimenting component (containing RNA-2), whereas ability to infect *Gomphrena globosa* systemically was determined by the faster sedimenting component (containing RNA-1) from strain R.

(A. T. Jones).

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

After indexing commercial stocks of narcissus, and propagating suitable plants, virus-tested clones of six cultivars are now available. Eight other cultivars were screened without success, but the results of a preliminary screening of plants grown from twin-scales offer promise of obtaining some plants free of infection. Thus about 1% of plants of cultivars King Alfred, Dutch Master, Fortune and Golden Harvest, propagated by twin-scales from mother plants containing only filamentous virus particles in low concentration, appeared to be free of infection.

Further tests on virus-tested clones propagated from selections made in previous years detected filamentous virus particles in the remaining three of the original five selections of Fortune. It seems therefore that the main problem in virus indexing is the dependence on electron microscopy for detecting low concentrations of filamentous virus particles. Detection seems to be more efficient by direct examination of sap than of clarified and concentrated leaf extracts. This problem emphasises the importance of repeated indexing of selections and of keeping plants together in clones that can be discarded later, should the need arise.

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

Virus spread in narcissus

Six of the fifteen viruses known to occur in narcissus grown in the UK are aphid-borne. All are transmitted in the non-persistent manner, and protecting virus-tested stocks from re-infection during propagation in the field potentially poses a major problem. A series of trials to assess re-infection rates at different localities was begun in 1975, using narcissus yellow stripe virus as an indicator and allowing spread to occur for a year. At planting the incidence of yellow stripe was 10% and the increase after one year was 2.5% at Rosewarne EHS, Cornwall, 2% at SHRI and nil at Craibstone Farm, Aberdeen. Of the new infections about one-third were next to infector plants.

(W. P. Mowat).

Control of field spread of tulip breaking (TBV) and lily symptomless viruses (LSV)

In 1975 three forms of barrier, each combined with a weekly spray of 1% emulsion of Albolineum oil, were compared for their effectiveness in protecting *Lilium formosanum* plants from infection by TBV and LSV. Rows of barley were spaced at either 30 cm or 60 cm, and 60 cm-high polyethylene windbreak screens (Rokolene) were spaced at 30 cm. Exposure of successive batches of 10 healthy *L. formosanum* plants for 3 wk intervals at the edge of the trial detected virus spread from June to September and all bait plants

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

exposed from the end of July to mid-August became infected. However, of the 40 plants in each treatment, one plant between the 30 cm rows of barley became infected, none between the 60 cm rows of barley, two between the polyethylene screens and all in the untreated plots. The barrier crop considerably restricted the growth of the *L. formosanum* plants. The weight of bulbs obtained from the polyethylene sheltered and untreated plots was twice that from plots with 60 cm barley rows which in turn was twice that from those with 30 cm barley rows. Polyethylene screens therefore seem a possible useful alternative to a plant barrier, which may be a host to potential virus vectors (see Annual Report for 1975) and may restrict growth.

(W. P. Mowat, J. A. T. Woodford¹).

04011 *Production of virus-tested bulb stocks*

Propagation of virus-tested narcissus

In 1976, 5,700 twin-scales were cut of the cultivars Carlton, Sempre Avanti, Barrett Browning and Verger but the proportion producing bulbils was somewhat lower than expected. Another factor of importance in propagation is the proportion of bulbils remaining dormant in the first year, and knowledge of the factors governing this and bulbil formation is much needed.

The treatment used to safeguard twin-scales against rotting during their first 12 wk is a 30 min immersion in 0.2% benomyl immediately after cutting. Although this has proved satisfactory so far, isolates of *Penicillium* spp. and *Botrytis cinerea* resistant to benomyl were obtained from treated twin-scales (see Mycology Section). Moreover, it has been suggested that benomyl might adversely affect bulbil formation. Thiram (2% solution of 80% wettable powder), therefore, was examined as an alternative fungicide. Of 500 twin scales treated with benomyl, 92% were suitable for planting as compared with 75% of those treated with thiram; the percentage of surviving twin-scales which formed bulbils was similar for the two fungicides. Also, it was found that treating bulbs with hot water (3 h at 44.2°C) before twin-scaling did not affect the survival of the twin-scales or the formation of bulbils.

In 1976, the first release of virus-tested clones from the Institute was made to the East and North of Scotland Colleges of Agriculture for further multiplication by twin-scaling. This issue consisted of three clones of Sempre Avanti and one of Carlton. Each clone consisted of 2 kg of flowered bulbs, the estimated quantity required by the Colleges to meet their output target of 22,000 bulbs for passing onto the third stage of propagation contracted for by SNSA (Flower Bulbs) Ltd.

(W. P. Mowat, J. Chambers).

¹Zoology Section.

RUBUS VIRUSES

04003 *Viruses infecting raspberry*

Black raspberry necrosis virus (BRNV)

A culture of the aphid- and sap-transmissible virus, code-named 52V, induced apical necrosis in *Rubus henryi*, *R. occidentalis* and *R. molaccanus*, a transient mottle in *R. procerus* cv. Himalaya Giant and symptomlessly infected four other *Rubus* species and 35 red raspberry (*R. idaeus*) cultivars. This host range and symptomatology parallels that reported for BRNV isolates in North America and supports previous circumstantial evidence indicating that 52V is an isolate of BRNV.

Electron microscopy of thin sections of BRNV-infected *Chenopodium quinoa*, *R. henryi* and *R. occidentalis* showed islands of dead cells in the vascular tissue and leaf blade. Some of the cells adjacent to these areas had cell wall outgrowths and many of the plasmodesmata contained virus-like particles ca. 25 nm in diameter arranged in a single file.

(A. T. Jones, I. M. Roberts).

Further results from a pot experiment confirmed that raspberry bushy dwarf virus (RBDV) infection alone is not the cause of bushy dwarf disease in cv. Lloyd George raspberry and that BRNV alone or in combination with other viruses is the probable cause of the disease.

(A. T. Jones).

Performance of aphid-resistant raspberry cultivars

Tests made 3 years after planting in the field showed that minor genes for resistance to their main vector, *Amphorophora rubi*, decreased the spread of aphid-borne viruses in raspberry cultivars almost as much as major genes. However, after 5 years, 55% of plants with minor gene resistance were infected compared with 25% of those with major gene resistance. All plants of *A. rubi*-susceptible cultivars were infected within 3 years after planting.

(A. T. Jones).

Wineberry latent virus (WLV)

This name was adopted for the sap-transmissible virus with filamentous particles ca. 510 × 12 nm obtained from *R. phoenicolasius* and previously code-named Rp7. WLV was not transmitted mechanically from *C. quinoa* to *Rubus* but, using scions from a field-infected *R. phoenicolasius* plant, it was graft transmitted to four *Rubus* species including *R. phoenicolasius* and four red raspberry cultivars. No symptoms were produced in these graft-infected plants that could not be attributed to infection with raspberry bushy dwarf virus, which also occurred in the field-infected source plant. Purified preparations of WLV did not react with antisera to four potexviruses, or to apple chlorotic leaf spot or apple stem grooving viruses.

(A. T. Jones).

04007 *Viruses affecting umbelliferous plants**Viruses from Heracleum sphondylium*

The virus code-named HV2 was transmitted by inoculation of sap to species in eight families of dicotyledonous plants, mostly in the Amaranthaceae, Chenopodiaceae, Solanaceae and Umbelliferae. In buffer extracts from *Chenopodium quinoa* leaves, HV2 lost infectivity after 10 min at 40–50°C, 1–2 days at room temperature and after dilution 10^{-4} – 10^{-5} . Infectivity was destroyed by treatment with organic solvents, but the virus was purified from *C. quinoa* extracts by clarification with bentonite, precipitation with polyethylene glycol (mol.wt. 6,000) and differential centrifugation. More virus was obtained from stems, petioles and leaf midribs than from leaf laminae. Virus yields were about 4 mg/100 g tissue.

Purified virus formed a single major band in sucrose density gradients with $s_{20,w}^{0} = ca. 96 S$. The particles are very flexuous filaments *ca.* 730 nm long, with obvious cross-banding, and have $A_{260}/A_{280} = ca. 1.5$. The particles contain a single polypeptide of mol.wt. *ca.* 23,000. HV2 resembles the closterovirus, apple chlorotic leaf spot, in many of its properties but showed no serological relationship to this virus, or to apple stem grooving, potato T or wineberry latent viruses. HV2, however, reacted well with its homologous antiserum.

HV2 was transmitted by the aphids *Cavariella aegopodii* and *C. pastinacae* from naturally infected hogweed plants but lost aphid transmissibility after manual transmission.

(F. Bem, A. F. Murant).

04014 *Identification of viruses in relation to diseases of other crop plants**Seed-borne viruses of field beans*

Further studies on the incidence, spread and effect of broad bean stain virus (BBSV) and Echte Ackerbohnenmosaik-virus (EAMV) in *Vicia faba* in eastern Scotland again failed to detect the main weevil vector, *Apion vorax*, in several commercial crops of field bean and broad bean in Fife and Angus. Seed-borne infection with BBSV and EAMV was identified in some crops but no spread was detected.

In a repeat of the previous year's experiment to study spread of BBSV and EAMV in more detail, plants at different locations within a 0.4 ha crop of virus-free cv. Minden were manually inoculated with one or other virus 8 wk after sowing. Uninoculated plants were examined throughout the season for evidence of virus spread and for weevil vectors. Fifteen uninoculated plants, mostly within 10 m of infectors, were found to contain EAMV but none

contained BBSV. *Apion* weevils were not detected but large populations of *Sitona* spp. developed later in the season. *Sitona* weevils are poor vectors of BBSV and EAMV but are known to transmit EAMV more efficiently than BBSV.

In a field experiment to determine the effect of time of plant infection with BBSV and EAMV on the amount of seed transmission, plants of Minden were manually inoculated with one or other virus at different times after emergence. Seed from inoculated plants was tested for infection by screening 1,500 seedlings from each treatment. Seed transmission from plants inoculated 3, 5, 7 and 11 wk after emergence respectively was 1.5, 2.7, 0.4 and 0.06% for BBSV, and 0.5, 2.1, 0.6 and 0% for EAMV.

These results indicate that although limited spread of EAMV and BBSV possibly occurs in some crops in the east of Scotland, this is likely to happen too late in the season to result in seed transmission.

(A. T. Jones).

An isolate of broad bean wilt virus serotype II from Helleborus vesicarius

A virus isolate obtained by W. T. Dale¹ from a plant of *Helleborus vesicarius* growing in a specialist nursery in Kent had 30 nm isometric particles and produced symptoms resembling those of broad bean wilt virus in a range of test plants. In gel-diffusion tests it gave reactions of identity using antiserum to a plantago isolate (serotype II) of broad bean wilt virus. It failed to react in gel-diffusion tests with antiserum to the parsley virus 3 isolate (serotype I) although a faint reaction with this antiserum was detected by electron microscope serology. This is believed to be the first report of serotype II occurring in Europe.

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

Viruses of grasses

Five viruses were obtained from grasses growing in fields and paths at SHRI or at other localities within 20 miles. Phleum mottle virus was obtained from mottled leaves of timothy and from cocksfoot plants. In gel-diffusion serological tests the isolates were indistinguishable from one another and from authentic phleum mottle virus. However, only the cocksfoot isolate infected this species and only the timothy isolate infected inoculated leaves of oat. Both isolates infected barley and wheat. Another isolate from cocksfoot was shown, by tests using antisera to authentic isolates, to be unrelated to cocksfoot mild mosaic or phleum mottle viruses. It did not react with antisera to festuca mottle, holcus transitory mottle or cocksfoot mottle viruses. It was transmitted to *Setaria italica* and wheat. We are indebted to Dr P. L. Catherall² for supplying the antisera used in these tests.

The third virus found in cocksfoot, alone or in mixtures with phleum mottle or cocksfoot mild mosaic viruses, had flexuous filamentous particles about 750 nm long, and produced symptoms in cocksfoot, Italian ryegrass

¹ADAS, Wye, Kent.

²Welsh Plant Breeding Station, Aberystwyth.

and perennial ryegrass but did not infect barley, oat, timothy or wheat. Its transmission by inoculation of sap was aided by the use of pH 5 to 6 acetate or citrate buffers containing mercaptoethanol; its host range and properties resemble those of cocksfoot streak virus.

Isolates of ryegrass mosaic virus (RMV) were obtained from streak-affected plants of Italian and perennial ryegrass, and from *Poa annua*. They reacted with antiserum to authentic RMV (kindly supplied by Dr Y. Paliwal¹), and were typical in particle morphology, host range and symptomatology.

Several ryegrass plants were found to contain isometric particles 30 nm in diameter in addition to the filaments of RMV. The virus mixture was readily transmitted to Italian and perennial ryegrass, meadow fescue and crested dogstail, and the symptoms produced were more severe than those of RMV alone. However, all attempts failed to separate the virus with isometric particles from RMV. It did not react with antisera to brome mosaic, cocksfoot mottle or phleum mottle group viruses.

(Lesley Torrance, B. D. Harrison).

04001 Potato viruses, especially soil-borne viruses

New viruses from potato

The symptoms caused by potato black ringspot virus (PBRV) in potatoes were studied in a number of British cultivars. Of those tested, Maris Bard was the most sensitive and developed black rings and spots in systemically infected leaves. The virus was transmitted to progeny plants from 80% of the tubers produced by artificially infected plants; some of these infected progeny plants emerged late and showed necrotic spots on the leaves, streaks on the stems and vein necrosis. In *Solanum tuberosum* ssp. *andigena*, symptoms differed only slightly from those in Maris Bard. PBRV was not transmitted by the aphid *Myzus persicae* or the nematode *Longidorus elongatus*.

Potato virus T (PVT) infected potato plants containing potato viruses M, S, X or Y, and infected genotypes hypersensitive to potato viruses M or S without producing symptoms. It induced incomplete top necrosis in graft-inoculated cv. Oakpark Beauty. In several solanaceous species it was transmitted through seed, often to half or more of the progeny seedlings. Serological tests confirmed its relationship to apple stem grooving virus but when the two viruses were inoculated together to *Chenopodium quinoa* the symptoms produced were more severe than those of either virus alone, suggesting a lack of interference between them. Analysis by optical diffraction of electron micrographs of virus particles stained with uranyl acetate, in collaboration with Dr P. Tollin² and Dr H. R. Wilson², gave evidence of alternative arrangements of the subunits of coat protein, apparently resulting from different degrees of tightness of the helix and hence different numbers

¹Agriculture Canada Research Station, Ottawa, Canada.

²University of Dundee.

of subunits per turn. Two types of degraded particles were found in purified preparations. One, called a 'ghost,' seemed to be produced by longitudinal stretching of the particles; it bound antibody to PVT more readily than intact particles. The other, which was disc-shaped and reacted with PVT antiserum, is presumably composed of coat protein subunits.

A third virus, called 14R, was found in plants of *S. tuberosum* ssp. *tuberosum* × ssp. *andigena* in Peru. It was transmitted by inoculation of sap to 35 out of 41 species tested but was restricted to the inoculated leaves of all except *Chenopodium ambrosoides*, *C. quinoa* and *C. amaranticolor*. Attempts to infect potatoes systemically were unsuccessful. Purified preparations of 14R contained rod-shaped particles similar to those of tobacco mosaic virus (TMV), and contained a RNA of ca. 2.4×10^6 daltons and a single species of protein of similar size to that of TMV. (L. F. Salazar, B. D. Harrison).

EXOTIC VIRUSES

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

Screening yams with minimal virus content

In a small project, undertaken for the Ministry of Overseas Development, twenty *Dioscorea alata* cv. White Lisbon plants, selected by S. H. Mantell¹ as potential mothers in a clonal propagation scheme, were examined for their virus content. All except one plant, which contained bacilliform particles and grew poorly, grew strongly and developed only faint or slight mosaic symptoms. All plants contained filamentous particles ca. 750 nm long; in serological tests assessed by electron microscopy, these reacted consistently but less strongly than the homologous virus with antiserum to pepper vein mottle virus, weakly with antiserum to potato virus Y, and not with antiserum to dasheen mosaic virus. Some plants appeared to contain a second kind of filamentous particle, which did not react with the antisera, and most of these plants grew somewhat less vigorously and developed more obvious symptoms. All plants also contained pinwheel inclusions, in some instances confined to a network of 'giant' cells similar to laticiferous cells.

It was concluded that the best available mother plants were infected by a potyvirus but should be free from other viruses detectable by electron microscopy. (I. M. Roberts, Aileen M. Hutcheson, B. D. Harrison).

Pepper vein mottle virus from Nigeria

Two virus isolates obtained from naturally infected tomato and tobacco in Nigeria by Dr J. L. Ladipo² were found to have flexuous filamentous particles of modal length 750–780 nm. Although the two differ in host range and

¹University of the West Indies, Bridgetown, Barbados.

²Department of Plant Science, University of Ife, Nigeria.

symptomatology, each reacted with antiserum to pepper veinal mottle virus in electron microscope serological tests to the end point of the antiserum against the homologous virus. This and other evidence suggest that a considerable variety of strains of this virus occur in West Africa.

(I. M. Roberts).

ELECTRON MICROSCOPE TECHNIQUES

04019 *Electron microscopy and analytical centrifugation of virus preparations*

Electron microscope serology

The technique described in last year's Report of examining serological reactions occurring in small drops, using the electron microscope, was improved and has been used increasingly throughout the year for virus diagnosis and detection of serological relationships. Some antisera that gave no reaction in precipitin or microprecipitin tests gave positive reactions with EM serology; the virus particles became coated with antibody although no precipitation occurred. Comparisons of homologous and heterologous reactions were made using EM serology, tube precipitin, microprecipitin and gel double-diffusion techniques. EM serology was reliable and always the most sensitive method.

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

Electrodes for evaporating carbon and metals

Two new electrode assemblies, for evaporation of carbon and of metals, etc., were designed and constructed. They are compact (30 × 30 × 100 mm), can be accurately prealigned and are 'bakeable.' They can be rotated through 360° both vertically and horizontally, and can be adjusted to any height. Carbon rods of any length down to 30 mm can be used. The electrodes are shielded and give less coating/contamination of the vacuum plant during use than conventional electrodes.

(I. M. Roberts).

Zoology

D. L. TRUDGILL

The recent upsurge in aphid-borne viruses in seed potatoes has been described as a disaster and the need for increased research on potato aphids in Scotland has been recognised by the award of a research grant from the Potato Marketing Board. Mr C. S. Aveyard has been appointed to undertake work on the effect of insecticides on virus spread, and recently established work on monitoring the time of aphid arrival, flight behaviour and numbers in relation to virus spread will continue.

The survey of raspberry cane midge, started in 1973, and the extensive programme of work on midge biology, control, and the effects of cane vigour control techniques on midge have continued. The importance of cane midge is now widely recognised and it is clear that the work done from 1973 to 1975, when midge was regarded by some as unimportant, was justified.

A number of surveys of nematode distribution were completed and published during the year, providing a basis for assessing the relative importance of different genera and species of plant parasitic nematodes. The surveys have also provided insight into the environmental factors which may influence nematode distribution and numbers, and provide a basis for studying the ecology and biology of a number of important species, about which we know all too little. Much still remains to be done. The distribution in Scotland of *Pratylenchus*, some species of which are pathogenic to raspberries, is unknown. Preliminary results suggest that *Longidorus elongatus* is damaging to a number of crops including strawberries, but survey information is required to assess the extent of the damage caused.

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

Survey of nematodes in vegetables

The survey of the nematodes associated with carrots in Scotland was completed in November 1976. Six hundred and fifteen soil samples were collected from 150 carrot fields. The 59 farms (some of which were visited in both 1975 and 1976) were distributed between East Lothian in the south and the Black Isle in the north. Longidorid nematodes were the most frequently occurring migratory ectoparasites (70% of samples contained longidorids).

However, numbers tended to be small and only in nine fields were there more than 250/kg soil. Spiral nematodes belonging to the genera *Rotylenchus* and *Helicotylenchus* were the next most common group followed by members of the genera *Trichodorus*, *Pratylenchus*, *Tylenchorhynchus*, *Criconemoides* s.l. and *Paratylenchus*.

An investigation into the possible association between cavity spot of carrots and the presence of nematodes was carried out in collaboration with D. A. Perry¹. No evidence of such a relationship was found.

A 2-year survey of nematodes associated with pea and field bean was started during the summer; 295 soil samples from pea fields and 80 from bean fields were collected in 1976. While sampling the bean fields, plants showing symptoms which might have been caused by *Ditylenchus dipsaci* damage were also examined; in only one of the 21 bean fields visited was *D. dipsaci* detected.

(B. Boag).

Criconematidae of the British Isles

In a survey of the British Isles nine genera and 28 species of criconematid nematodes were identified including 22 species which had not previously been reported. An analysis of the distribution of 11 of the most abundant species showed that the majority preferred woody hosts, except for *Macroposthonia rustica* and *Criconemoides informis* which were most abundant in pasture and arable soils.

(B. Boag).

Rotylenchus robustus damage to carrots

The effect of aldicarb 3.36 kg a.i./ha (3 lb a.i./ac) on the growth of three cultivars of carrot (Nantes, Berlicum and Cluseed New Stump Rooted) was tested for a second year at a site heavily infested with *Rotylenchus robustus* (ca. 1,000/kg soil). Following treatment, the numbers of *R. robustus* and trichodorids decreased slowly until August when there were 32% and 21% respectively of the numbers in the untreated plots. When harvested at the end of August there were no significant differences in yield between carrot cultivars but aldicarb had increased the average fresh weight yield by 46%.

(B. Boag).

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

Population changes in field plots

The study of a population of *T. primitivus* on a site sown with a grass/clover mixture in spring 1975 has continued. Changes in the population structure were similar to those observed in 1975. Females outnumbered males by at least 2:1 at each sampling date. The percentage of larvae increased to about 50% of the population by August, but decreased to about 30% during the winter, as larvae developed into adults.

¹Mycology Section.

On an adjacent site the effect of crop rotation on trichodorid numbers was studied. Seven strips each 4 m × 26 m were cropped with grass, pea, carrot, barley, swede, potato and fallowed respectively. These crops are to be planted each year, the direction of sowing being changed through 90°. In 1976, soil samples were taken from each strip at 8-weekly intervals and examined for trichodorids. Numbers increased, soon after planting, on all crops except potato and swede. No common trend in population structure or development could be identified, perhaps because of the dry summer.

Differences in suitability of crop samples as hosts for trichodorids was also studied at two other sites. At one site *Paratrichodorus pachydermus* and *Trichodorus cylindricus* were present and at the other *P. pachydermus* and *T. similis*. At both sites numbers of trichodorids increased two-fold between April and September under barley. Under potato the populations decreased during the summer to less than 50% of the April level, but by September had increased to the April level at one site and to a level 60% greater than the original at the other.

(T. J. W. Alphey).

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

Longidorus elongatus and strawberry

Results from Sweden and Canada suggest that *L. elongatus*, a nematode which is widespread in Scotland, may be an important pathogen of strawberry. However, results from a field trial at SHRI suggest that detectable damage is caused only by large populations. In a field trial, started in April 1974 with a pre-planting population of 40 *L. elongatus* per 200 g soil, strawberry growth was not improved, in the first 2 years, in plots where *L. elongatus* had been controlled. Only in the third year, when numbers of *L. elongatus* in the untreated plots exceeded 300 per 200 g soil, was growth significantly improved in plots which had received nematicides. When plants were defoliated in the autumn of the third year the weight of leaves recovered was 30% greater from plots which had received a pre-plant treatment of dazomet 336 kg/ha (300 lb/ac), benomyl 22.5 kg a.i./ha (20 lb a.i./ac) or oxamyl 22.5 kg a.i./ac (20 lb a.i./ac) than from the untreated control plots.

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

Damage caused by Longidorus elongatus

Aldicarb 3.36 kg/ha (3 lb a.i./ac) was incorporated at sowing into plots heavily infested with *L. elongatus* (2200/kg soil). Crops grown were barley, grass, carrot, pea, swede or potato. Nematode numbers decreased in all plots but the rate of decrease was slightly greater in the plots treated with aldicarb so that by August treated plots had on average 27% fewer *L. elongatus* than untreated plots. The greatest decrease was under barley and the least under swedes.

The effect of aldicarb on the growth of the crops varied. The dried weight of grass in June from the aldicarb treated plots was 45% greater than from untreated plots. Treatment with aldicarb increased the fresh weight of carrots lifted in July by 30%, but when finally harvested in October, there was no significant difference in yield between aldicarb treated and untreated plots. The fresh weight of swedes was increased by 70% in June and by 35% in November. Aldicarb did not affect the yields of barley, pea or potato although it significantly increased the absolute number and weight of weeds (mainly field pansy) removed, in June, from the fallow plots.

(B. Boag, D. L. Trudgill).

Observations on the life cycle and pathogenicity of Paralongidorus maximus

A forest nursery growing Scots pine was sampled at five different depths each month during 1975 for *Paralongidorus maximus*. From the slow rate of change in the relative proportions of the different larval stages it seems probable that the complete life cycle of *P. maximus*, from egg to adult, takes at least 1 year. Growth in the second year after planting out and overall height of Scots pine seedlings were inversely related to the numbers of *P. maximus*.

In a glasshouse experiment the growth of Scots pine and European larch, but not of Sitka spruce, was decreased by increasing numbers of *P. maximus*. A possible relationship between *P. maximus*, *Cylindrocarpon destructans* and the death of small numbers of Scots pine was also observed.

In Europe, *P. maximus* has been reported damaging vegetables and trees. As this is only the third time *P. maximus* has been reported in Great Britain and on each occasion it has been recovered from a nursery or garden this suggests that it has been introduced from Europe in soil adhering to planting material.

(B. Boag).

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

Control of spraing in potatoes by foliar applications of oxamyl

In 1976 varying the rates and times of spraying the oximecarbamate nematocide, oxamyl, was tested on the incidence of spraing. Oxamyl was sprayed once at 4000 ppm (to give 5.6 kg a.i./ha) on to potato cv. Pentland Dell at 10 wk, 12 wk, 14 wk and 16 wk post-planting. Also, sprays equivalent to 2.8 kg a.i./ha and 1.4 kg a.i./ha were applied at 10 wk post-planting. The mean tuber diameter at 10 wk (2 cm) in 1976 was comparable to that at 8 wk in 1975. Trichodorid counts were made throughout the growing season and the percentage incidence of spraing recorded at harvest.

In untreated control plots trichodorid numbers decreased slightly; at harvest, 29% of the tubers showed symptoms of spraing. In plots sprayed with oxamyl, numbers of trichodorids also decreased but did not significantly

differ from the untreated control; the incidence of spraing was significantly decreased (to 17.5% and 17.6%) only by spray treatments of 5.6 kg a.i./ha applied at 10 wk or at 12 wk post-planting respectively. Sprays applied at 14 and 16 wk failed to decrease the incidence of spraing. These results taken together with those obtained in 1975 suggest that the majority of TRV transmission occurs prior to 10 wk post-planting and before tubers reach 2 cm diameter. Hence, the optimum time for applying oxamyl sprays appears to have been missed in 1976 making it difficult to evaluate the likely effectiveness of the lower dose rate sprays.

(T. J. W. Alphey).

In pot studies the relative efficiencies of oxamyl applied as soil drenches or as foliar dips were compared. Oxamyl drenches were applied at 1, 2.5 or 10 ppm to give 0.008, 0.02 and 0.08 mg a.i. oxamyl per pot in soil infected with *Longidorus elongatus* carrying RRV. A single *Chenopodium quinoa* seedling was planted in each pot. The foliage of other *C. quinoa* seedlings was dipped, at the start of the experiment, in oxamyl solutions of 500 or 1000 ppm, care being taken to prevent oxamyl coming into contact with the roots. These seedlings retained, on average, 0.049 and 0.098 mg a.i. of oxamyl. To assess how long oxamyl remained effective groups of pots were examined after different time intervals. Nematodes were extracted and counted and the seedlings were examined for root galls and tested for virus. Initially, none of the treatments significantly decreased numbers of nematodes. Four weeks after treatment there were fewer *L. elongatus* in the 10 ppm soil drench treatment and after 6 wk there were fewer *L. elongatus* in all drench treatments and in the 1000 ppm foliar dip treatment, compared with the untreated controls. Feeding of the *L. elongatus*, as measured by root galling, was inhibited for 2 wk by the 500 ppm foliar dip, for 4 wk by the 1 and 2.5 ppm soil drenches and the 1000 ppm foliar dip and for at least 6 wk by the 10 ppm soil drench. Only low rates of virus transmission were obtained in the untreated controls. Both drench and dip treatments appeared to decrease the rate of transmission. The results showed that soil applications were considerably more effective than foliar dips.

(T. J. W. Alphey, R. Farnan¹).

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

Feeding behaviour of Xiphinema diversicaudatum

In the Annual Report for 1975 (p. 83) it was suggested that *Xiphinema diversicaudatum* might be salivating during the long quiescent phases that occurred in most feeds. Recently, large ducts have been identified, using Nomarski interference microscopy, in association with the anterior gland cell in the oesophageal bulb of *X. diversicaudatum*. These ducts have been seen to fill and empty during the feeding of *X. diversicaudatum*. Preliminary

¹Dundee College of Technology.

observations have shown that these ducts, which are thought to contain saliva, empty during the brief pause between the completion of cell wall penetration and the onset of ingestion. They also appear to empty during brief pauses, lasting only a few seconds, during ingestion. (D. L. Trudgill).

Transmission of viruses

Further studies have confirmed that *X. diversicaudatum* is an efficient vector of arabis mosaic virus (AMV), 20 out of 20 bait plants becoming infected when only two nematodes per bait plant were tested. Similarly, following a relatively brief acquisition feed on *Chenopodium quinoa* plants infected with strawberry latent ringspot virus (SLRV), groups of five *X. diversicaudatum* infected 22 out of 27 bait plants with SLRV.

Studies on the frequency of transmission of viruses by *Longidorus* spp. have also continued. An isolate of tomato black ring virus (TBRV-E) originally obtained from a virus infected population of *L. attenuatus* was efficiently transmitted by a second, originally virus free, population of *L. attenuatus*. Using two nematodes per bait plant, 25 of 29 bait plants became infected with TBRV-E. However, when eight nematodes exposed to *Petunia hybrida* plants infected with TBRV were fixed, sectioned and examined with the electron microscope only two were found with virus particles retained between the odontostyle and the guide sheath. Recent tests have shown also that *L. elongatus* adults are efficient vectors of a Scottish strain (W22) of TBRV. When pairs of nematodes from two populations were bait-tested after 20 days on *P. hybrida* infector plants, 10 of 20 bait plants became infected with W22 using the first population and 16 of 20 bait plants became infected with W22 when exposed to the second population of *L. elongatus*.

Rates of transmission of a Scottish isolate of raspberry ringspot virus (RRV, strain 4B7) by *L. elongatus* are variable and frequently are low. In one test, when 68 pairs of nematodes were macerated and inoculated to *C. quinoa* assay plants (slash-tested) 72% of the assay plants became infected with virus but in a bait test comparable pairs of nematodes infected only three of 68 *P. hybrida* bait plants with virus. Results obtained from examining sections from the feeding apparatus of adult nematodes with the electron microscope suggest that this low rate of transmission is due to many nematodes ingesting but not retaining virus within their feeding apparatus.

In laboratory tests *L. macrosoma* has also proved to be an inefficient vector of an English strain (Himalaya) of RRV with which it has been found associated in the field. Groups of five *L. macrosoma* from *P. hybrida* infector plants infected only two of 15 bait plants with the Himalaya isolate and only one of 15 bait plants with the 4B7 isolate of RRV. Eighty per cent of the nematodes were recovered at the end of the bait test and from numbers of root-tip galls formed most of the nematodes seemed to have fed. When comparable groups of nematodes from the infector plants were slash-tested, 12 of 15 assay plants were infected with the Himalaya isolate and 13 of 15

were infected with the 4B7 isolate. Examination of the feeding apparatus of eight nematodes exposed to each isolate with the electron microscope showed that most contained virus-like particles retained within the odontostyle and between the odontostyle and the guide sheath. These results suggest that *L. macrosoma* which had virus particles adsorbed on to their odontostyle were unable to infect bait plants with that virus.

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

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

Salivary glands in Xiphinema index

An initial examination of the oesophageal bulb of *Xiphinema index* has shown that there are two ducts extending from the main dorsal salivary gland duct, to the posterior region of the bulb. Both ducts, which lie close to the oesophageal bulb wall in subdorsal positions, are formed by an infolding of the gland cell wall and in thin sections, have been seen to be either collapsed or in varying amounts of dilation up to 6 μ m diameter in the posterior region.

The dorsal gland nucleus lies in the anterior part of the bulb close to the opening of its main duct into the food canal. The two posterior glands occupy subventral positions and their gland nuclei lie in the mid region of the oesophageal bulb some distance from their collecting ducts. The posterior gland ducts open into the food canal approximately half-way between their gland nuclei and the oesophageal-intestinal valve. (W. M. Robertson).

Oesophageal innervation in Longidorus leptocephalus

Nerve processes which link with nerves in the slender oesophagus are associated with each of the salivary gland cells in *Longidorus leptocephalus*. *L. leptocephalus* has two neurones on the ventral side of the anterior oesophageal bulb. Both neurones have nerve processes in close association with the food canal wall for approximately 6 μ m immediately anterior to the oesophageal bulb platelets. There are also two sets of nerve processes in the region where the posterior salivary glands open into the food canal. Both sets of nerve processes contact the dorsal side of the food canal wall; one immediately opposite the salivary duct opening and the second approximately 8 μ m anterior. (W. M. Robertson).

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

In 1974 small areas of poorly growing raspberries at a farm in Perthshire were found to be infested with large numbers of *Pratylenchus penetrans*. During 1975, several others were discovered showing areas of poor growth associated with *P. penetrans* and three of them were chosen for more detailed investigation. Soil was taken from the areas of depressed growth and from

adjacent areas where the crop appeared to be growing normally. Usually the areas where growth appeared to be normal were infested with *P. crenatus* and therefore soil was also taken from a raspberry plot which, following treatment in 1972 with dazomet, was free from nematodes. Each soil sample was mixed and divided to provide three treatments for a pot test. In two of the treatments, the plant parasitic nematodes were killed by either freezing the soil for 1 wk at -20°C or by treating the soil with aldicarb (10 mg a.i. per 15 cm pot) at planting. A small (5 cm diameter) raspberry plant cv. Glen Clova was planted in each pot and the plants grown in a glasshouse for 17 wk. At the end of the experiment, plant roots and tops were harvested and the nematode population estimated.

Plant height and root and shoot weight were significantly increased, by deep freezing and aldicarb treatments in all soils containing *P. penetrans*. In the soils not infested with *P. penetrans* there were generally smaller non-significant increases in height and root and top weight.

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

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

Investigations are continuing into how endoparasitic root feeding nematodes, such as potato cyst nematode (*Globodera rostochiensis*), decrease crop yields. Analysis of potato haulm from field experiments showed that nematode infested plants contained less nitrogen (N), potassium (K) and phosphorus (P) per unit weight of dry matter than uninfested plants growing at the same site. These results suggested that the poor haulm growth of nematode infested plants might result from chronic shortage of plant nutrients. This hypothesis was tested by comparing the growth of potato plants growing in pots of potato cyst nematode infested soil to which differing amounts of N, P or K fertiliser had been added. The level of each plant nutrient was varied independently of the others. Similar treatments were also applied to pots which had been treated with aldicarb to protect the potato plants from nematode damage.

In the first 7 wk of the experiment, growth was only slightly affected by the nutrient treatments but was greatly improved by aldicarb. In the second 7 wk of the experiment, growth of the nematode infested but not of the aldicarb treated plants was greatly improved by luxury amounts of K and especially of P. Luxury amounts of P increased the mean haulm weight of nematode infested potato plants 14 wk after planting from 88 g to 196 g. Weight of roots was increased from 11 g to 56 g and of tubers from 100 g to 168 g. Luxury amounts of N improved the growth of both nematode infested and aldicarb treated plants, increasing haulm weight from 88 g to 254 g and from 287 g to 434 g respectively.

(D. L. Trudgill).

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

Raspberry cane midge *Resseliella theobaldi*

Biology

Adult midges started to emerge in a cv. Glen Clova plantation at SHRI in the third week of May. Most had emerged by the end of May, but emergence continued into the second week of June. Eggs were first found on the primocanes of Glen Clova on 27 May and larvae on 3 June. No further first generation eggs were found after 10 June and most first generation larvae had completed feeding by the third week of July. Second generation eggs were found from 14 July to 25 August. Larvae were found every week until sampling ceased on 6 October. The maximum number of larvae was found in the last week of August.

In previous work on the effect of machine harvesting on raspberry cane midge more larvae were found in primocanes from machine harvested plants than in primocanes from hand-picked plants. The damage caused by the catching plates on the harvester provided additional sites for egg-laying. In 1976 the relationship between frequency of mechanical damage and larval numbers was examined. The effect of repeated catching plate damage was simulated by lightly rasping one primocane cane on each of 25 stools of cv. Malling Jewel on six occasions over a 3 wk period in July and August. Another cane was damaged in the same way on the first and fourth occasion, whilst two canes were left as undamaged controls. In mid-August, 10 days after the last date on which canes were damaged all the canes were cut and examined for midge larvae.

Most of the larvae in natural splits were found in the basal 20 cm region of the cane. There were significantly fewer larvae in natural splits on canes damaged on two occasions or left undamaged, than on canes damaged six times. Increasing the frequency of 'harvesting' damage did not increase the number of larvae found in the simulated catching plate wounds, possibly because the repeated damage destroyed eggs and developing larvae. Similarly, there was no significant difference between the total number of larvae per cane in the two simulated harvesting treatments. There were, however, very significantly more larvae per cane in both treatments than in the untreated controls as a result of oviposition where the canes had been damaged.

Numbers of overwintering midge cocoons were estimated in plots of Glen Clova where the first flush of canes had been removed in the previous year at differing stages of growth. Cane removal in 1975, either by cutting or by spraying with dinoseb-in-oil, decreased the numbers of cocoons found early in May 1976. The decrease in midge numbers in plots where the first flush of canes were removed appears to be due to the replacement canes having very few splits at the time when first generation midges are searching for egg-laying sites. Fewest cocoons were found in plots where the first replacement

canes were also removed. In plots where dinoseb-in-oil had been used to destroy canes there was a greater proportion of dead cocoons than in plots where canes were cut out or left untreated. This suggests that dinoseb-in-oil may also have a direct insecticide effect on midges in the soil.

Chemical control

Two chemical control trials were done at SHRI on an established plantation of cv. Glen Clova. In the first trial six treatments were applied to part of the plantation where all the fruiting canes had been removed in March. The treatments, applied to single row plots, were 8% tar oil winterwash (5 February); HCH 0.1% a.i. (10 June); fenitrothion 0.05% a.i. (11 June); fenitrothion (0.5% a.i.) applied twice (18 July and 2 August) and an untreated control. All treatments were applied by tractor-mounted sprayer at a rate equivalent to 1123 l/ha (100 gal/ac) except the tar oil winterwash which was applied at 913 l/ha (81 gal/ac). Fenitrothion applied on 11 June killed 96% of first generation midge larvae under the epidermis. However, assessments of second and third generation midge damage in November by scraping the epidermis to reveal midge feeding sites showed that only late sprays of fenitrothion (18 July and 2 August) had significantly decreased damage.

Fewer overwintering cocoons were recovered from the soil from plots which had received fenitrothion sprays than from the tar oil winterwash, HCH or untreated control plots.

In a second trial, 8% tar oil winterwash, HCH (0.01% a.i.) HCH+tar oil winterwash, diazinon (0.11% a.i.), chlorpyrifos (0.08% a.i.), triazaphos (0.04% a.i.) and fenitrothion (0.05% a.i.) were tested. All chemical sprays were directed at the basal 75 cm of the plant and applied with a knapsack sprayer to run-off at a rate equivalent to 1380 l/ha, except for tar oil which was applied by tractor-mounted spray at 913 l/ha. In this trial fairly low levels of midge attack were found when the canes were scored in November and none of the treatments significantly reduced damage.

Distribution

Previous surveys for raspberry cane midge in 1973 and 1974 showed that the main area of infestation was confined to eastern Perthshire, southern Angus and Lanarkshire. In a wider survey for midge in July and August 1976, samples were taken from 31 cv. Glen Clova and 52 cv. Malling Jewel plantations throughout Scotland. Plantations in the north east, south west (except Lanarkshire) and the south east of Scotland were generally free of midge but plantations in Angus, Perthshire, Fife and Lanarkshire were heavily infested. Generally, Glen Clova supported larger populations of midge than Malling Jewel. Many growers had attempted to control the first generation of midges with HCH sprays in the spring, but this treatment appeared to have been generally unsuccessful, many of the treated plantations having large numbers of midge infested canes.

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

Raspberry mite

Changes in the numbers of raspberry mite, *Phyllocoptes gracilis*, were again assessed on leaves of both fruiting and primocanes of unsprayed raspberry cv. Malling Jewel. Although the numbers of mites on the leaves followed a similar trend to those of the previous year, the maximum mean number of mites per primocane leaflet was only 104.5, compared with over 500 mites per leaflet in 1975. There were fewer predatory mites (*Typhlodromus pyri*) on the leaves of the primocanes in the late summer compared with 1975, although greater numbers were present on the leaves of the fruiting canes in late May and in June than at the same time in 1975. Damage symptoms appeared to be less severe than in 1975.

(S. C. Gordon).

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

Potato

Aphid arrival in potato crops was monitored at two sites at SHRI (main crops) and at three sites nearby (early crops). Potato aphids first colonised crops about a week earlier than in 1975. Again the numbers of *Myzus persicae* and *Macrosiphum euphorbiae* frequently exceeded the 'spray threshold' (five *M. persicae* or ten *M. euphorbiae*/100 hills) before crop emergence was complete. In contrast with 1975 there was a very close agreement between the 'spray threshold' date (1 June) estimated from crop sampling at SHRI, and the date when the first *M. persicae* was caught by the SHRI 12.2 m suction trap (31 May). However, the trap caught only one specimen of *M. persicae* during the period when winged aphids were accumulating on the crop, and the next *M. persicae* was not caught until 2 July. The maximum numbers of spring migrants at SHRI were found on potatoes in the second week of June.

Aphid populations reached their maxima at the end of the first (*M. persicae*) or second (*M. euphorbiae*) week of July. Numbers of winged *M. persicae* produced on the crop reached a peak on 19 July. Greatest numbers of *M. persicae* were caught in the 12.2 m suction trap a few days later. Ten water-filled yellow pans placed along the headland of the sampled potato crop caught only one *M. persicae*/trap during the first migration, but caught large numbers during the later migration of winged *M. persicae* which had developed on the crop.

(J. A. T. Woodford).

An experiment was started to determine the efficiency of aphicides in preventing the spread of potato leaf-roll virus (PLRV). The experiment was done in a 0.2 ha (0.5 ac) crop of FSI cv. Maris Piper. The centre position of the middle four rows of each of nine plots was planted with a tuber of cv. Up to Date, infected with PLRV. Disulfoton granules were incorporated into the drill at planting at a rate equivalent to 1.1 kg a.i./ha (1 lb a.i./ac).

Disulfoton granules did not decrease the numbers of winged *M. persicae* and *M. euphorbiae* found on potato plants in early June but did prevent aphid multiplication for about 10 wk after planting. On 28 September six tubers from six hills on either side of each infector plant were collected and stored for growing on in 1977 to record the spread of PLRV in each plot.

(J. A. T. Woodford, B. D. Harrison¹, L. F. Salazar¹).

Field bean

The effect of aphids (*Aphis fabae*) on yields of field beans has been investigated over 4 years by applying aphicidal sprays to protect the crop throughout the summer or at specific growth stages. In 1976 the populations of *A. fabae* which developed on untreated plots were small in comparison with those found in 1973 and 1974 and by early August few aphids remained on the crop.

There were significantly fewer *A. fabae* on 26 July in plots which had been sprayed with menazon 40% ec and demeton-S-methyl 58% ec (0.7 l menazon + 0.07 l demeton-S-methyl/560 l water/ha) on 21 July. Earlier treatments had no effect on the aphid numbers at this time and a pre-flowering spray of menazon 40% ec (0.7 l/450 l/ha) applied on 13 June depressed the number of pods and, therefore, the number of seeds/plant. Mean seed weight, however, was correspondingly increased. Overall, none of the treatments significantly increased yield. The average yield of beans in this experiment was 2.89 t/ha (23 cwt/ac). This low yield appeared to be due mainly to the failure to set pods because of the prolonged drought, the plants producing only half as many pods as in previous years.

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

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

Our experiments in 1973-1975 showed that a combination of weekly sprays of 1% emulsion of Albolineum oil and barrier rows of barley are highly effective in protecting *Lilium formosanum* plants from infection by tulip breaking virus and lily symptomless virus. The experiment in 1976 was designed to find a barrier system which would compete less with the growth of the protected lilies. Albolineum was sprayed to run-off at weekly intervals from May to October on single rows of ten *L. formosanum* plants. These 'bait' plants were shielded from rows of infected lilies by barriers of barley at 30 cm or 60 cm or by a polythene windbreak screen (Rokolene) spaced at 30 cm. All three barrier treatments were highly effective in preventing virus spread, but the artificial barrier gave the best result because it caused little decrease in bulb weight in comparison with the barley barriers.

Numbers of aphids caught by sticky traps in the four untreated plots were greatest in the period from mid July to early August, corresponding to the time when most virus was spread to healthy *L. formosanum* which were exposed in successive batches of 10 plants for 3 wk periods (see Virology Section report p. 79).

(J. A. T. Woodford, W. P. Mowat¹).

¹Virology Section.

Estate

W. I. A. JACK

Farming years tend to be remembered for the weather conditions at peak periods of work; 1976 was no exception with the months of June to August being the sunniest, warmest and driest since records were made at SHRI. Despite the problems dry seasons bring, the year was one of good progress in the work of the section as a whole.

As costs continue to escalate greater crop yields are required to maintain profitability and every new technique which can assist in increasing the value of the crop has to be tried. Also, successive cereal crops demand a high standard of hygiene. Accordingly the tram-lining system was introduced at the Institute this year. This allows equipment into the crop at later stages of development without causing damage. It also permits timeliness of spraying operations thus providing more efficient control of diseases, and ensures the production of grain of the highest quality.

Farm and experimental crops

Rain in May gave sufficient moisture to see most crops through to harvest. Despite the summer drought conditions and the high pest and diseases incidence in most crops, the yield reductions that might have been expected did not result.

Farm crops included 35.4 ha (87.5 acres) barley, 8.5 ha (21 acres) hay, 2.8 ha (6.9 acres) grass, 0.8 ha (2 acres) potatoes, 4.1 ha (20.4 acres) fallow; the farm cropping area decreased by 4.3 ha (10.7 acres) from the previous year as more land was required to meet the needs of the field experiments programme.

Despite an open winter, satisfactory clodfree seedbeds were obtained for all spring crops; barley drilling started on 27 February and was almost completed when the weather broke on 10 March and the last field of barley was finally sown on 29 March. Some concern was felt when the crop developed manganese deficiency symptoms, severe outbreaks of mildew (*Erysiphe graminis*), and drought symptoms on some of the lighter land. It was expected that yields would be down on the previous year. Harvesting started on 31 July, 8 days earlier than in 1975 and was completed by 9 August, the earliest and easiest on record at SHRI. In general, samples of grain were of low bushel weight, thin and with little boldness about it. The yield was 5.9 t/ha (47.04 cwt/ac) but quality exceeded expectations and despite being one of the poorest years for quality malting barley since 1968, nevertheless all the grain was sold for malting.

Hay cuttings started on 21 June and baling was completed by 26 June; a second cut from one field was taken in August. It was of excellent quality and was little affected by the drought conditions; the yield of 10.88 t/ha (86.7 cwt/ac) was up 4.28 t/ha (34.1 cwt/ac) from 1975.

Field experiments included 15.1 ha (37.3 acres) raspberries, 5.75 ha (14.2 acres) black currants, 2.2 ha (5.4 acres) blackberries, 2.9 ha (7.2 acres) strawberries, 0.4 ha (1 acre) blueberries, 5.0 ha (12.4 acres) vegetables, 3.3 ha (8.2 acres) potatoes, 1.2 ha (3 acres) field beans, 0.9 ha (2.2 acres) ornamental bulbs, 1.9 ha (4.5 acres) other crops; this shows an increase of 4.2 ha (10.4 acres) on the previous year.

Strawberry picking started the soft fruit season on 29 June, followed by raspberries on 7 July, blackberries and loganberries on 14 July, black currants on 17 July, blueberries on 30 July and finally cranberries on 13 December. The weather was excellent throughout the fruit season with the exception of 13 and 15 July when rain interrupted picking. Losses through botrytis were negligible. The fruit, although smaller than usual, was of exceptional quality and sold readily. The fruit crop sold totalled 16.6 t (16.3 tons) more than 1975 and included 42.5 t (41.8 tons) raspberries, 13.9 t (13.7 tons) strawberries, 4.2 t (4.1 tons) black currants, 1 t (1 ton) blackberries, 0.5 t (0.5 ton) blueberries, 0.3 t (0.3 ton) loganberries.

Potato haulms started to die back early, particularly cv. King Edward on the lighter soils, and the yield was 27 t/ha (10.8 t/ac) down on 1975. Potato lifting was protracted as a result of difficult ground conditions and was completed by early November.

Vegetable trials provided quantities of Brussels sprouts, cabbages, calabrese, carrots, beetroot, French beans and peas, all of which were marketed locally.

Field work was greatly affected by the weather in the last quarter of the year; stubble cleaning operations had to be set aside to allow ploughing to be done when conditions were suitable and most was completed by the time of the freeze-up in early December. The spell of bad weather persisted throughout December and all land work stopped, labour resources then being directed to maintenance operations on roads, fences and buildings.

During the year the estate was enlarged by 5.8 ha (14.4 acre) when No. 2 Holding, East Pilmore, Longforgan, was leased from the Secretary of State for Scotland: a verminproof boundary fence was erected around the property.

New farm equipment acquired during the year included a combine harvester, a bale collector and a chisel plough. Several items of farm equipment were renovated and a tractor-mounted sprayer was designed and built by the farm workshop.

Glasshouse

One of the major problems associated with year-round production of pot plants under glass is the high degree of skill necessary to maintain level

growth and it is a credit to the glasshouse foreman and the staff that, despite difficulties resulting from the very hot summer, all requests for plant material were met.

Plant production at 128,508 was down by 20,000 plants on 1975; 60% of production was for the Virology and Zoology sections. Although 5,000 raspberry plants were raised from root cuttings of virus-tested stock for the SNSA, raspberry plants raised from root cuttings for domestic use fell this year by ca. 10,000 plants which accounted for almost half the reduction in plant production.

During the year investigations were started to try to improve the propagation of blackberries, hybrid-berries and some cultivars of rasp particular cv. Glen Clova, using cuttings.

Although aphids were numerous outside this year, no particular problems were encountered and infestations were readily controlled with nicotine fumigating compound. Whitefly (*Trialeurodes vaporariorum*) was brought under greater control by a combination of techniques: the routine use of resmethrin where possible, the spot treatment of plants with Pynosect 30, and the rather crude but effective method of reducing adult populations by the use of yellow painted labels smeared with Sticktite; also aldicarb, now used as standard treatment on ornamentals at SHRI (1975 Report) was used to good effect on French beans for the first time although with some leaf damage. Other pests such as red spider, black fly and slugs were kept well under control with regular routine management spraying and fumigation programmes.

During the year a new Cambridge style propagation house was erected over the site of the original wooden one with considerable improvement in light penetration and ease of maintenance. Four wooden Dutch-light houses were put up; two were clad with Tygan to provide insect-proof accommodation for stocks of raspberry plants for domestic use, whilst the other two were glazed. Gale-force winds on 28 March caused considerable damage to two of the smaller glasshouses, one of which had to be dismantled completely and the other required extensive repairs.

To overcome problems of drainage in the cold glasshouse area, several tile drains were put in and connected to the existing drainage system.

Information Services

R. J. A. EXLEY

Once again the turnover of the Visual Aids Section has increased and the services of the part-time printer were required for an additional 24 half days during a 12 week period in the summer. Continuation of this trend can only be met satisfactorily by an increase in staff otherwise some form of job vetting or an extension of job completion times will be unavoidable.

For the first time the Institute was represented at the Ayr Flower Show, the premier event of its kind in Scotland. 'Calabrese—a new crop for Scotland' was the Institute's chosen theme, in part because the 1976 Ayr Show provided the venue for the British National Vegetable Championship. The interest shown by the public was almost overwhelming and acknowledgment is due, in particular, to those staff of the SHRI West of Scotland Unit who manned the exhibit.

Visual Aids

A comparison of work analyses shows that Visual Aids were busier in 1976 than the preceding year, and completed more jobs than in any year since records began.

	Jobs	Photography			E.M. Prints	Graphics
		Colour	Monochrome	Diazo		Jobs
1975	1040	2654	708	215	3929	92
1976	1136	4465	2455	318	3413	122

Thirty-six sets of colour transparencies of nematode ultra-structure were completed towards the end of the year, each comprising 15 coloured graphics, 17 electron micrographs, four introductory slides and a printed booklet of lecture notes. Many references have been made acknowledging the quality and techniques used and it is gratifying to know that the package has become a dollar earner.

Specialised photographic activities during the year included time lapse of seedling emergence, growth analysis of tulips and rape, and aerial colour infra-red assessment of field bean crops.

Thirteen exhibition boards were completed during the year for internal and external demonstration purposes.

The production of colour prints from transparencies was introduced as a new service in November using the Cibachrome method but because of the lack of a colour analyzer and automated processor their use will be restricted to display boards for the present.

Some new items of equipment were purchased during the year either as replacements, or to supplement an already proven system, as instanced by a Zeiss illuminator and micro-flash unit apparatus designed for use with the section's Tessovar but also adaptable to the other Zeiss microscopes in the Institute.

Close links were maintained with the Audio Visual Department of Dundee University, and established with the Medical Photography Unit at Ninewells Hospital; acknowledgment of their co-operation and help in the editing of video-tapes and processing of Ektachrome films, respectively, is gratefully given.

T. G. Geoghegan and S. Malecki attended the second ARC Photographers Conference at the John Innes Institute on 9–10 September.

(T. G. Geoghegan).

Library

Library finances were better than previous years which enabled the purchase of 75 books, one new journal subscription and a good stock of British Library loan forms. Several translations of Russian and difficult language papers also were made possible.

During the year meetings were attended of the Scottish branch of ASLIB and the local branch of the Scottish Library Association. A day school on computers in libraries held at Dundee College of Education proved very useful.

A new 'book card' system was introduced. When a book is removed from the shelf on loan, it is replaced by a card recording the author, title, classification number, borrower and section. This system will enable a user to be quickly aware that a book is on loan and not misplaced, and if required, will in the future readily enable an analysis to be made of the number of times a volume has been borrowed.

(Bente Bogen).

Scottish Horticultural Research Institute Association

In common with most other organisations which are financed by subscriptions it was decided that substantial increases in the rates were necessary. Accordingly, at the Annual General meeting of the Association on 12 May it was decided that the Individual membership would be increased to £4, Corporate membership to £8, and it was agreed that Life Membership, with the exception of those already paid up, would be discontinued. After the business of the meeting was concluded papers were read by Institute research staff on 'The qualities that make a new strawberry cultivar' and 'A summary of results from NFT raspberry cultivar trials at SHRI and Brogdale, 1971-75.'

The annual viewing of some of the field experiments took place on 24 July when particular interest was focussed by members on plots of raspberry in the first cropping year of a biennial cropping cycle, which were being demonstrated for the first time.

On 16 December an Association meeting on 'The problems of seedling and plant establishment' was held at the Institute. Various aspects of this subject have been researched for several years at the SHRI but this was the first occasion when an integrated picture of the work has been presented to the membership. Also, a paper based on work at the NIAE clearly showed that improvements in seed drill design were being actively pursued.

Bulletin No. 11 (February 1976)*

'Potato Aphids.'

The biology of potato aphids *by* M. W. Shaw, North of Scotland College of Agriculture, p. 2-7.

Recent trends in the activity of aphids infesting potatoes in south-east Scotland in relation to virus incidence in the crop *by* Lindsay A. D. Sparrow, DAFS, Agricultural Scientific Services, p. 8-14.

The importance of aphid flight behaviour for the spread of potato viruses *by* J. A. T. Woodford, SHRI, p. 15-20.

Biological factors controlling aphid populations of potatoes *by* G. N. Foster, West of Scotland Agricultural College, p. 21-26.

Bulletin No. 12 (July 1976)

Papers presented at a meeting on 'Vegetables for processing' held by the Association on 11 December 1975:

Vegetables for processing—the growers' point of view: Peas and carrots *by* A. G. M. Forbes, Omachie, Kingennie, Dundee, p. 2-8.

Vegetables for processing—the growers' point of view: russels sprouts and cauliflowers *by* J. K. Measures, Sea Acres, Croft Marsh, Skegness, p. 9-14.

The marketing of frozen vegetables *by* M. I. Player, Anglo European Foods Ltd, 19-20 Old Bailey, London, p. 15-16.

The agronomic problems of growing vegetables for specific outlets *by* R. Thompson, SHRI, p. 17-23.

Disease problems in Scotland associated with the pea and carrot crops *by* D. A. Perry, SHRI, p. 24-30.

Effects of weeds and weed control practices on vegetables for processing *by* H. M. Lawson, SHRI, p. 31-34.

*Out of print.

Meteorological Records 1976

01046 *Agro-meteorological recording*

MYLNEFIELD

The summer of 1976 was memorable. During the months of June to August the weather was the sunniest, warmest and driest since records were first made at SHRI. Average windspeeds too were unusually low over this period.

Such are the vagaries of the weather however that there were also some very wet and some very cold months, so that taking the year as a whole it would appear 'average.'

Wind

Windspeeds over the year were about average for the period 1959-74, very high average windspeeds in January and September being offset by low average windspeeds in June, November and December. June was the least windy since records began in 1959.

The highest winds, gusting up to 105 km h^{-1} , occurred on 28 March.

Temperature

The winter of 1975-76 was the fifth mild winter in succession but this current winter of 1976-77 promises to end the series, temperatures in November and December being lower than average. The mean maximum for December was the lowest on record at SHRI.

Although the highest temperature recorded this year has been exceeded in previous years this was the hottest summer since our records began, with both the mean maximum and mean minimum for the period June to August being higher than previously recorded. The lowest temperatures of the year occurred on 5 December when the air minimum was -7.0°C and the grass minimum was -9.5°C .

Rainfall

In Scotland as a whole the period June to August was the driest this century with the exception of 1955. The drought caused a lowering of the yield of some crops, but the depression was not as great as might have been expected, as the pattern of wet and dry months in spring gave many crops a good start, and a plentiful supply of rain in May gave sufficient soil moisture to see most crops through to harvest. The dry spell broke during September and this was followed by the wettest October since 1960.

The estimated* maximum soil moisture deficit during the growing season reached 131 mm in mid-September. This value and that for 1975 (133 mm) were the two largest estimated deficits in the last 17 years, over which period the mean maximum value was 80 mm.

Sunshine and solar radiation

The total of hours of sunshine in 1976 was about average. However, August was the sunniest since records began at SHRI and July was the sunniest since 1955.

The mean total solar radiation received in July and August was similarly the highest since our records began. (D. K. L. MacKerron, G. Nicol).

AUCHINCUIVE

Temperature

Temperatures were higher than average for most of the year with the exception of December which proved to be much colder than normal.

Rainfall

The summer months had a large rainfall deficit resulting in good strawberry picking conditions and a low incidence of *Botrytis* but mildew and dust were troublesome. Rainfall overall for the year was slightly higher than average.

Sunshine

July and August were the sunniest months with well over the average hours of sunshine. However, most other months were heavily overcast, resulting in only a slightly greater amount of sunshine than average for the year.

Note:

We are indebted to the Plant Pathology Department, WSAC, for the collection of meteorological data which this year for the first time includes daily solar radiation and wind speed. (R. J. McNicol).

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

MYLNEFIELD 1976

Month	Temperature										Days Ground Frost	Potential Evap-oration mm	Rainfall		Bright Sunshine		Mean daily Solar Radiation		Windspeed	
	Daily Air maxima		Daily Air minima		0.1m Soil		0.3m Earth		Accumulated Day-Degrees				Total mm	DFA*	Total h	DFA*	mWh cm ⁻²	Mean km h ⁻¹		DFA†
	Mean °C	DFA*	Mean °C	DFA*	Mean °C	DFA*	Mean °C	DFA*	Above 6°C	Below 6°C										
January	6.8	+1.3	0.9	+0.9	2.8	+1.4	4.3	+2.0	21	78	26	6.4	51.6	-8.8	55.8	+3.6	54	17.3	+4.8	
February	6.8	+1.1	1.9	+1.8	2.9	+1.4	4.1	+1.6	18	75	19	11.2	35.0	-8.4	52.3	-24.5	78	13.2	+0.6	
March	6.9	-1.1	1.6	0.0	3.2	0.0	4.8	+0.7	15	74	16	36.5	71.1	+28.0	105.9	+0.9	+166	16.5	+1.8	
April	11.3	+0.1	3.8	+0.7	6.5	+0.2	7.7	+0.8	66	27	13	59.2	22.7	-19.0	140.4	-21.4	337	13.6	-1.3	
May	13.2	-0.6	6.9	+1.1	10.0	-0.1	10.3	+0.2	116	4	5	71.4	82.1	+23.4	134.3	-46.1	341	14.5	+1.3	
June	18.7	+1.8	10.4	+1.9	15.0	+1.2	14.4	+0.9	253	0	1	94.6	16.3	-34.9	183.3	+2.8	481	11.1	-0.8	
July	20.3	+2.0	11.7	+1.8	17.5	+2.5	17.0	+2.0	308	0	0	109.9	51.0	-15.5	252.8	+79.9	529	9.6	-1.4	
August	20.1	+2.2	11.0	+1.2	16.4	+2.4	16.2	+1.6	289	0	0	86.0	13.2	-60.4	230.0	+81.1	433	7.9	-2.0	
September	15.0	-0.9	9.1	+0.6	11.8	+0.2	13.0	+0.4	180	0	0	48.4	87.8	+31.6	91.2	-30.3	212	14.2	+4.1	
October	11.9	-0.8	6.8	+0.7	8.4	+0.2	10.6	+0.9	108	5	5	16.4	13.5	+83.7	81.2	-10.6	+133	11.8	+0.9	
November	7.9	-0.3	1.3	-0.7	3.4	-0.6	5.9	+0.4	22	25	25	0.2	47.8	-10.9	89.8	+24.6	79	8.9	-3.1	
December	3.4	-2.9	0.9	-1.7	0.3	-2.0	2.1	-1.4	0	27	27	0.0	88.3	+23.1	60.2	+15.9	41	8.3	-4.0	
TOTALS	—	—	—	—	—	—	—	—	1396	503	137	—	705.4	+31.9	1477.2	+75.9	—	—	—	

*DFA — Deviation from average 1954-1974.

†DFA — Deviation from average 1959-1974.

‡Includes estimated values.

AUCHINCRAIVE 1976

Month	Temperature °C										Days Ground Frost	Rainfall mm		Bright Sunshine		Mean daily Solar Radiation		Windspeed
	Daily Air maxima		Daily Air minima		0.1m Soil		0.3m Earth		Accumulated Day-Degrees			Total	DFA*	Total	DFA*	mWh cm ⁻²	Mean Kmh ⁻¹	
	Mean	DFA*	Mean	DFA*	Mean	DFA*	Mean	DFA*	Above 6°C	Below 6°C								
January	7.9	+1.2	3.4	+1.3	4.3	+1.3	6.2	+1.3	33	44	13	105.6	+15.3	54.7	+12.0	50.7	15.2	
February	7.2	+0.9	2.5	+1.6	3.2	+1.6	3.8	+0.2	21	55	17	46.4	-21.1	40.2	-33.7	80.7	9.2	
March	7.8	+0.2	1.9	+0.1	3.3	+0.1	5.4	+0.2	22	54	13	74.1	+34.3	88.9	-16.1	198.9	11.2	
April	11.4	+0.3	4.4	+1.2	7.3	+0.8	8.1	+0.8	71	17	11	54.6	+16.4	147.4	-20.6	363.2	9.6	
May	14.1	0.0	7.0	+0.5	10.8	+0.6	10.8	+0.6	143	5	4	77.8	+21.1	144.7	-29.2	412.2	10.3	
June	18.3	+1.2	10.6	+2.1	14.7	+0.7	13.7	+0.7	246	0	0	29.9	-21.9	185.5	-20.8	484.4	11.0	
July	20.7	+3.1	12.9	+2.3	17.2	+1.6	16.1	+1.6	329	0	0	25.7	-44.2	219.3	+47.7	490.3	7.8	
August	21.1	+3.3	10.1	-0.7	15.5	+0.6	15.2	+0.6	294	0	0	17.6	-50.0	260.8	+107.8	467.1	7.0	
September	15.8	+0.1	9.3	+0.5	11.4	+0.5	13.0	-0.1	187	0	3	141.9	+72.5	107.5	-18.2	226.9	9.4	
October	12.7	-0.3	7.2	+0.7	8.5	+0.7	11.1	+0.6	121	3	0	98.1	+27.3	83.5	-16.2	131.4	8.3	
November	9.0	+0.5	3.6	+0.7	4.9	+0.7	7.6	0.0	34	32	15	108.3	+9.3	74.1	+18.5	74.4	8.0	
December	4.2	-3.6	-1.1	-4.1	1.1	-4.1	4.0	-2.1	0	128	24	70.8	-13.1	49.3	+11.0	47.4	6.7	
TOTALS	—	—	—	—	—	—	—	—	1501	338	100	850.8	+45.9	1455.9	+42.2	—	—	

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

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Institutes for Agricultural Research in Great Britain

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

ARC Institutes

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

State-aided Institutes in England and Wales

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

State-aided Institutes in Scotland

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

Abbreviations

AAB	Association of Applied Biology
ACAS	Agricultural Chemicals Approval Scheme
ADAS	Agricultural Development and Advisory Service
ARC	Agricultural Research Council
ARS	Agricultural Research Service
ASLIB	Association of Special Libraries and Information Bureaux
BAPB	British Association of Plant Breeders
BBC	British Broadcasting Corporation
DAFS	Department of Agriculture and Fisheries for Scotland
EM	Electron microscope
ESCA	East of Scotland College of Agriculture
ERCC	Edinburgh Regional Computing Centre
EAPR	European Association for Potato Research
EHS	Experimental Horticultural Station
HEA	Horticultural Education Association
IPCS	Institute of Professional Civil Servants
ISHS	International Society for Horticultural Science
JCO	Joint Consultative Organisation
NFU	National Farmers Union
NFT	National Fruit Trial
NIAB	National Institute of Agricultural Botany
NIAE	National Institute for Agricultural Engineering
NVRS	National Vegetable Research Station
NATO	North Atlantic Treaty Organisation
NSA	Nuclear Stock Association
NSDO	National Seed Development Organisation
RHS	Royal Horticultural Society
SNSA	Scottish Nuclear Stock Association
UC	University of California
VTSC	Virus tested stem cutting
WSAC	West of Scotland Agricultural College

