SCOTTISH PLANT BREEDING STATION

REPORT

April 1979 to March 1980

And the Report to the fifty-ninth
Annual General Meeting of the

SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING

PENTLANDFIELD, ROSLIN, MIDLOTHIAN EH25 9RF
Telephone 031-445 2171

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(in post 31st March 1980)

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* Part-time

DIRECTOR'S REPORT

R. C. F. MACER

In my report last year I described the background leading up to the establishment of the Working Party set up by Her Majesty's Secretary of State for Scotland to review the future requirements for state-funded plant breeding and crop research in Scotland, and to its report in 1978. Early in the year under review the Board of the Society accepted, in principle, the main recommendations of the Working Party. It was then hoped that the Secretary of State would quickly decide whether to accept, or to reject, the recommendations. In the event, and for a variety of reasons, including a General Election followed by a change of Government, the decision of the Secretary of State was delayed until 19th December 1979. His decision, to accept the recommendations, was announced during Question Time in the House of Commons and a paper was subsequently laid in the Library of the House. The paper stated:—

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

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

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

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

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

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

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

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

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

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

I am convinced that my acceptance of the Working Party's recommendation will offer staff at the combined institute a more rewarding future with prospects of more effective research than would be possible under the present organisational arrangements."

The recommendations, when fully implemented, will end the separate existence of the Scottish Plant Breeding Station at Pentlandfield, where it has been situated for twenty five years, and the SHRI at Mylnefield. Both will be amalgamated into a new crop research institute at Mylnefield near Dundee. Therefore, this, the fifty-ninth Report to the Society, will be the last describing a full year's operation of the Scottish Plant Breeding Station.

The building of new facilities will take a number of years and, when appropriate, the research work will be transferred to Dundee. After the Secretary of State's announcement, intensive discussions and planning commenced to put the recommendations into effect. The planning will continue into next year and beyond and the amalgamation will clearly be a complex operation affecting both the professional and private lives of the staff and the research programme of the Station. Assurances have been given to staff about job prospects at Dundee, and locally on the Bush Estate. It is hoped that most staff will transfer to the new institute over a period of years. The future use of the Pentlandfield site has not yet been decided.

As part of the planning process for the establishment of the new crop research institute, the Agricultural Research Council set up a Programme Review Group with a remit to review the existing research programmes of the two amalgamating Sections, and to recommend to ARC and to DAFS the research programme for the new institute. The Programme Review Group, whose membership was:—

Professor J. L. Jinks	ARC Council (Chairman)
Mr W. A. Biggar	ARC Council
Dr G. W. Cooke	ARC HQ
Professor J. D. Hayes	University College of Wales
Professor D. L. Lee	University of Leeds
Professor N. F. Robertson	East of Scotland College of Agriculture
Professor W. J. Whittington	University of Nottingham

met in Edinburgh on 24th-26th March 1980 and its report is awaited.

For part of the year under review there was an embargo on staff recruitment which had an inevitable effect on the Station's research programme but most vacant posts were filled by the end of the year. Also, no major capital investment in buildings or fixed equipment was started, although on-going projects have been completed—sometimes to reduced specifications. This curtailment of building has affected progress with some of the research projects.

It has been possible, however, to complete the up-grading of the Chemistry Department and a Neotec 6350 Infra-red Reflectance Analyser was installed in 1979. SPBS is now the leading station in developing the application of this analytical technique to plant breeding programmes.

All three major crops (Brassicas, Cereals and Potatoes) were grown at the Experimental Station at the Murrays, near Pathhead.

Two potato varieties and five barley varieties were submitted to Plant Variety Rights and National List Trials in 1980. The four potato varieties, the two swede varieties and one of the two barley varieties submitted for statutory trials in 1979 will continue in trials in 1980. The early maincrop potato variety Pentland Squire has now been transferred from category PG (provisional recommendation) to category G (for general use) on the NIAB Recommended List of potato varieties. The spring oat variety Fyne was added to the Provisionally Recommended List of cereal varieties for 1980. The potato varieties Pentland Beauty, Red Pentland Beauty, Pentland Marble and Strath, the oat varieties Etive and Leven, and the turnip variety Ballater, were removed from the National List.

This year the review article is written by Dr T. M. W. Davidson. Dr Davidson retired as Head of the Commercial Potato Breeding Department on 31st January 1980 after a distinguished career in the Station. We all wish Dr Davidson well in his retirement. In the review article Dr Davidson has described work that has been done at the Station on potato viruses and the breeding of virus resistant potato varieties. Mr G. R. Mackay has been appointed as Head of the Commercial Potato Breeding Department to succeed Dr Davidson.

A new Division, Chemistry, was established at the Station on 1st January 1980, incorporating the Chemistry Department. This represents a development of the management structure established in 1977. Dr M. J. Allison has been appointed Head of the Chemistry Division. Dr F. J. W. England and Mr J. R. Love have been appointed Heads of the Agronomy and Administration Divisions, respectively.

I should like to thank Mr G. R. Mackay and his colleagues on the Editorial Board who have edited this Report and who have seen it through the press.

INFORMATION CONCERNING STAFF AND VISITORS

Director

Dr R. C. F. Macer continued to serve as a member of the JCO Arable Crops and Forage Board and as Chairman of its Cereals Committee. He also continued to serve on the Selection Panel of the Scientific Awards Advisory Committee of the Royal Agricultural Society of England, as a member of the NSDO Advisory Committee and as a member of the Board and of several Committees of the Edinburgh Centre of Rural Economy.

He completed his term as External Examiner in the Departments of Agricultural Botany and Agricultural Genetics of Queen's University, Belfast, Northern Ireland, and he continued as External Examiner in the Department of Genetics in the University of Birmingham.

Staff

Dr T. M. W. Davidson retired as Head of the Commercial Breeding Department of the Potato Division.

New appointments during the year were: M. F. B. Dale, B.Sc. (Higher Scientific Officer); D. C. Cuthbertson, D. J. Hall, Miss G. Horne, Miss A. McRitchie and Miss M. L. Williamson (Assistant Scientific Officers); R. Blyth and J. Doyle (Agricultural Workers).

Resignations included: Mrs R. M. Hine, B.Sc. (Higher Scientific Officer); Miss C. M. MacParland (Assistant Scientific Officer); Mrs I. Davidson (Experimental Worker); L. W. Fenty (Assistant Craftsman); Mrs J. E. Heritage (Shorthand Typist); M. C. Osinski and W. Russell (Agricultural Workers).

The following were promoted during the year: R. J. Killick to Principal Scientific Officer; Mrs D. J. Barclay, Miss F. M. Bruce, J. Brown and G. E. L. Swan to Scientific Officers and D. H. Goodall to Tractorman.

New Qualifications

Miss F. Mathison, Miss J. E. Middlefell, Miss D. C. Page and Miss E. A. Young obtained HNC in Biology. Miss Middlefell was awarded the Preece Memorial Prize by the Institute of Biology as the highest placed student in the HNC Biology examinations in Scotland.

Miss C. E. Anderson, Miss D. J. Fullerton, Miss D. L. Harris, Miss M. E. Pearce, Miss S. Milligan and A. C. Wilkinson gained ONC Biology.

Visitors

There were a number of visitors to the Station during the year from ARC Headquarters, including Mr G. Jenkins, ARC adviser on plant breeding, Dr J. Ingle, ARC adviser on plant physiology, Mr D. C. M. Corbett, ARC adviser on plant pathology and Mr E. Long, formerly editor of ARC publications.

Other visitors included Dr L. Fowden, F.R.S., Director of RES who delivered the Ninth SSRPB Lecture (*Ann. Rep. 1978-79,* 159-168); Dr J. Bowman of Nickerson RPB Ltd. to discuss rape breeding; Dr L. W. Briggle from the USDA to discuss cereal and potato breeding; Dr R. Mackie of the Wolfson Micro-electronics Unit, Mr L. Marsh of NIAE and Mr C. Nicholas of ERCC to discuss computer-linked data capture techniques; Dr J. Bowman, Dr P. Gymer, Dr R. Marshall and Mr D. C. Myers of Nickerson RPB Ltd. and Dr A. Rhodes, Miln Marsters to discuss small scale malting quality tests; Dr G. Bathgate of Moray Firth Maltings and Dr A. C. Brown of H. J. Heinz & Co. Ltd. to see the Comparamill; Dr I. Morrison, HRI, and Mrs C. Starr, PBI, to study the operation of the Neotec 6350; Dr J. M. McEwan, DSIR, New Zealand, to discuss exchange of cereals; Dr R. C. Close, Lincoln College, New Zealand, to discuss cereal diseases; Dr R. J. Mitchell of St Andrews University to discuss plant collecting in China; Mr J. Cameron and Mr R. I. Sandilands, President and Deputy General Secretary, respectively, of the NFU of Scotland to see the work of the Station; Professor P. M. A. Tigerstedt of the University of Helsinki, Finland, to discuss brassica breeding and cytogenetics; Mr J. Rossiter of GRI to discuss the testing of brassicas for South American conditions; Dr G. A. M. Sharman and Mr W. J. Lawson, RRI, and Mr J. Eadie, HFRO, to discuss collaborative brassica grazing trials; Mr K. Kozicki and Mr A. Urquhart of Scottish Agricultural Industries Ltd. to discuss developments in leafy brassicas; Dr J. C. Holmes, ESCA, to discuss collaborative work with the joint Scottish Colleges; Dr P. A. Portmann from the Department of Agriculture, Western Australia and Dr K. W. Campbell of Agriculture Canada, from Manitoba, to see the work of the Cereal Department; Dr E. J. M. Kirby and Miss M. Appleyard from the PBI to discuss collaborative work on barley physiology; Mr G. Grantham, Chairman of the PMB and Mr I. Dodd and Mr D. Edwards, Nickerson RPB Ltd., to see the work of the Potato Division; Messrs J. Trip, J. Vollema and R. Dankerts of ROPTA Plant Breeders, The Netherlands, and Ir. W. Prummel from B.V. Verenigde Kweekbedrijven, The Netherlands, to discuss potato breeding; Dr C. Brown of the CIP, Lima, Peru, Miss Y. Gonenc, CIP, Turkey, and Mr D. S. Rogers-Lewis and Mr C. F. Hayward from Terrington EHF to see potato work and give a seminar on their work on potato varieties; Dr J. Philis of The Agricultural Research Service, Cyprus, to discuss potato nematology; Ing. D. Z. Maat, IPO, The Netherlands, and Mr A. Gartland from Mueem Research Station, Norway, to discuss work on potato viruses; Mr H. Kawanami of the

Co-operative Agricola Cotia C.C., Sao Paulo, Brazil, to see the potato breeding work; Mr M. Masson of the Société Clause, France, to discuss dihaploid potatoes; Dr I. Brown and Miss D. Williams from the Department of Forestry, University of Aberdeen, to discuss cytological procedures; Dr J. Sebesta of the Research Institute for Plant Production, Czechoslovakia, to discuss cereal pathology and breeding; Dr D. U. Khan and Mr S. A. Moquit from the Bangladesh Development Corporation to see the work of the Cereal and Brassica Departments; Mr K. Anthony, ODA, to consider the role of the SPBS in overseas programmes; Mr M. Davidson of Maxwell Davidson Ltd. and Messrs E. M. Achten, N. Versteeg and A. Daelemans from the Heidemy Group, The Netherlands, to discuss breeding for malting quality in barley; Messrs H. Spychiger and A. Bartschi from Huswil, Switzerland, to discuss potato harvesting machinery.

There were visits from several groups, including a group of Directors of SARI, to see and discuss the Neotec 6350; a number of visits from NSDO personnel to discuss trials, seed multiplication and the promotion of brassicas, cereals and potatoes; a party from the BAPB and from the AAB residential meeting in Edinburgh to see demonstrations of various aspects of the work at the SPBS; two groups from the SHRI on fact-finding visits; the ARS Brassica Breeders and Cereal Breeders, meeting in Edinburgh and at the SPBS respectively, to see breeding and related work on these crops; the Advisory Committee to the Fourth International Barley Genetics Symposium, 1981, representing agricultural research, industrial and other interests in the Edinburgh area, which met at the SPBS; a group from the Scottish Potato Trade Association and a party of Swedish Potato Growers to see the work of the Potato Division; the Potato Processors Association Technical Group, PBI and DANI potato breeders to discuss collaborative trials of advanced potato clones. In addition several members of staff demonstrated various aspects of SPBS work to parties of university students from the Departments of Genetics and Zoology, Manchester; the Departments of Genetics and Plant Biology, Birmingham; the Institute of Genetics and Department of Botany, Glasgow; the Department of Botany, Aberdeen; the Edinburgh School of Agriculture; the Deventer Agricultural College, The Netherlands, and the Department of Botany, WSAC.

Visits abroad

S. Gowers, W. H. Macfarlane Smith and Miss C. J. Williamson attended the Eucarpia Conference, "Cruciferae 1979" in Wageningen, The Netherlands. Dr Gowers presented two papers, one entitled "Self-incompatibility in *Brassica napus* and another (with Mrs D. Barclay) entitled "The induction of flowering in swedes (*Brassica napus* ssp. *rapifera*)". Dr Macfarlane Smith presented a paper on behalf of I. H. McNaughton entitled "The current position and problems in the breeding of *Raphanobrassica* (radicole) as a forage crop".

G. R. Mackay visited Valencia, Spain, and La Pueblo, Majorca, to inspect SPBS potato trials and discuss collaboration with L. Matutano S.A.

A. M. Hayter spent three months at Gore, New Zealand, selecting and harvesting SPBS barley breeding material.

Miss H. E. Stewart visited the Swedish Seed Association at Svalov, and the University of Agricultural Sciences, Uppsala, Sweden, to study research in progress on potato late blight.

M. J. Allison and I. A. Cowe attended a Neotec 6350 Training Course at Silver Springs, Maryland, USA.

Conferences, Visits and Lectures within the UK

The Plant Breeding Group of the AAB and the FBPP held a meeting on "Screening Techniques in Plant Breeding" in Edinburgh from 3rd-5th July 1979. Staff of the Station played a major role in the planning, organisation and running of the meeting, and in providing papers. The meeting was organised by R. J. Killick, F. J. W. England and W. Spoor (ESCA). The Director and R. N. H. Whitehouse both chaired sessions and the following papers were read by members of staff: "Two screening tests for endosperm attributes of barley that relate to malting quality", by M. J. Allison; "Breeding for tolerance to low soil pH in barley", by R. P. Ellis; "Screening methods for cytological variation in plant breeding", by C. P. Carroll and J. A. Fantes; "Screening potatoes for resistance to potato cyst-nematodes", by J. M. S. Forrest, M. S. Phillips and L. A. Wilson; "Exploration of breeding systems", by G. R. Mackay and C. J. Williamson; "Assessment of resistance to late blight of potatoes", by H. E. Stewart and R. L. Wastie; "Screening for resistance to potato storage diseases", by R. L. Wastie and H. E. Stewart.

The first meeting of ARS Brassica Breeders was arranged by the Scottish Plant Breeding Station and was held at Pollock Halls, Edinburgh, and SPBS on the 19th and 20th September 1979. A total of twenty one members attended, including representatives of ARC Headquarters, PBI, NVRS, WPBS and SHRI. The Director, Dr Macer, welcomed the delegates. Papers, followed by discussion, were given by Dr Macfarlane Smith (SPBS), Dr Macer (SPBS), Dr Wills (SHRI) and Dr Crisp (NVRS). A visit was made to laboratories at Pentlandfield, and to Brassica Department trials at the Murrays.

The fifth meeting of ARS Cereal Breeders was held at Pentlandfield and the Murrays on 30th and 31st July with thirty six people taking part.

F. J. W. England, J. M. S. Forrest and M. J. C. Asher attended the AAB seventy-fifth anniversary meeting "Advances in crop production and crop protection" at the University of Reading. J. M. S. Forrest presented a paper on "Practical problems associated with breeding for resistance to potato cyst-nematodes".

F. J. W. England, I. H. McNaughton, Miss H. E. Stewart, Miss R. M. Solomon and Miss L. A. Wilson attended the FBPP meeting at the University of Leeds, entitled "Methods in Plant Pathology". Miss C. J. Williamson and Mrs C. L. Ross provided demonstrations at the meeting.

G. R. Mackay, R. J. Killick, R. L. Wastie, Miss C. J. Williamson, Miss I. B. Majewicz and Miss R. M. Solomon were present at the joint AAB/FBPP meeting "Breeding for resistance to virus diseases".

C. P. Carroll and M. J. De Maine attended the Second International Haploid Conference at Norwich where M. J. De Maine contributed a poster demonstration. C. P. Carroll also visited the FRI to discuss aspects of potato quality.

R. P. Ellis attended the Society for Experimental Biology's annual meeting where he presented a paper on "The development of barley in Scotland and England".

J. H. W. Holden attended the ADAS meeting, "Early potato production" in Tenby, Pembrokeshire, the PMB meeting in London on "Potatoes for Export" and the AGM of the BAPB in Peebles, Scotland. He also visited Birmingham University and RES to discuss micropropagation and protoplast culture in potato breeding.

The Director, R. C. F. Macer, R. N. H. Whitehouse and Mrs D. J. Barclay attended the Open Day on "Plant Breeding" at NVRS, Wellesbourne.

From the Chemistry Department M. J. Allison and R. H. McHale visited the FRI, Norwich, and the NIAB, Cambridge, to discuss work on potato glycoalkaloids and I. A. Cowe visited the PBI, Cambridge, and the Flour Milling and Baking Research Station, Chorleywood, to discuss techniques in infra-red reflectance analysis.

I. H. McNaughton and W. H. Macfarlane Smith visited the RRI, Aberdeen, to inspect grazing experiments and discuss work on toxic factors in brassicas, and W. H. Macfarlane Smith also visited Nickerson RPB Ltd., and Germinal Holdings, Cranwell, to discuss brassica breeding in general.

Miss C. J. Williamson visited the WPBS to discuss *Poa* breeding and the breeding and pathology of brassica crops. J. E. Bradshaw and R. Borzucki also visited WPBS, to discuss toxic factors in brassicas, and J. E. Bradshaw evaluated direct-drilled brassica crops at Scottish Agricultural Industries Ltd., Dumfries.

J. M. S. Forrest spent two days at RES and the PBI discussing potato cyst-nematodes and Miss I. B. Majewicz visited the NIAB, EMRS and the SHRI to learn details of the work with potato viruses. Miss L. A. Wilson spent some time at the Botany Department, University of Edinburgh, studying tissue culture techniques.

R. P. Ellis visited the PBI to discuss collaborative work on barley physiology.

D. W. Speed attended a conference of ARS Safety Officers in London and an ARC Safety Seminar at the HFRO.

Several members of staff gave lectures to external bodies; these included the Director, on "Plant Breeding—the way ahead in crop production" to the Yorkshire Philosophical Society, "The Work of a Plant Breeding Station" at the Botany Department, University of Edinburgh, and "Limits of World Food Production" to the Science Studies Unit at the University of Edinburgh.

R. N. H. Whitehouse presented a paper jointly with W. H. Macfarlane Smith and S. Gowers to the JCO Grassland and Forage Committee, meeting at the Grassland Research Institute, Hurley. The paper was entitled "Research needs for plant breeding in forage brassicas and fodder beet".

J. H. W. Holden delivered a course of twelve lectures to Honours students in the Department of Botany at the University of Edinburgh and was elected an Honorary Fellow of the Faculty of Science of the University. He also gave a talk to the Italian Potato Trade Delegation on potato breeding at Pentlandfield.

F. J. W. England, G. R. Mackay and R. P. Ellis gave lectures on aspects of plant breeding to students at the Department of Agriculture, University of Aberdeen.

G. R. Mackay, J. E. Bradshaw and R. P. Ellis also gave talks on seed production techniques to M.Sc. students at the Edinburgh University School of Agriculture.

W. H. Macfarlane Smith spoke at a seminar of ARS brassica breeders on "The validity of trial methods, the lack of uniformity between trials and the need for greater co-operation".

A. M. Hayter gave a lecture to the British Association for the Advancement of Science entitled "Barley breeding requirements for Scotland" and, on the occasion of the ESCA Open Day, a lecture on "Barley breeding for Scotland". He conducted a seminar on the same topic with students at the Edinburgh University School of Agriculture.

I. A. Cowe gave a talk to students at the Department of Botany, University of Edinburgh, on "Screening techniques in the chemical assessment of malting barley".

Seminars

Winter seminars included "Uniformity trials with potatoes", by R. J. Killick (SPBS); "The production of monosomic and disomic addition lines of *Brassica campestris*", by J. A. Fantes (SPBS); "Techniques in infra-red analysis: use of the Neotec Infra-red Scanner in the analysis of biological materials", by I. A. Cowe (SPBS); "Use of protoplast-systems for studying the behaviour of plant viruses", by Dr B. D. Harrison (SHRI) and "Mechanization of the potato crop", by Mr D. C. McRae and Mr A. J. Hamilton (SIAE).

Membership of Committees

R. N. H. Whitehouse continued as a member of the International Organising Committee and as Chairman of the Executive Committee of the Fourth

International Barley Genetics Symposium, 1981. Several other members of staff served on the Executive Committee. Mr Whitehouse also continued to act as co-editor of the *Eucarpia, Cruciferae Newsletter*.

J. H. W. Holden served as a member of the Potatoes Committee of the JCO Arable Crops and Forage Board and as a member of the BAPB Potato Committee and was Chairman of the Breeding and Varietal Assessment Section of the European Association of Potato Research.

Miss J. F. Malcolmson continued to serve on the Scottish Joint Committee for National Certificates and Diplomas in Biology and on sub-committee E (Infraspecific) of the International Mycological Association.

F. J. W. England continued to act as co-ordinator for the BAPB spring barley trials during the year and as convener of the plant breeding group of the AAB up until July 1979.

A. M. Hayter served on the BAPB Cereals Group Committee.

R. J. Killick acted as a committee member of the Plant Breeding Group of the AAB.

W. H. Macfarlane Smith served as a member of the Eucarpia Crucifer Genetic Conservation Group.

J. M. S. Forrest continued to serve on the Nematology Group Committee of the AAB and as a member of the ADAS Potato Nematode Working Party.

M. J. C. Asher continued as a member of the JCO Cereal Diseases Working Party and was elected to the Committee of the Federation of British Plant Pathologists.

Courses attended

A number of staff attended SRC/ARC management training courses and an ARC Selection Interviewing course. Several members of staff also attended Fortran programming and other computer courses at ERCC. Day-release courses leading to City and Guilds, ONC and HNC qualifications continued.

Visiting research workers and students

Dr W. F. Bourne of the Lanchester Polytechnic spent four months as a visiting research worker in the Potato Pathology Department working on bacterial soft rot in potato tubers.

Miss J. C. M. Rose, a CASE award student at the Botany Department, University of Glasgow, and Miss S. M. McFarlane, a sandwich student at Napier College of Commerce and Technology, Edinburgh, also spent several months working in the Potato Pathology Department, on resistance to blight in tubers and foliage and on potato cyst-nematode resistance.

Mr C. R. Tapsell, a CASE award student from the Department of Genetics, University of Birmingham, and Miss K. Buick, a sandwich student from the Dundee College of Technology, both spent several months working in the Cereals Department, the former on cross prediction in barley and the latter on the physiology of barley development.

Mr S. Ng, a sandwich student from the Sheffield City Polytechnic, worked for six months in the Data Preparation and Statistics Unit writing programmes for the Wang computer.

Miss M. Vettriano, a sandwich student from the Dundee College of Technology, spent some time working in the Chemistry Division on potato glycoalkaloids.

Mr R. Bain and Miss C. Johnston, both final year honours students at the University of Edinburgh School of Agriculture, carried out projects in the Potato Pathology Department.

Mr A. Ould Ramoul, from Algeria, studying for one year at the University of Edinburgh, spent some time in the Potato Breeding and Pathology Departments.

Dr W. J. Thomson, a former CASE award student from the University of Stirling, completed his postgraduate studies and was awarded the degree of Ph.D. for his thesis, entitled "The effect of day length on apical development and grain production in barley cultivars".

COLLABORATORS

This list of collaborators in the work of the Station includes farmers, landowners, colleges and official organisations who have provided field facilities, and workers in universities and official and industrial laboratories who have provided valuable scientific help. We hope that the list is complete, and to all collaborators, named or (perchance) unnamed, we offer our thanks.

(a) Agricultural Research Council Institutes

There has been direct collaboration during the year with the fourteen ARC and State-aided Institutes marked with asterisks in the list on pp 115-16.

(b) Other official bodies

Agricultural Development and Advisory Service at Bangor, Cambridge, Wolverhampton, Leeds, Newcastle and March, Cambs.; and at Gleadthorpe, Terrington and Arthur Rickwood Experimental Husbandry Farms.

Department of Agriculture and Fisheries for Scotland, Agricultural Scientific Services, Edinburgh.

Department of Scientific and Industrial Research, Crop Research Division, New Zealand.

Edinburgh Centre of Rural Economy.

Forestry Commission, Northern Research Branch, Edinburgh.

National Institute of Agricultural Botany, Cambridge, Cockle Park and Headley Hall.

National Seed Development Organisation, Cambridge.

Potato Marketing Board, London.

Royal Botanic Garden, Edinburgh.

Swedish Seed Association, Svalöf.

(c) Universities and Colleges

Agricultural Research Council Unit of Statistics, Edinburgh University.

Birmingham University, Department of Genetics.

East of Scotland College of Agriculture, Edinburgh.

Edinburgh Regional Computing Centre.

Edinburgh University, School of Agriculture, Department of Botany and Wolfson Micro-electronics Unit.

Heriot-Watt University, Department of Brewing and Chemistry.

Imperial College of Science and Technology, London, Department of Zoology and Applied Entomology.
Newcastle upon Tyne University, School of Agriculture.
North of Scotland College of Agriculture, Aberdeen.
University College of Wales, Aberystwyth.
West of Scotland College of Agriculture, Ayr.

(d) Industrial Collaborators

American Calan Inc., Route 4, Northwood, New Hampshire, USA.
Brewing Research Foundation, Redhill, Surrey.
Calan Electronics Ltd., near Ormiston, East Lothian.
Dalgety Agricultural Research, Timaru, New Zealand.
East Coast Viners Grain, Ltd., Drumlithie, Stonehaven, Aberdeenshire.
J. E. England and Sons (Wellington) Ltd., Perthshire.
Fisons Ltd., Levington Research Station, Ipswich, Suffolk.
Flour Milling and Baking Research Station, Chorleywood, Herts.
Fridlington Farms Ltd., Plantation Farms, Sheriff Hutton, Yorks.
Golden Wonder Ltd., Broxburn, W. Lothian.
H. J. Heinz Co. Ltd., Hayes Park, Hayes, Middlesex.
Miln Marsters Group, Chester.
Moray Firth Maltings, Inverness.
Nickerson RPB Ltd., Lincs.
Pauls and Sanders Ltd., Key Street, Ipswich, Suffolk.
Potato Processors Association, Food Manufacturers Federation, London.
Rahr Malting Co. Inc., Shakopee, Minneapolis, Minnesota, USA.
Saphir Foods Ltd., Lime Walk, Long Sutton, Lincs.
Scottish Agricultural Industries Ltd., Edinburgh.
Sinclair McGill (Scotland) Ltd., Ayr.
A. H. Worth Co. Ltd., Manor Farm, Holbeach Hurn, Nr. Spalding, Lincs.

(e) Individuals

J. Black, Drochil Castle, Peeblesshire.
A. Baird, Ardoch Farming Company, Springbank Farm, Braco, Perthshire.
J. Craigs, Tritlington Hall, Tritlington, Northumberland.
T. Dale, Scoughall, North Berwick, East Lothian.
Professor S. Desborough, University of Minnesota, USA.
V. Evans, Bubbleton, Penally, Dyfed.
G. Finlay, Shanwell Farm, Tayport, Fife.
J. Barclay Forrest, Whitemire, Duns, Berwickshire.
A. Gordon, Balmuchy, Fearn, Ross and Cromarty.
J. S. Graham, Queenstonbank, East Lothian.

E. Jones, Lunnon Farm, Lunnon, Swansea.
D. Killen, Kittles Home Farm, Penrice, Glamorgan.
J. F. MacBrayne, West Byres, Ormiston, E. Lothian.
W. McCrone, Cairnside, Kirkcolm, Stranraer, Wigtown.
J. MacFarlane, Flichity Farm, Farr, Inverness.
I. K. MacKenzie, Inverarnie, Farr, Inverness.
Dr P. Mattusch, Institut fur Pflanzenschutz in Gemusebau, Marktweg 60, 5030 Hurth-Fischenich, Fed. Rep. Germany.
R. Miller, Tullochgorum, Inverness-shire.
A. G. Porter, East Scryne, Carnoustie, Angus.
W. H. Porter, West Scryne, Carnoustie, Angus.
J. Riddell, West Peaston Farm, Ormiston, E. Lothian.
T. Rowe and Sons, Over Ardoch, Braco, Perthshire.
C. D. Scott, Waterside, Newburgh, Aberdeen.
C. G. Spence, Biel, Dunbar, E. Lothian.
G. A. Storrar, Rossie, Auchtermuchty, Fife.
B. Thomas, Carswell Farm, Penally, Dyfed.
W. R. E. Thomson, 33 St Mary's Street, Edinburgh.
R. Trotter, Ormiston Mains, Ormiston, E. Lothian.
A. B. Turnbull, Home Farm, Penrice, Glamorgan.

LIST OF ABBREVIATIONS

Organisations:

AAB	Association of Applied Biologists.
ADAS	Agricultural Development and Advisory Service.
ARC	Agricultural Research Council.
ARCUS	Agricultural Research Council, Unit of Statistics.
ARS	Agricultural Research Service.
BAPB	British Association of Plant Breeders.
CIP	International Potato Centre, Lima, Peru.
DAFS	Department of Agriculture and Fisheries for Scotland.
DANI	Department of Agriculture for Northern Ireland.
DSIR	Department of Scientific and Industrial Research (New Zealand).
EHF	Experimental Husbandry Farm.
EMRS	East Malling Research Station.
ERCC	Edinburgh Regional Computing Centre.
ESCA	East of Scotland College of Agriculture.
FBPP	Federation of British Plant Pathologists.
FRI	Food Research Institute.
GCRI	Glasshouse Crops Research Institute.
GRI	Grassland Research Institute.
HFRO	Hill Farming Research Organisation.
HRI	Hannah Research Institute.
IBPGR	International Board for Plant Genetic Resources.
IPO	Institute for Plant Protection Research (The Netherlands).
JCO	Joint Consultative Organisation.
NIAB	National Institute of Agricultural Botany.
NIAE	National Institute of Agricultural Engineering.
NFU	National Farmers' Union.
NSDO	National Seed Development Organisation.
NVRS	National Vegetable Research Station.
ODA	Overseas Development Agency.
PBI	Plant Breeding Institute (Cambridge).
PMB	Potato Marketing Board.
PPA	Potato Processors Association.
RES	Rothamsted Experimental Station.
RRI	Rowett Research Institute.
SARI	Scottish Agricultural Research Institutes.
SHRI	Scottish Horticultural Research Institute.
SIAE	Scottish Institute of Agricultural Engineering.
SPBS	Scottish Plant Breeding Station.

SRC	Science Research Council.
SSRPB	Scottish Society for Research in Plant Breeding.
UCW	University College of Wales.
USDA	United States Department of Agriculture.
WPBS	Welsh Plant Breeding Station (Aberystwyth).
WSAC	West of Scotland Agricultural College.

Others:

CASE	Co-operative Awards in Science and Engineering.
CNS^-	Thiocyanate.
CVT	Co-ordinated Variety Trials (also a computer program for their design and analysis).
DM %	Dry Matter Percentage.
DMY	Dry Matter Yield.
DOMD	Digestible Organic Matter in the Dry Weight.
ECD	European Club-root Differential.
ELISA	Enzyme-linked Immunosorbent Assay.
EMAS	Edinburgh Multiple Access (Computer) System.
EMS	Ethyl Methane Sulphonate.
NLT	National List Trials.
PCN	Potato Cyst Nematode.
PCV	Packed Cell Volume.
PLRV	Potato Leafroll Virus.
PMTV	Potato Mop-top Virus.
PVA	Potato Virus A.
PVY	Potato Virus Y.
SAN	Semi-artificial Napus.
SMCO	S-Methyl Cysteine Sulphoxide.
TRV	Tobacco Rattle Virus.
UV	Ultra-violet.

INDEX OF DEPARTMENTAL REPORTS

AGRONOMY DIVISION

The Agronomy Division provides farm and greenhouse services for the station both at Pentlandfield and the Murrays. Nearly all field trial work is carried out at the Murrays where approximately 40 hectares (out of a total of 133) are in experimental use in any one year. In addition the Division includes the Field Trials Unit and the Statistics and Computing Unit.

The Field Trials Unit carries out, on a "contract" basis, trials of breeders' advanced material of cereals and brassicas and also conducts "invitation" trials for sister institutes and other bodies. It is particularly well equipped for carrying out off-site trials since it has its own transport and small plot machinery.

The detailed reports of the Murrays Farm Unit and the Field Trials Unit appear below, that of the Statistics and Computing Service appears with those of other service units on page 98.

F. J. W. England

Field Trials Unit

Assessment of advanced generation breeding material of cereals and brassicas continued. Cereal drilling was approximately three weeks later than average, as a result of the very unfavourable late March drilling period. Kale and swede trials were sown in the first fortnight of May. Cereal harvests took place through early September, the barleys combining well but the oats were badly battered by the strong winds and rains of early September and grain loss and lodging were severe in the oat trials. Sprouting in the ear was seen in barley at one off-station trial and in the oats at the Murrays. The brassica crops produced only moderate yields but harvest went smoothly.

Cereal and Brassica mildew were the most prevalent foliar diseases, both reached levels that would have necessitated spraying in commercial crops.

The spring barleys yielded about 6·0 t ha^{-1} and the spring oats 5·0 t ha^{-1} which were higher than expected considering the very short spring season. The winter wheats were high yielding, averaging 10·1 t ha^{-1}, one variety yielding 12·3 t ha^{-1}. Coefficients of variation for the thirty two spring cereal trials varied between 2·1 and 7·4 per cent.

The kale and swede trials conducted at three and four centres respectively yielded about 10·0 t ha^{-1} of dry matter. The coefficients of variation for the fresh weight yields were between 3·8 and 13·5 per cent.

Cereal trial collaboration with sister institutes and other bodies expanded and further additional trials will be grown in the future at the Murrays. These will include the BAPB spring oat and winter barley trials and the joint European Genotype × Variety Interaction spring barley trial.

The 1979-80 winter trials were drilled in late November at least one month behind the preferred sowing date. The braird, following the extremely wet and mild early December did not become fully established until late in December. The winter trials now occupy approximately one hectare at the Murrays, about 1,000 plots being handled, a high proportion of these being of winter wheat in connection with the PBI breeding programme. The station does not yet have material for inclusion in winter cereal trials but a winter barley programme has been established.

The station now has available a low loading lorry for general departmental use. It is hoped that this will accelerate the servicing of trial centres at sowing and harvest when heavy equipment requires conveying to the sites.

No new experimental equipment was obtained this past year. The Unit has now been reduced in size from five to four members of staff.

I. M. Chapman
A. Young

Murrays Farm Unit

The winter of 1978-79 was a very cold one and the spring of 1979 was wet, cold and late, in addition autumn rainfall was well above average; these factors led to a late harvest but, in spite of adverse conditions, growth was satisfactory and yields better than usual. The weather during both cereal and potato harvests was reasonable and both operations proceeded with little interruption.

The 17·3 hectares of wheat, *cvs.* Mardler and Score, sown in Potato Shed and Wall fields, overwintered well; both crops received a top dressing of fertiliser (20-10-10) at a rate of 375 kg ha^{-1} at the end of April and were harvested in late September. Both cultivars were sold as one lot, for feeding. The yield averaged 6·48 t ha^{-1}.

Commercial spring barley was sown in Sunnyside and Folly, an area of 25·7 hectares. Sowing began on 17th April and was completed by 20th April. The cultivar was Golden Promise, treated with mildewicide; 375 kg ha^{-1} of grain fertiliser were applied to the seed bed. Growth was good and there was very little disease present. Harvesting began on 13th September and finished on 19th September. The yield averaged 5·47 t ha^{-1}; all the grain was sold for malting and the straw chopped before being ploughed in. In addition to the commercial barley crop a further 22·0 hectares was grown, either as experimental and selection plots or the surrounds associated with them.

Most of our potato area is used for experimental material and this year was grown in Wee Murrays. Planting began on 27th April and was completed on 8th May; 1,255 kg ha^{-1} of potato fertiliser (15-15-20) was broadcast before planting and phorate granular aphicide was applied to the drills before covering. Metribuzin herbicide was sprayed on part of the crop but the wet and windy conditions delayed application in other areas beyond the stage at which it would be safe to spray without risking damage to the crop; as a result a considerable amount of hand weeding was necessary during the summer. Aphicide sprays were applied at fortnightly intervals from early July and routine fungicide applications were made towards the end of the season. The trial of early material was harvested on 24th July and maincrop harvesting lasted from 2nd October until the 21st. Some otherwise unused ground in the field was sown with stubble turnips on 22nd August and these were grazed by sheep belonging to HFRO from 9th November until 14th December.

Brassica trials, this year, were in Crow field. Sowing began on 8th May and finished, with the sowing of the catch-crop brassicas in mid-August. Any spare ground in the field was sown to stubble turnips. The ground used for swede trials received 880 kg ha^{-1} of 22-11-11. Trifluralin was incorporated in the soil before each sowing and chlorfenvinphos at sowing. Despite the latter application there was a considerable infestation of flea beetle and cabbage root fly and some areas had to be sprayed with HCH and chlorpyrifos. Growth of all brassicas was good although marked edge effects were apparent in some trials. Harvesting began at the end of October and, apart from some material required for assessing winter resistance, was completed just before Christmas.

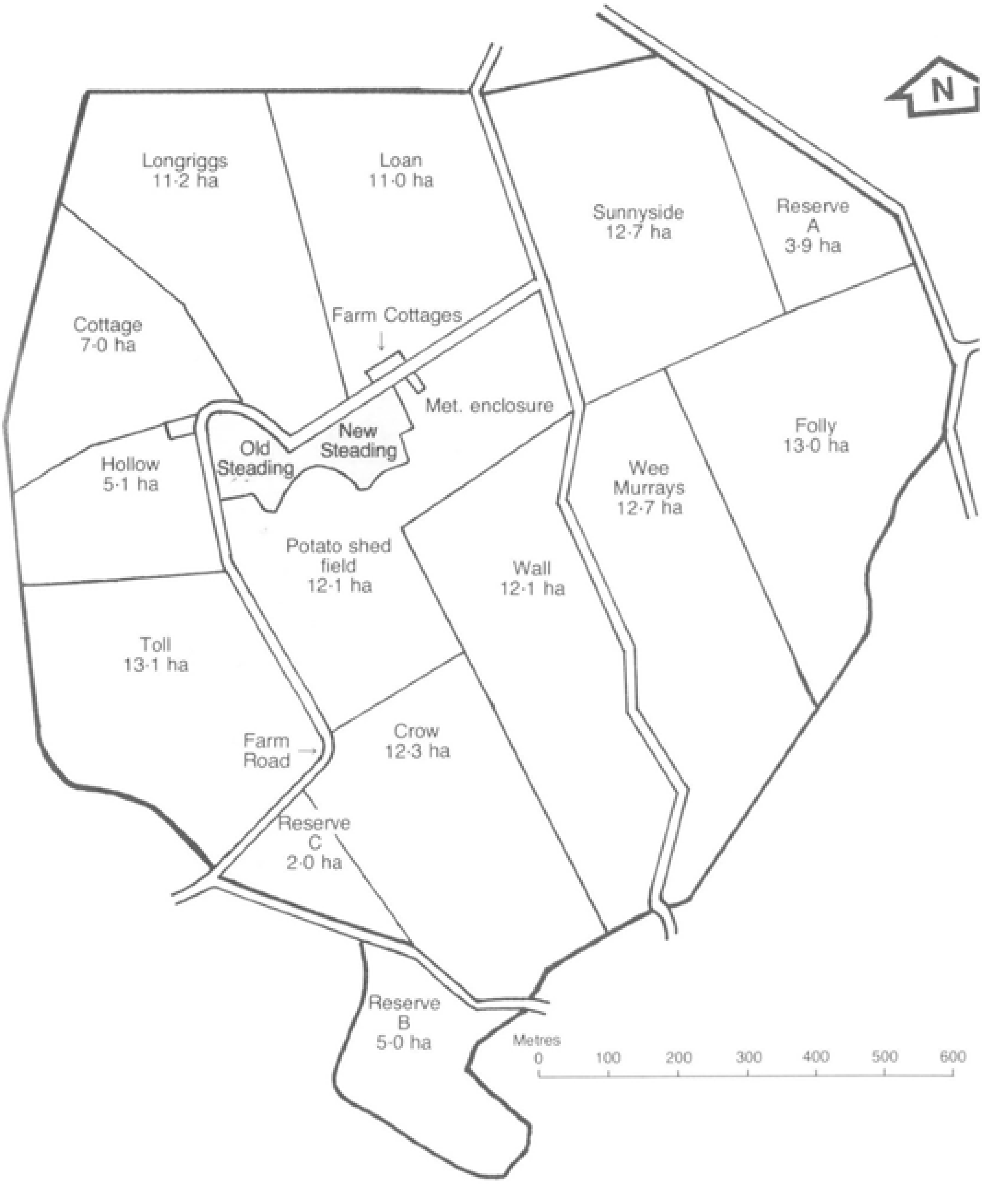
The winter beans, sown in October 1978, were harvested in December and yielded 4·51 t ha^{-1}.

Longrigg and Toll were fallowed to facilitate control of potato ground keepers and couch grass and both were sprayed with glyphosate at the beginning of August and ploughed at the end of that month. Longriggs was sown with winter wheat, *cv.* Mardler, in mid-October except for an area required for spring sowing of cereal pure stocks. Fertiliser (8-20-16) was applied to the seed bed at 314 kg ha^{-1}. The braird was slow but the crop eventually established well. Potato Shed field was also sown with Mardler winter wheat in late October.

Sunnyside and Reserve B were sown with a grass mixture at the end of September and in both fields the crop has established well in spite of the late sowing and there is little frost damage apparent.

G. R. White

Map of the Murrays showing field areas



Meteorological Summary. The Murrays 1979

TABLE 1

Month	*Mean temperature °C* *Max.*	*Min.*	*Mean soil temperature °C* *5 cm.*	*10 cm.*	*Number of days temperature ≤ 0°C* *Air*	*Grass*	*Total rainfall mm.*	*Number of wet days > 1·0 mm.*
January	2·4	−2·8	−0·2	0·5	26	29	23·2	9
February	3·1	−1·6	−0·5	−0·2	19	23	6·5	3
March	5·5	−0·2	1·8	1·8	16	23	83·0	15
April	9·1	2·9	6·1	5·1	4	13	53·9	13
May	12·1	4·6	10·3	8·6	2	8	76·2	16
June	17·0	9·1	14·9	13·7	0	0	22·6	6
July	17·9	10·3	15·4	14·2	0	0	38·6	10
August	16·5	9·0	14·3	13·3	0	0	52·5	12
September	15·8	8·0	11·5	11·0	0	4	16·1	6
October	12·5	7·3	9·0	9·0	0	3	70·6	12
November	8·5	2·8	4·1	4·6	6	12	71·7	14
December	6·4	1·8	2·9	3·3	8	16	84·4	15
Annual total (365 days)	—	—	—	—	81	131	599·3	131
Annual mean	10·6	4·3	7·2	7·1	—	—	—	—

CHEMISTRY DIVISION

Over the past few years Chemistry Division facilities have expanded from an *in vitro* digestibility system and auto analysers for nitrogen and malt enzyme determinations, all housed in one laboratory, to include an increasing development of infra-red analysis and both routine and research work on malting quality occupying a total of five laboratories.

This year further expansion of infra-red work continued with the acquisition of the Neotec 6350, a scanning infra-red analyser. In August 1979, the station demonstration room was converted to a spectral analysis laboratory and the Neotec was installed in this laboratory at the end of August. Since then operators have been trained and the analysis procedure organised to ensure an efficient throughput of work. At the end of the year meetings were held with SARI representatives to promote collaborative work on infra-red analysis. For example, the Neotec can be used to identify the relevant wavelengths for the prediction of quality components by less sophisticated machines.

In addition to infra-red analysis, routine and research work continued on toxic factors in brassicas, and on the role played by milling energy in malting quality. Preliminary investigations were also made this year of methods used to measure potato glycoalkaloids. It is expected that a recently acquired gas chromatograph will help in this work.

It is likely that our infra-red work will expand in the future not only as collaborative work with other institutes increases, but it is also hoped that it will cope with much of the present routine work.

M. J. Allison

Chemistry Department

The work of the Chemistry Department is mainly concerned with the routine analysis of quality factors important in plant breeding. Over the past few years infra-red (IR) techniques have been used increasingly to measure important quality factors, e.g. protein in plants. Because of our success in using a fixed wavelength IR machine, the Technicon "InfraAlyser" to estimate nitrogen in various crops and in screening for low β-glucan content in barley, and the potential of this technique for agricultural research, we acquired a sophisticated continuous scanning IR analyser, the Neotec 6350, at the end of August 1979.

The Neotec 6350 is a computer-controlled spectral analyser capable of measuring up to 1400 reflectance or absorption energies for each sample scanned. The instrument has the ability to display the spectrum obtained and store the energy values for future analysis. Any part of the spectrum between 300 and 2,500 nm can be scanned. The energy values stored on floppy disks can be subjected to various mathematical treatments by the integral Nova 3 computer and a regression analysis can be used to identify the best combination of wavelengths that give a predictive equation with the highest correlation to any constituent of interest. This part of the procedure depends on having a calibration population of samples, that have been analysed carefully by a standard method. It is also important that this population has values evenly spread over the range normally encountered during routine analysis, and that the ratio of range to standard error is greater than 10:1.

Once the wavelengths giving the best prediction of manual values of the calibration population are known, they are used in an equation usually in the form $y = k_0 + k_1 \log 1 + k_2 \log 2$ etc. where y is the constituent of interest k_0, k_1, k_2, etc. are constants and log 1, etc. are logarithms of the reflected or absorbance energies at the chosen wavelengths. Manual and scan data on a calibration population, usually of sixty samples or more, are used to derive the constants in the equation. Unknown samples can then be scanned and the quality constituent predicted. Scanning and prediction is completed at a rate of approximately one minute per sample and up to five constituents can be predicted simultaneously. The Neotec requires about 10 g usually of a milled sample, or it can scan liquids and there is also a solid sample attachment which will, for example, take a whole potato.

At the end of August 1979 the station demonstration room was converted into a spectral analysis laboratory to house the Neotec 6350 as there was no suitable space in the present chemistry laboratories.

In the last few months Neotec procedures have been reorganised and it is expected that a number of analyses can be processed through the Neotec system during 1980. As part of the justification for SPBS purchasing the Neotec it was agreed that it would, to some extent, act as a service to other ARS institutes that have simpler fixed wavelength machines. For example, PBI, Cambridge, now have a Technicon "400" IR analyser with nineteen filters and a readily interchangeable filter wheel. The Neotec could be used to predict fibre content, for example, in brassicas and filters for the relevant wavelengths could be made relatively cheaply and used in the Technicon 400. We have agreed to collaborate in this way with the chemistry department at PBI on aspects of forage and wheat quality. In order to facilitate such collaboration two meetings were held at the end of the year; one, in which the Neotec was demonstrated to SARI directors and a second, more detailed demonstration to a number of heads of departments of SARI institutes. Many useful suggestions resulted from these meetings and it is hoped that IR analysis can be used successfully for at least some of the suggested analyses.

Development of a new milling system for the rapid measurement of kernel hardness of cereals called the "Comparamill" (*Ann. Rep. 1978-79*, 27), in collaboration with Calan Electronics Ltd., was held up continually during the year because of staff shortages at Calan. These problems culminated at the end of the year in notice being given by Calan that they would cease production in the UK early in 1980, and, consequently, the Comparamill would not be produced commercially in the near future. Assurance was given, however, that the prototype developed for our station would be completed. The manufacture of existing Calan Products will be taken over by Amcal Inc. of New Hampshire, USA, and future development of the Comparamill will be considered in this context.

Further investigations of the milling energy of cereals, using the original apparatus, have shown that estimates of the energy required to mill oat samples relate well to the kernel percentage of oats. In contrast to the sharp peak produced on the chart recorder when barley is milled, oats give a distinct peak and "tail" when milled. By stopping the milling operation at different times it was observed that only husk was left in the mill during the tail period. Thus the areas under the tail of the recorder trace can be used for a rapid estimation of husk percentage in oats. However, it is not yet possible to process oats through the Comparamill as the high oil content causes the flour to "cake" round the sieve and the automated cleaning system (flushes of compressed gas) which works well for barley flour, needs to be modified. It was also shown that the energy required to mill winter wheat relates well to particle size index (PSI) measurements which in turn give an indication of baking quality. The milling energy test is faster and uses less material than the PSI test.

It was reported previously (*Ann. Rep. 1978-79*, 27) that an infra-red analysis method (IR) could be used for a rapid screening of barleys that have low contents of acid-soluble β-glucan. Subsequent work done at the Moray Firth Maltings Laboratory has demonstrated that enzymes affecting the viscosity of extracts of barley flour remain active during extraction at pH 1·5. It was confirmed in our laboratory that an endo β 1,3 glucanase is active during extraction. On retesting after enzyme inhibition of samples classified as having a low β-glucan content by IR, it was found that only cultivars with high β-glucan contents showed an increase in extract viscocity after enzyme inhibition. It appears, therefore, that our IR method can still be used as a rapid screen for barleys with a low content of acid-soluble β-glucan. Further work on improving the IR calibration for the rapid prediction of malting quality is in progress. Attempts to assay nitrate reductase in barley leaves as a possible component of yield (*Ann. Rep. 1978-79*, 26) proved unsuccessful because this enzyme is highly unstable.

Routine chemical analysis during the year included digestibility measurements (1,300 brassica samples); Kjeldahl nitrogen (800 brassica and barley samples); malt analyses including α-amylase and diastase determinations (400 barley samples); predicted diastatic activity (900 barley samples); S-methyl cysteine sulphoxide (SMCO) a factor in kale causing haemolytic anaemia in ruminants and thiocyanates (2,100 and 1,000 brassica samples, respectively). In the first six months of the year approximately half of the SMCO determinations were made using an electrophoretic method. While this method is satisfactory when dealing with small numbers of samples it proved to be unsuitable for screening breeding material because of a low throughput due to repeated power pack failures and the necessity of having at least three standard samples on each electrophoretic plate. In mid-summer an automated method first developed by A. F. Gosden of the WPBS, was built and is proving to be more repeatable together with a higher throughput than the electrophoretic method. A start was also made this year in comparing methods, for the measurement of glycoalkaloids in potatoes. It is hoped that a recently acquired gas chromatograph (on loan from the PBI, Cambridge) will play an essential part in identifying the potato glycoalkaloids.

It is likely that some parts of our routine work can be analysed rapidly using IR in the near future.

DAFS Package 4
ARC Project 03002
DAFS Package 1
ARC Projects 04009-04012 inc.

M. J. Allison
I. A. Cowe
R. Borzucki
R. McHale
Miss F. Bruce

FORAGE DIVISION

Brassica Department

As part of the feasibility study of F_1 hybrid swedes, work continued on the introgression and isolation of S-alleles. Plots were also established to estimate the extent to which S-allele heterozygotes were pollinated by a marker line. Inbred lines, the potential parents of future hybrids, were tested for yield. Those from some cultivars outyielded their parents. The effect of inbreeding was examined by testing stocks that had various degrees of selfing. Selection for high dry matter content, following inbreeding, was continued.

Two swede lines completed first year National List Trials. Selections in advanced trials at several sites gave satisfactory performances. A wide range of genotypes has been used as parents of crosses in early generations and strong selection pressures have been applied. Forage rape was used as one parent to introduce disease resistance and other characters into swedes. Attempts to introgress characters from turnips to swedes were largely unsuccessful. Additional cultivars contributed to the swede gene-bank were multiplied or tested.

Trials of traditional turnip lines derived from either a yellow-fleshed or a white-fleshed polycross were grown in trial. The former gave the higher yields and the latter the higher contents of dry matter. Further selections were made. Resistance to club-root is being introduced into traditional turnips from crosses with stubble turnips.

Kale polycross progenies grown in 1978 produced yields and quality assessments similar to the means of six controls. A breeding programme for fodder cabbage has been started.

Forage rape breeding is being established on a pedigree system with natural and artificial *Brassica napus* lines as parents. Material in F_3 was assessed in a replicated trial for field performance and quality characters. Several advanced lines derived from artificial rapes were tested in New Zealand. In a small programme to induce mutations, M_1 plants surviving a chemical treatment were selfed.

Eight new plants of forage rape were synthesised from their diploid component species using embryo culture and colchicine treatment. Estimates of dry matter content of semi-artificial rapes in a late sown (catch crop) trial were rather lower than for existing rape cultivars. A range of semi-artificial rapes was multiplied preparatory to trial in 1980. Selfed progenies of an artificial rape produced in co-operation with Svalöf were studied in observation plots.

Plants of several kinds were examined for suitability as catch crops in comparison with stubble turnips which although quick growing are low in dry matter content. Amongst these were rapes, their hybrids with leafy turnips, selections from traditional-turnip polycrosses and imported material mostly members of the species *B.campestris* but there were few entries to challenge stubble turnips in yield of dry matter although some lines had higher dry matter contents.

Multiplication of a new stock of Crail radish, stabilised for root colour, proceeded but there was insufficient seed to resubmit for National List Trials in 1980. In the quest for a truly biennial fodder radish, selections were made from hybrids with sea radish.

A large assessment programme of a forage crop was undertaken jointly by RRI, HFRO and SPBS using three trial sites and about 200 lambs. The crops, one radicole selection and one rape cultivar, and the animals were carefully monitored with particular attention to crop utilisation, animal health and live weight gain. Although there were no veterinary problems preliminary results showed that, at two of the sites, live weights increased more slowly on the radicole.

Further assessments have been made on toxic components in radicole, the SMCO content being intermediate between rape and kale, and the CNS⁻ content being similar to kale, but no ill effects due to these compounds have been detected in lambs. Creation and selection of new radicole material continued using additional kale and radish parents, and paying attention to the known deficiencies of the varieties selected previously.

Methods of testing for reaction to *Plasmodiophora brassicae* were improved. The use of rooted leaf cuttings was examined. Pathogen populations with various virulences were used to assess club-root resistance in swede, rape, radish and radicole. The importance of some environmental factors in determining the outcome of clubroot tests was investigated. Experimental work with mildew was initiated by growing a field trial in which the dates of infection of three swede cultivars was controlled.

R. N. H. Whitehouse

Studies of Swede Hybrids

SELF-INCOMPATIBILITY

To estimate the degree of outcrossing produced in the field, five isolation plots were set up each with an S-gene line and a marker line. The S-gene lines were heterozygous for self-compatible and self-incompatible alleles, and they were set up at a pollen donor: recipient ratio of one to three. Sibling plants grown in a glasshouse were scored for pollen germination and pollen tube penetration of the stigma, to check that the self-incompatibility as scored by UV-microscopy relates to the degree of outcrossing enforced by self-incompatibility in the field. Seed from the isolation plots will be sown in 1980 to give estimates of outcrossing.

Work on the introgression and isolation of S-allele lines continued, with thirty-five lines being examined for homozygosity and the effectiveness of their S-genes when heterozygous with self-compatible alleles. Homozygous S-allele lines from Bangholm Sahna, Ruta Øtofte and Wilhelmsburger Danila have been produced, and lines from Bangholm Wilby and Fenix should be available in 1980. Based on the results of the 1978 diallel trial, work will now concentrate on producing lines from Criffel, Marian and Pentland Harvester.

The diallel trials carried out so far have been from crosses between cultivars which were rather variable. To produce results which are more dependable requires greater uniformity, and several lines have now been produced which are sufficiently inbred to give more reliable predictions. Plants of eleven lines are being grown on for pollination to produce a half-diallel cross in 1980.

PRODUCTION AND EVALUATION OF INBRED LINES

Six sets of inbred lines were in trial at the Murrays in 1979 for evaluation and selection. First generation lines of Emerald King and second generation lines of Bangholm Wilby, Bangholm Magres, Ruta Øtofte and Marian were examined. Emerald King has a low dry matter content, and, with fresh weight yields only equal to the control varieties Ruta Øtofte and Marian, the dry matter yields were lower. There was little variation in the dry matter contents of the Magres and Marian lines, but in the Ruta Øtofte lines it ranged from 10·1 to 12·8 per cent (parent cultivar = 10·7 per cent). The yields from the selections from Ruta Øtofte and Magres were generally higher than the parental cultivars (mean dry weight yields 5 and 3 per cent higher respectively), but most of the Marian lines were lower yielding, with the mean of the selections being 5 per cent lower. These results may be due to the specialised breeding programme for club-root resistance used to produce Marian.

To examine the effect of inbreeding on a normal mass-selected cultivar, lines from Scotia were multiplied at various levels of inbreeding. Families produced after one, two or three generations of selfing were sown in trial, along with a multiplication of the original selection and also the parent cultivar. As seen from Table 2 selection appears to have overcome inbreeding depression in the first two generations, but not in the third generation. The best third-generation inbreds were, however, equal to the top second-generation lines. These results indicate that two generations of selfing with selection can increase yield and uniformity, and that a third generation of selfing is only necessary when greater uniformity is required, as may be the case for F_1 hybrids.

The dry matter content of F_1 hybrids has been found, in general, to be intermediate between the parents. To produce a high dry matter F_1 hybrid

TABLE 2

Dry matter yields of progenies at various levels of inbreeding, from a single plant of Scotia, compared with the original cultivar

Breeding history from single plant; O = Open-pollinated I = Self-pollinated	*Line Number*	*Mean Yields* t. ha⁻¹*
OO	SC3	10·2
OIO	SC3F	11·5
OIIO	SC3FF†	11·6
	FG	11·6
	FH	11·6
	FI	12·1
OIII	SC3FF‡	11·6
	FG‡	11·1
	FH‡	10·7
	FI‡	11·5
	Scotia	11·0
	S.E.	0·36

* Means of four replications with two entries in each, except five lines with single entry of each.

† Top four families selected from twelve.

‡ Means of five lines bag selfed.

may, therefore, require a parent with very high dry matter content. Work on inbreds with high dry matter content has mainly concentrated on lines from Bangholm Wilby, although a line from Bangholm Magres has been produced which also has good mildew resistance. Further selections from the Bangholm Wilby lines showed much lower dry matter contents in 1979-80 than those reported previously (*Ann. Rep. 1978-79,* 40) but it is assumed that these are mainly due to seasonal differences. The selections had dry matter contents between 11·8 and 13·8 per cent, in comparison to Bangholm (Hurst), one of the highest commercial cultivars, which had a dry matter content of 10·6 per cent. From the regression of dry matter percentage on fresh weight yield, twenty six plants had dry matter contents which were over 1 per cent higher than that expected. These plants will be selfed again to try to increase further the dry matter content and uniformity of these lines.

Swede Breeding

INBRED LINES FROM INTER-CULTIVAR AND OTHER CROSSES

Traditionally swedes are used either for animal or human consumption. In the past it has been assumed that this would require the breeding of both high and low dry matter varieties. There are now indications that high dry matter swedes are suitable for most, if not all, uses, and accordingly much of the emphasis is now on the breeding of high yielding swedes with high dry matter content. However, varietal performance depends on many other factors, and of equal importance are improved disease resistance, faster establishment and growth, better winter hardiness, better storage characteristics, improved suitability both for mechanical harvesting and *in situ* grazing, and, looking to the future, suitability for processing and freezing.

A wide range of new inter-cultivar crosses was made in 1979, the parents used included Ruta Øtofte and Seefelder, as sources of resistance to powdery mildew, and Marian for its resistance to both club-root and powdery mildew. Ruta Øtofte and Vogesa were also included in these crosses along with the prospective new cultivars, SPBS 9939 and SPBS 9943. F_1 plants were raised to produce F_2 seed for single plant selection in 1981.

F_2 and F_3 generations from 1978 trials were multiplied in 1979, either by self pollination of single plants or by isolation of twenty to twenty five plant families.

An F_3 trial was sown at the Murrays in 1979, this consisted of 154 lines from a wide range of inter-cultivar crosses together with appropriate controls. Thirteen cultivars had been used in the initial crosses with the aim of improving fresh weight and dry matter yield and, in some crosses, improved disease resistance. Single row observation plots were sown for each line in trial to assess winter hardiness and provide plants for seed production. Twenty lines were retained for F_4 trials in 1981, based on the yield data obtained.

An F_4 trial was also conducted at the Murrays in 1979, this contained twenty selections multiplied from the 1977 F_3 trial. The parents used—Ruta Øtofte, Gullacker, Bangholm Danila and Pentland Harvester—were selected to improve dry matter content, resistance to internal browning ("raan"), disease resistance and winter hardiness. On the basis of these characters and other yield data, ten lines were retained for multiplication in 1980 and F_5 trials in 1981.

Several of the F_6 lines grown in trial at the Murrays in 1977 were significantly higher in dry matter yield than the controls (*Ann. Rep. 1978-79*, 35). As far as seed allowed this trial was repeated in 1978, but the results of the previous year were not corroborated. In 1979 the number of sites was, therefore, increased and trials were grown at the Murrays, Pentlandfield, and at Callands farm, Peeblesshire. Each trial contained twenty five F_7 lines, five F_6 lines and six controls which included SPBS 9939 and SPBS 9943. Detailed analyses of these trials have not yet been completed.

The Field Trials Unit carried out trials of F_7 lines which had done well in 1977 or 1978 using four sites: the Murrays; Tritlington Hall, near Cockle Park, Northumberland; Yonderton Farm, Ayr; and Tullochgorum, Inverness-shire. The results are given in Table 3. Dry matter content was relatively high in all eight lines with Da 703 above all the other lines and controls at each site. Dry matter production varied over sites but that of Da 700 was significantly higher than Wilhelmsburger Sator at three sites out of four. All the advanced lines have been tested for club-root resistance (this Report page 51).

TABLE 3

Performance of eight advanced swede lines and of four cultivars at four sites in 1979. Dry matter yields are given as percentages of Wilhelmsburger Sator

	The Murrays		*Cockle Park*		*Ayr*		*Tullochgorum*	
	DM%	*DMY*	*DM%*	*DMY*	*DM%*	*DMY*	*DM%*	*DMY*
W. Sator	12·0	100	11·7	100	13·2	100	12·5	100
Marian	10·8	105	9·7	111	11·1	96	11·1	127
Merrick	9·8	100	9·8	101	10·3	101	10·5	99
Ruta Øtofte	11·4	113	—	—	11·8	119	12·0	136
Da 690	12·1	110	11·3	110	12·0	102	12·7	128
Da 697	13·3	113	12·6	107	13·6	121	13·0	125
Da 698	13·7	115	12·2	105	13·7	110	12·9	119
Da 699	12·9	110	12·4	106	13·4	112	12·7	140
Da 700	13·7	118	13·1	124	14·4	123	13·6	111
Da 703	14·2	111	13·2	109	14·8	124	14·2	115
Da 705	13·4	110	13·0	110	14·7	96	13·6	107
Da 713	12·0	109	11·2	108	13·0	102	13·0	127
SED	0·24	0·65	0·27	0·69	0·38	0·55	0·16	0·45

In a small trial at WPBS the dry matter yield of Da 700 was again high.

The most advanced swede lines, SPBS 9939 and SPBS 9943, completed their first year in National List Trials and are expected to progress into second year trials. These lines were derived from a programme, commenced in 1966, to produce a replacement for Pentland Harvester with higher yielding, late maturing, uniform types, suitable for mechanical harvesting, but with less susceptibility to boron deficiency.

INTROGRESSION OF CHARACTERS FROM RAPE INTO SWEDES

Approximately 6,000 F_2 plants, originating from crosses between Canard rape and six swede cultivars, were grown in the field in 1979. Assessment was made for speed of growth, top size, root size, lack of premature flowering and powdery mildew resistance. Seventy plants were retained for seed production in 1980 and an F_3 trial in 1981.

A number of other swede × rape crosses were made in 1978, the rape parents having resistance to either club-root or powdery mildew (*Ann. Rep. 1978-79*, 34). F_1 plants were grown and sufficient seed obtained for F_2 selection plots to be sown in 1980.

INTROGRESSION OF CHARACTERS FROM TURNIPS INTO SWEDES

Lines from crosses between stubble-turnips and swede cultivars were in trials in 1978 (*Ann. Rep. 1978-79*, 38). Ten of these lines were retained for seed production in 1979 and replicated trials in 1980. In addition, seed of these lines has been passed to the Cytology Unit to check chromosome numbers. Useful plants will be retained for seed production and further crosses.

During the work on producing swede types from the turnip × swede crosses, attempts were also made to isolate fertile aneuploid lines. As the aneuploids examined were not completely stable cytologically, it was decided to examine the lines for agronomic potential before making any serious effort to stabilise meiosis by selection. Two small trials were carried out, one with single plant selections from a thirty six chromosome plant, and the other with multiplications of thirty six and thirty eight chromosome plants from a thirty seven chromosome plant. Both sets of experimental lines appeared to be poorly adapted and suffered badly from splits, cracks and subsequent rotting. Ruta Øtofte and Marian outyielded the other entries in both trials. Only one selection from the thirty six chromosome plant gave a higher yield of dry matter than the third swede control, Merrick, and in the other trial the experimental lines were very poor. The mean of the three swedes in this trial was equivalent to 9·5 t ha^{-1} whilst the mean of five thirty eight chromosome lines was 5·2 t ha^{-1} and the mean of the four thirty six chromosome lines was only 3·3 t ha^{-1}. No further work will be carried out on this material, with the exception of the one selection that gave a reasonable yield, and it does not seem worthwhile continuing such studies until the missing chromosomes can be identified and correlated with performance.

Swede Gene Bank

Plants from thirty cultivars gave sufficient seed on multiplication in 1978 to be grown at the Murrays in 1979. Several characters, including dry matter content, have been scored.

During 1979 further cultivars were planted in insect cages for multiplication. Only seven of these produced seed, while fifteen, which failed to flower, have been left *in situ* to flower in 1980.

Multiplication from plants of other cultivars will be continued in 1980.

The major problem with some accessions of old seed is low viability. Only when we have sufficient plants to produce new seed, can we score field characters and assess the value of these old cultivars for future breeding work.

Turnip Breeding

Seed of the two polycrosses set up in 1978 was sown in trials in 1979. From forty eight plants isolated in each polycross, forty plants from the yellow-fleshed group gave enough seed to sow in trial, but only twenty seven from the white-fleshed group could be included. The two trials were sown in adjacent plots, and the similarity of results for the common control cultivar allowed a general comparison of results to be made. The yellow-fleshed trial gave higher dry weight yields than the white-fleshed trial, with the best yellow-fleshed line yielding the equivalent of 7·2 t ha^{-1} and the best white-fleshed line giving 6·2 t ha^{-1}. The white-fleshed material, however, had higher dry matter contents in comparison with the highest yellow-fleshed line. It is proposed, therefore, to set up a joint polycross of white and yellow-fleshed lines to try to combine higher dry matter contents with higher yields.

A multiplication has been made of an old Danish cultivar, May Turnip, which had the highest dry matter content in the NIAB trials held in the period 1963-1969. This cultivar had been discontinued, and only old seed of very poor germination was available. However, seventeen plants produced seed in an isolation plot in 1978 and fourteen gave enough to sow in a small trial in 1979. Dry matter content was very variable, ranging from 9 to 11 per cent. It may be possible, therefore, to select for high dry matter content if inbreeding depression in such a small population can be avoided.

Plants from the crosses of European Clubroot Differential 04 with traditional turnips (*Ann. Rep. 1978-79,* 43) were grown overwinter in the glasshouse for pollination in summer 1979. The first backcrosses were made with the traditional turnips as recurrent parents. Resistant plants selected after club-root testing will be backcrossed again, and they will also be intercrossed to produce a population from which to select a stubble-turnip type.

Kale and Fodder Cabbage Breeding

KALE BREEDING

In expanding the small kale research programme into a larger breeding effort it has been necessary to re-assess the place of kale in UK agriculture. Today kale is mainly grazed *in situ* by dairy cattle in the autumn, and also into the winter in the milder parts of the country. On arable farms in the drier parts of the country it is usually sown early into a prepared seed-bed and utilised at the beginning of the autumn. On grass farms it is now common to direct drill kale into killed grass, after grazing or a first cut of silage, for utilisation from the beginning of October to Christmas. Kale thus complements autumn grass and allows silage to be kept for housed stock later in the winter. Some kale is also grazed *in situ* by sheep. Hence the main breeding effort will be on improving the nutritional value of autumn kale, adapted to both early sowing into a conventional seed-bed and to later direct drilling into killed grass, and suitable for strip grazing with an electric fence.

Where stock (both beef and dairy) are housed throughout the whole of the autumn and winter period, kale can still be utilised in the autumn by zero-grazing with a forage harvester. Here a high harvestable yield of digestible organic dry matter is the most important breeding objective. This has been the main selection criterion in the small kale polycross improvement programme started in 1971. In 1978 seventy two S_3 generation single-plant, polycross progenies were grown both in a replicated yield trial and in observation plots. The trial was harvested during November. The toxic factor and digestibility analyses were completed by the Chemistry Department early in 1979. Compared with the mean of Giganta, Greendale, Kestrel, Midas, Proteor and Vulcan, the S_3 population mean was similar for yield of digestible organic dry matter, with a lower fresh weight yield but a higher dry matter content. With respect to height, lodging resistance, levels of S-methyl cysteine sulphoxide (SMCO, the haemolytic factor) and thiocyanate ion (a goitrogen), digestibility (DOMD%) and crude protein content, the population means were similar to the means of these controls. Reasonable levels of usable genetical variation remain in the population for lodging resistance, fresh weight yield and thiocyanate ion level so that further progress can be expected in selecting for these characters. Unfortunately the S_3 observation plots did not survive the exceptionally severe winter of January to March 1979, and hence a year has been lost in producing the S_4 generation.

Although the S_1 and S_2 families in trial in 1978 performed satisfactorily, it is unlikely that a variety with sufficient yield of digestible organic dry matter and uniform enough for NLT submission can be produced until the S_4 generation. Such a variety will be a tall open pollinated marrowstem kale, with a high dry matter content and a high yield of digestible organic dry matter, and hence particularly suitable for zero-grazing in the autumn.

FODDER CABBAGE BREEDING

Cabbage for stockfeeding, by both sheep and cattle, is a very minor crop compared to kale and renewed interest seems confined to rather special situations such as finishing store lambs after Christmas on the Yorkshire Wolds. However, at present there is no fodder cabbage breeding in the UK, and the trend in horticultural cabbage breeding is towards F_1s for uniformity with little emphasis on high dry matter content. Also in horticultural cabbages low SMCO levels are not required. Hence SPBS can justify a small fodder cabbage breeding programme. The aim is to produce both autumn and winter maturing cabbages, suitable both for grazing *in situ* by sheep and for cutting for housed beef and dairy cattle. This will require open-pollinated varieties (for cheap seed) with a high dry matter content, high heart to leaf ratio, low in toxic factors, with good establishment, club-root resistance, and in the case of winter varieties, winter hardiness.

Forage Rape Breeding

PEDIGREE BREEDING

Work continued on the establishment of a pedigree breeding programme for forage rape. One of the major aims of this is the improvement of disease resistance since susceptibility is probably a major factor preventing the expansion of this crop. Of the cultivars on the NIAB Recommended List only Nevin has any claim for club-root resistance, whilst Lair represents the best available resistance to powdery mildew. Accordingly, some of the crosses made in 1979 utilised Nevin and Lair. The Swedish low thiocyanate cultivar, Samo, was also used as a parent. F_1 plants were vernalised over-winter 1979-80 to produce F_2 seed for selection in 1981.

In 1978 an artificial *Brassica napus* line possessing a wide spectrum of resistance to club-root was used as a parent in crosses with cultivars. This resistance was originally obtained from a *B. campestris* club-root differential, ECD 04, by inter-specific transfer (*Ann. Rep. 1976-77,* 37), F_1 plants from these crosses produced seed for F_2 selections in 1980.

F_3 seed was obtained from F_2 hybrids involving AR5 and AR6 semi-artificial rapes (*Ann. Rep. 1978-79,* 46) and the cultivar Samo. Twenty four plants, which survived the 1977-78 winter, produced sufficient seed for a trial sown at the Murrays on 29th June 1979. Bishop, Canard, Emerald, Lair, Nevin and Samo were used as controls.

The trial plots were scored for vigour, height, flowering and occurrence of powdery mildew, although the incidence of the latter was too low for scores to be meaningful. Data were obtained for fresh weight, dry matter content and dry matter yield and samples taken for analysis of DOMD and crude protein contents as well as for SMCO and thiocyanate. Observation plots were sown for all lines in the trial to provide additional information on disease resistance and winter hardiness. A summary of dry matter yield, dry matter content, height and mildew scores, for the best ten lines and the controls, is given in Table 4. These ten lines, with the highest dry matter yield, together with good mildew resistance and acceptable height, will advance to F_4 trials in 1981. Two other lines, with high dry matter contents were retained for use in further crosses.

TABLE 4

Performance of the ten best rape breeding lines
and six control cultivars at the Murrays, 1979

Line or Cultivar	*Dry weight kg/plot*	*Dry weight % of controls*	*Dry matter content (%)*	*Height 1=short 9=tall*	*Mildew 1=resistant 9=susceptible*
B15	8·64	134	10·9	8	1
B20	8·05	125	10·6	8	1
B17	7·71	119	11·1	8	1
C7	7·56	117	12·3	8	1
G2	7·21	112	12·1	6	1
D5	6·72	104	12·0	8	2
D1	6·65	103	11·1	8	2
E4	6·46	100	13·1	8	3
A5	6·22	96	10·2	6	2
B2	5·51	85	8·3	8	2
Bishop	6·07	100	12·0	7	4
Canard	6·99		11·8	8	4
Emerald	6·48		11·5	9	3
Lair	7·56		11·3	9	3
Nevin	5·76		12·2	4	6
Samo	5·91		11·9	3	4
SE	0·511		0·61		
Coefficient of variation	12·3		8·5		

The most promising advanced lines, developed from AR5 and AR6 semi-artificial rapes (*Ann. Rep. 1978-79,* 46) were multiplied in 1979 to produce seed for trials in the UK and in New Zealand in 1980.

Several AR5 lines, which had performed well in a 1978 SPBS trial, were grown in a DSIR trial at Gore, New Zealand, where they showed better vigour and resistance to local races of club-root than local cultivars.

MUTATION BREEDING

A small mutation breeding programme for *B. napus* was started in 1978 (*Ann. Rep. 1978-79,* 37) using the chemical mugaten, Ethyl methane sulphonate (EMS). Treatment with a 0·05 M solution of EMS in phosphate buffer, pH7, for one hour at 30°C followed by washing gave 25 per cent survival. Seeds of the rape cultivar, Nevin, treated as above, were grown initially on filter paper in Petri dishes and the survivors transferred to compost in 10 cm pots. These plants were selfed in 1979 to provide M_2 seed for screening in 1980 for disease resistance and other useful characters.

Exploitation of Inter-specific crosses as possible Rape substitutes or as New Forage Species

Eight novel types, all from diploid *Brassica oleracea* × *B. campestris* crosses, were produced in 1979. These hybrids have been treated with colchicine to produce artificial *B. napus* for crossing with commercial cultivars in 1980 to produce semi-artificial (SAN) form for evaluation and selection. The initial crosses were facilitated by the use of embryo culture.

A range of SAN rapes, including those selected from a catch crop trial (*Ann. Rep. 1978-79,* 47), were multiplied in the glasshouse. Sufficient seed was obtained to sow a small observation experiment, but not a fully replicated trial, which was sown late under catch crop conditions. Six leading commercial rape cultivars and two stubble-turnips were grown for comparison. Most of the SAN rapes grew well and showed surprisingly little segregation. Samples were taken from each plot to obtain an estimate of yield potential and dry matter content.

Some of the SAN rapes had relatively low dry matter contents, possibly inherited from the *B. campestris* parent used in the initial, artificial *B. napus* synthesis. The range of dry matter contents was between 9·5 and 11·7 per cent for the SAN rapes, compared with 10·6 and 12·3 per cent for the rape cultivars.

Further evidence of yield potential of these SAN rapes is clearly required and plants were selected for seed production with a view to a replicated catch crop trial in 1980 and a full term rape trial in 1981.

Other SAN rapes of diverse origins were multiplied in 1979 and sufficient seed was produced for their inclusion in a full term trial in 1980.

A number of selfed progenies of artificial rapes (parents 4x *B. oleracea*, marrow-stem kale, and 4x *B. campestris* ssp. *nipposinica*) were examined as transplants in replicated plots with rape cultivars as controls. Several appeared promising in being leafy, with good leaf retention, tillering habit and high resistance to powdery mildew. Plants were selected for further multiplication and for incorporation in the pedigree breeding programme. This material was originally obtained from the Swedish Seed Association, Svalöf, the tetraploid *B. campestris* parent being provided by SPBS. It has since undergone two mass selections, mainly to eliminate premature flowering, and one selfing.

Progenies obtained by self-pollinating 2n = 38 chromosome plants, derived from crossing a single allotriploid hybrid (2n = 28) with leafy *B. napus* (rape) forms, were also observed as transplants. The allotriploid was obtained from a cross between 2x *B. campestris* (stubble-turnip) × 4x *B. oleracea* (marrow-stem kale), with a view to introducing new variation into *B. napus*. Some plants flowered prematurely and a number, although leafy, lacked good leaf retention and were more susceptible to powdery mildew than rape cultivar controls.

Although of academic interest nothing of agronomic potential seemed to be forthcoming from this latter work which will now be terminated.

Catch Crops

TURNIPS AND STUBBLE-TURNIPS

In a catch crop trial, sown on 10th August 1979, a number of stubble-turnips, Civasto, Debra, Gelria R, Ponda (diploids) and Marco, Taronda and Tigra (tetraploids) were compared with more recently produced leafier types, Cyclon and Typhon (diploids) and Appin and Perko (tetraploids). Two hybrid selections, from crosses between Appin and Marco and Taronda, and three rape cultivars, Canard, Fora and Lair, were also included in the trial which was harvested on 18th and 19th December.

The stubble-turnips, as a group, produced dry matter yields 30 per cent higher than the rapes, in spite of possessing dry matter contents averaging just below 10 per cent, compared with average dry matter contents of over 12 per cent for the rapes. Cyclon produced marginally the highest dry matter yield in the trial. The better hybrid was not significantly different in dry matter yield than eleven commercial cultivars.

F_2 seed was produced from hybrids between two of the best stubble-turnip cultivars, Civasto and Ponda, and a form of the leafy, oriental salad vegetable, *B. campestris* ssp. *nipposinica*.

Although Dutch stubble-turnips are quick growing and have good club-root resistance, they tend to have low dry matter content, especially in the bulb. Traditional-type turnips generally have higher dry matter contents, and seed from the turnip breeding programme was put in trial to examine the possibility of developing a catch-crop turnip from this material. Thirty nine lines from the yellow-fleshed polycross and six lines from the white-fleshed polycross were sown, with Debra, Ponda and Civasto as controls. The trial was sown on 31st July, and harvested at the beginning of December. Dry matter contents were determined from leaf samples and the crop was harvested by cutting at ground level. The polycross material was up to 1 per cent higher in dry matter content than the stubble-turnips, but fresh weight yields were much lower. The harvesting procedure tended to favour the stubble-turnips, as they had produced harvestable sized bulbs which would have had lower dry matter contents. This bias in dry weight yields may have made the difference between the lowest yielding control (4·99 t ha^{-1}) and the highest yielding line (4·76 t ha^{-1}), but even so this was 10 per cent lower than the mean of the controls. It seems unlikely, therefore, that this material could be improved sufficiently for use as a catch crop, although it may be useful as a source of breeding material.

Another small trial was grown to examine the possible use of other types of brassicas as catch crops. Apart from radish, rape and kale, also included were turnip greens and tendergreens from the United States and broccoli raab from New Zealand, all of which are types of *Brassica campestris* (Table 5).

TABLE 5

Performance of various brassicas when sown as catch crops

	Fresh Weight, t ha^{-1}	*Dry matter, percentage*	*Dry Weight, t ha^{-1}*
Stubble-turnips*	42·3	11·3	4·8
Appin	48·2	9·9	4·8
Southern Prize	43·2	10·1	4·4
Seven Top	29·5	12·4	3·6
Broccoli Raab	31·8	12·5	4·0
Tendergreen	32·6	9·4	3·0
Rape*	24·6	13·1	3·2
Radish*	26·0	11·0	2·9
Kale*	12·6	13·0	1·6

* Means of three cultivars.

Civasto and Ponda gave the highest yields of dry matter, whilst Appin, which had the highest fresh weight yield, gave slightly less dry weight yield because of its low dry matter content. The highest yielding turnip greens, Southern Prize, gave similar yields to Appin but it also had a low dry matter content. The other turnip greens, Seven Tops, and broccoli raab gave equivalent yields to Debra whilst having a dry matter content of nearly 12·5 per cent in comparison with 11 to 11·5 per cent for the stubble-turnips. The fodder rapes, with high dry matter contents, and the fodder radishes which had also been included came next, along with mustard tendergreen, which had looked promising but which had the lowest dry matter content in the trial. The lowest yielding cultivars were the kale hybrids tested, but these had suffered severe bird damage in the early stages of growth and had little chance to recover. From these results, the only types of interest as breeding material would appear to be the higher dry matter turnip greens and broccoli raab.

FODDER RADISH

Further selections were made from diploid and tetraploid fodder radish/sea radish (*R. sativus*/*R. maritimus*) hybrids. The hybrids varied considerably in leafiness, degree of leaf dissection, size of "bulb" or "root", etc. Most of the hybrids appeared to be biennial. A small number of the diploid hybrids flowered from an 11th July sowing. No flowering was observed in the tetraploids. In comparison virtually all plants of the fodder radish cultivars, Neris and Slobolt, flowered in adjacent plots sown at the same time.

Reselection of the late flowering, tetraploid radish, Crail, were grown for seed production both at Pentlandfield and at NSDO, Cambridge. Selection had been carried out to stabilise pinkish-red "root" colour, considered to be recessive (*Ann. Rep. 1978-79,* 51). Flower colour, although known to be genetically linked to "root" colour, remained somewhat variable with degrees of intensity of basically pink pigmentation. There was, unfortunately, insufficient seed of the new stock of Crail to be submitted for National List testing in 1980. A further multiplication is proposed to produce seed for re-submission in 1981.

A diploid, late flowering selection, variable for pigmentation, was further selected to stabilise "root" and flower colour.

Raphanobrassica (Radicole)

GRAZING TRIALS

In conjunction with HFRO and RRI, trials were conducted in 1979 at three sites: the Murrays, Hartwood Farm, Shotts (HFRO) and at Bucksburn, Aberdeen (RRI), the objectives being to assess the potential of radicole in terms of utilisation and lamb performance, as well as to clearly ascertain any effect of deleterious factors in the crop, such as SMCO and thiocyanate.

One selection of radicole (RB10/76/77) was compared with Lair rape. The radicole seed was obtained from a multiplication carried out by NSDO.

Four plots of approximately 0·2 ha of each crop were sown in early July at each site. Allowances were made for the lower germinability of the radicole seed in comparison with rape.

Comparable plant populations of the two crops were obtained at the

Murrays site which was precision sown in drills 50 cm apart. At Hartwood the crops were drilled at closer spacing (11·5 cm) and plant populations for radicole were approximately 30 per cent lower than for rape. At Bucksburn the seed was broadcast.

At the Murrays and Hartwood the plots were randomised and two plots of each crop were reduced by one third to provide utilisation rates based on 50 per cent and 70 per cent predicted crop consumption with an intake of 1 kg dry matter per lamb per day.

Estimated initial dry matter yields were marginally higher for radicole than rape at the Murrays (5·0 and 4·8 t ha^{-1} respectively) and Hartwood (4·2 and 4·0 t ha^{-1}). At Bucksburn the yield of radicole was approximately 20 per cent lower than rape (5·0 and 6·3 t ha^{-1} respectively), a large contributory factor being the lower plant populations achieved for radicole.

Crop yields were assessed by cutting plants near ground level within five randomly placed 1 m × 1 m quadrats within each plot. Fresh weights and dry matter yields were assessed, prior to grazing, in order to establish stocking rates. Attempts were made to estimate utilisation and wastage by sampling the plots, by the quadrat method, at fortnightly intervals during the grazing period which extended from late October to mid-December. The plots were also sampled at the end of the grazing period. Estimates of standing plant material were obtained by cutting plants near ground level and deriving dry matter yields. Following cutting within each quadrat, the amount of plant debris on the ground was assessed on a visual basis. This consisted mainly of detached, soiled green leaves as well as senescent leaves.

Twenty plants were taken at random from each main plot, divided into leaf and stem fractions, and samples of each fraction deep frozen, prior to freeze drying, for the analysis of SMCO and thiocyanate content.

The lambs at all three sites were provided, from a Black Face flock, by HFRO. HFRO also provided the fencing for the Murrays and Hartwood sites.

At each site the lambs were weighed and divided into two thirty two-lamb flocks which were placed in separate radicole and rape run-in areas for a period of four weeks. The lambs were again weighed and graded, before entry into the assessment plots, so that the average weights of lambs in each plot were as equal as possible. Following crop yield estimates, eight lambs were allocated to each plot at each site.

Blood samples were taken from the lambs before grazing and at regular weekly intervals throughout the assessment period in order to measure packed cell volume (PCV), haemoglobin content and Heinz-Ehrlich body counts. Blood glutathione levels were assessed initially, since lambs low in glutathione might be more susceptible to anaemia.

Preliminary results have shown that the lambs performed better, in terms of daily live weight gain, on the rape crop at both the Murrays and Hartwood sites and as a consequence target live weights were more rapidly attained by lambs grazing the rape plots than the radicole. The difference in lamb performance was greatest in the high utilisation, *i.e.*, high stocking rate plots. At Bucksburn live weight gains were marginally superior for the lambs from the radicole plots than from the rape. No veterinary problems were reported with any of the 192 lambs at the three sites and there were no apparent differences in carcass weight or quality of lambs from the two crops.

The plant assessment work at the Murrays and Hartwood sites was carried out by SPBS staff. It was evident that there was a considerable amount of leaf wastage of both crops at each site. Wastage was greater for the radicole than for rape. At the end of the grazing period there was very little standing crop of either radicole or rape at either site. Many data have been obtained for both the plant and animal aspects and await statistical analysis.

TOXIC FACTORS

There is an accumulation of evidence, from chemical analyses of 1978 field experiments, which show clearly that the SMCO content of radicole is somewhat higher than of rape, but not as high as normally found in kale. Levels of thiocyanate (CNS^-) have been consistently higher in radicole than in rape, sometimes several fold higher and at a level usually occurring in kale. Data have been provided by trials carried out at a number of sites by the Scottish Colleges of Agriculture, GRI, Hurley, RRI, Aberdeen, and by SPBS Trials Unit. Although levels of SMCO are higher than rape there is no evidence from the 1979 trials, or from previous experiments, of any serious anaemia problems with lambs grazing radicole or that the relatively higher thiocyanate levels of radicole have any pronounced deleterious effects.

BREEDING

F_2 seed was produced by selfing and inter-crossing a number of F_1 radicoles obtained by hybridising 4x *Raphanus sativus*/*R. maritimus* plants with 4x *Brassica oleracea* (various kales). The F_1 plants proved highly sterile, some totally. Just over 100 seeds resulted from approximately 5,000 pollinations.

A number of F_2 radicoles, derived from crosses between a line developed by The Swedish Seed Association, Svalöf, and an SPBS line, were observed in drilled plots in the field. The Svalöf radicole had marrow-stem kale as the *Brassica* parent, the SPBS line had thousand-head kale and curly kale in its ancestry. Selections of vigorous, leafy, medium-stemmed plants, as well as taller types, resembling marrow-stem kale were made for seed production in 1980. Plants varied considerably in frost tolerance; in general the taller types were less winter hardy and were also subject to lodging.

Forty five radicole selections, mainly F_7 lines derived from F_6 plants with the highest seed fertility, were compared in a trial with three of the highest yielding Giant rape cultivars; Canard, Emerald and Lair. None of the radicole lines produced dry matter yields significantly higher than the mean of the rape controls, eighteen radicoles gave yields not significantly different from the best rape control, Canard. In spite of seed being checked for viability prior to sowing, lower plant stands were generally achieved for the radicoles in comparison with the rape cultivars. Dry matter contents of radicoles averaged 10·5 per cent, compared with 12·4 per cent for the rapes.

Three radicole lines which were uninfected by virulent races of *Plasmodiophora brassicae* and several others, which had given low disease indices in recent screening tests, are currently being multiplied.

Crosses are planned for 1980 involving the most resistant lines and less resistant, but otherwise promising, material.

Brassica Pathology

CLUB-ROOT (*PLASMODIOPHORA BRASSICAE*) SCREENING METHODS

Methods developed during the past year have improved several aspects of the glasshouse seedling tests which are used to screen breeding lines and families for resistance to *Plasmodiophora brassicae*. Germinated seeds are pricked out into pot units with one seedling in each. A standard quantity of spore suspension is applied to each seedling using a bottle dispenser. The use of pot units minimises root damage to seedlings during washing and scoring, an important consideration when resistant seedlings from tests are retained for seed production.

The *P. brassicae* populations used in screening tests infect all the *Brassica napus* and *B. oleracea* ECD hosts, and up to three of the *B. campestris* differentials. Populations with a wider virulence spectrum than this occur only rarely in the UK at present.

The use of rooted leaf cuttings in screening tests has been investigated; this test will enable simultaneous assessment of agronomic characters and of disease resistance where seed is limited. Young leaves were cut near the base of the petiole and kept in a mist propagator for about twelve days. At this stage the first roots were just visible and leaf cuttings were transferred to a soil-peat mixture and inoculated using the method described for seedlings.

In a comparison of disease development on seedlings and leaf cuttings of the ECD host set, comparable results were obtained. Callus developed at the base of some leaf cuttings, but it could usually be distinguished from infected gall tissue. Sections stained with cotton blue in lactophenol clearly differentiated infected and uninfected tissues.

SCREENING FOR RESISTANCE TO *P. BRASSICAE*

Twenty eight cultivars from the Swede Gene Bank which were tested were all susceptible to a local population of *P. brassicae* which gave a 21-31-31 reaction on the ECD host set. This population, and a less pathogenic isolate, were used to screen twenty seven advanced swede breeding lines and ten lines selected for high dry matter content. Nine of the advanced lines were resistant to the latter population, but all were susceptible to the former which infects all the swede cultivars so far tested at SPBS.

Twenty three rape cultivars, and thirty families with resistance derived from the cultivar Nevin were tested using two populations of *P. brassicae*. None showed a higher level of resistance than Nevin. Many of the local soil populations of *P. brassicae* infect Nevin so it is clear that a wider spectrum of resistance is needed in the forage rapes. Second generation semi-artificial rape families, which had the resistant ECD host line 04 as the *B. campestris* parent in the original crosses, were inoculated with an aggressive population which gave a 21-31-31 reaction. One family was fully susceptible and so was Nevin; seedlings in the other twenty families segregated for resistance to this population with an overall mean of about 30 per cent of plants infected.

Four fodder radish cultivars, two breeding lines and thirty eight accessions of radish supplied by Dr P. Mattusch were inoculated with the same *P. brassicae* population that was used to test the semi-artificial rapes. Only two accessions of radish had less than 10 per cent of plants infected. An SPBS selection from a *Raphanus sativus* × *R. maritimus* hybrid had only 16 per cent of seedlings infected compared with 29 per cent in the best cultivar, Neris. The remaining accessions varied in the proportion of resistant plants recorded, only one accession was fully susceptible. A similar reaction was obtained to this *P. brassicae* population from 121 radicole families. Three families were fully resistant, thirty four families had some resistant plants but the remainder were susceptible.

INFLUENCE OF ENVIRONMENT ON HOST-PATHOGEN RELATIONSHIPS

Seedlings from four cultivars of kale were inoculated in April and grown (1) in a glasshouse in standard seedling test conditions throughout, (2) in a glasshouse for ten days (to ensure that primary infection occurred) before being transferred to a cold frame, (3) in a cold frame. Seedling and root fresh weights were recorded five and seven weeks after inoculation.

Early seedling growth and disease development were more rapid in the glasshouse than in cold frames. At the first harvest, seedlings of all cultivars in the glasshouse showed severe disease symptoms with few healthy roots remaining; by the second harvest nearly all the seedlings were dying. In contrast, seedlings in the cold frame grew more slowly, all seedlings were infected but disease development was also slow. After seven weeks, club size was greater than on seedlings in the glasshouse, but seedlings in the cold frame appeared still to be growing vigorously and to have healthy root systems. These results give an indication of the effect the environment may have on disease development.

The response of four swede cultivars to two populations of *P. brassicae* is being studied in a series of trials. Population (1) gave a 16-31-31 and population (2) a 20-31-31 reaction on the ECD host set. Inoculated and control (uninoculated) seedlings of the four cultivars Doon Major, Marian, Ruta Øtofte and Wilhelmsburger Sator were grown in pots outside during July and August; batches of plants were harvested weekly from the third to the eighth week after inoculation.

When plants were inoculated with *P. brassicae* population (1) disease symptoms developed earlier on Doon Major and Ruta Øtofte than on the other two cultivars. The lowest fresh weight of infected tissues was recorded on Wilhelmsburger Sator at each harvest, but Marian gave the greatest plant fresh weights.

On plants inoculated with *P. brassicae* population (2) disease symptoms developed more rapidly on all cultivars than with population (1). The ranking of the cultivars for fresh weight of clubs was similar at each harvest, Marian having the lowest, then Wilhelmsburger Sator, then Ruta Øtofte and Doon Major with the greatest club size. There was no apparent reduction in fresh weight yield per plant of Marian at the last harvest date, but the other three cultivars showed approximately 50 per cent reduction compared to control plants six weeks after inoculation.

Inoculated and uninoculated seedlings of the same four swede cultivars were planted out in a field trial and harvested in November. Plants inoculated with *P. brassicae* population (2) were discarded owing to severe pigeon damage. Plants inoculated with population (1) gave similar results to those obtained from seedlings. The most severe infections were recorded on Doon Major, then on Ruta Øtofte, Marian and the least on Wilhelmsburger Sator. The highest fresh weight and dry matter yields per plot were obtained from Marian. A severe reduction in yield only occurred with Doon Major where the mean dry matter yield per ten plant plot was reduced by 67 per cent compared with control plots.

POWDERY MILDEW (*ERYSIPHE CRUCIFERARUM*)

The effect of mildew infection at progressive dates on yield of three swede cultivars was examined in a field trial. Infection was successfully initiated by transferring mildew infected seedlings to spreader rows of the susceptible cv. Doon Major. Spreader rows were inoculated at the end of June, July or August. The fungicide Persulon was used to prevent early infection on the plots with later inoculation dates and on control plots. The first mildew infections were seen at the beginning of August. By the end of August about 5 per cent of the leaf area was infected in the cultivar Marian and up to 25 per cent on Doon Major. In late September this had increased to 25 to 50 per cent on Marian and 75 to 90 per cent on Doon Major. Analyses of disease and yield data have not yet been completed.

TURNIP MOSAIC VIRUS

Seed samples and plants from inbred lines derived from the swede cultivar Ruta Øtofte and selected for resistance to turnip mosaic virus by Dr J.

Tomlinson at NVRS have been received from NVRS. This material will be incorporated in breeding programmes during 1980.

DAFS Package 4
ARC Project 03001
03003
03005–03015 inc.

I. H. McNaughton
W. H. Macfarlane-Smith
S. Gowers
J. E. Bradshaw
I. K. Munro
C. L. Ross
C. J. Williamson
D. J. Barclay

An investigation into methods of cross prediction continued in conjunction with Birmingham University. Evidence for additive and dominance effects was found for both height and maturity in four of the five crosses but for yield and its components the results were less consistent. Some lines were multiplied in New Zealand and then grown in yield trials at the Murrays as part of this very comprehensive experiment which seeks to assess the predictive value of triple test crosses. Other genetic experiments include the mapping of dwarfing genes in barley and the study of quantitative characters in oats. Both are in their early stages. Work on the biochemistry of barley enzymes also continued and is reported by the Chemistry Division (this Report page 31).

The apical development of three barley varieties was studied, in collaboration with PBI. The use of two sites and two sowing dates allowed the combined effects of different daylengths and accumulated temperatures to be investigated. Accumulated temperature appears to be an important factor distinguishing the environments used. One objective of this work is to explain why the national yields for barley in Scotland are higher than in England and Wales; in this connection it may be significant that observations in previous years showed that tillers at SPBS bore more and larger ears than at PBI.

The Cereals Department started work with winter barley. Comparable autumn and spring sown trials on the same site showed the yield advantage from autumn sowing despite the severe winter which destroyed almost all the expanded leaves from the autumn sowing. Two spring varieties sown in the autumn survived but did not yield well. Apical development was monitored throughout the winter and was extended to include measurements of leaf area during the summer in collaboration with the Edinburgh School of Agriculture.

Separate field disease nurseries were established and inoculated with four barley diseases, using artificial irrigation when necessary. Three methods of inoculation were compared in the yellow rust nursery. A survey of barley mildew using mobile nurseries, undertaken throughout the season at the Murrays, demonstrated a high frequency of five virulence genes and the presence of four others. Selection for partial resistance to mildew in the barley collection has isolated several lines for more detailed study. A further portion of the *Hordeum spontaneum* collection was multiplied to provide seed for evaluation. Screening with mildew demonstrated a high proportion of resistant material.

More information from the barley collection was entered into the computer-based data bank jointly operated with WPBS and PBI. Improved programs for stock control and data handling have also been written so the collection and its associated data bank can now be used more effectively.

A collection of oat varieties was multiplied as part of the new breeding programme with oats, which is concentrating on yield, earliness, quality and resistance to grain loss. The old programme culminated with the Recommendation of Fyne by NIAB. Its characteristics are likely to make it of interest to Scottish growers also.

One of the two barley varieties in National List Trials will continue in 1980 when it will be joined by five others; all are expected to give satisfactory field performances and four of the new entries, together with the one advanced to NLT 2, have enhanced diastatic power and should therefore be capable of replacing imported grain. Material entering advanced trials at the Station is described. Selection for tolerance of low soil pH in barley continued successfully. Reference is made to two new field drills.

R. N. H. Whitehouse

Barley Genetics

SPRING BARLEY

The investigations into cross prediction in barley were continued in collaboration with Professor J. L. Jinks of the University of Birmingham (*Ann. Rep. 1977-78*, 24; *Ann. Rep. 1978-79*, 26-27). Mr C. R. Tapsell, a CASE award student, analysed the data accumulated from the triple test cross experiment grown at the Murrays in 1978, on the characters height at ear emergence, final height, number of grains per ear, thousand corn weight and plant yield. This was in partial fulfilment of the requirement for an M.Sc. degree in Applied Genetics. Mr Tapsell will continue working with this experiment in 1980.

The analyses of data for height at ear emergence and final height showed consistent genetic effects over four of the five pair crosses studied (Golden Promise × Mazurka, Universe × Mazurka, Golden Promise × Ark Royal, BH4/143/2 × Ark Royal and Clipper × Ymer). Significant additive and dominance effects were detected with incomplete directional dominance towards a high expression of the characters, except in the case of the Clipper × Ymer cross where interaction with a daylength insensitivity factor was the probable cause of a reversal in the direction of dominance. Little evidence of epistasis was found.

The results for plant yield and yield components were not as consistent over the crosses as were those for height. Dominance, when detected, was complete, or nearly so, and in the direction of high expression of the characters. Significant additive and dominance effects for number of grains per ear and thousand corn weight were found in all crosses with the exception of

Universe × Mazurka where no significant genetic variation was found. Epistasis was detected in some crosses. Significant additive and dominance effects were also found for single plant yield but, in contrast to the yield components, little epistasis was found.

The five populations of random F_2 selections made within each pair cross in 1977 (*Ann. Rep. 1978-79*, 26) were multiplied in New Zealand during 1978/79 and seed returned to Scotland for yield trials in 1979. Ninety random selections from each cross were grown in generalised lattice trials with three control varieties and the parents of the cross studied. All the plots were scored for developmental characters, morphology, yield and its components. Grain samples have been retained for quality tests. The Universe × Mazurka random selections trial suffered severe head loss due to strong winds before harvest and this will necessitate the regrowing of this trial in 1980.

The populations, derived using normal plant breeding practice, from four of the five crosses (*Ann. Rep. 1978-79*, 26) were sown as observation plots in 1979 and again selected for agronomically important characters. A total of ninety selections was made from the four crosses, with the Golden Promise × Ark Royal, and Universe × Mazurka crosses predominating. These selections will be grown in large plot yield trials in 1980 and the results will give an estimate of the genetic advance made in each cross. This can then be compared with the total genetic potential, estimated from trials of the random selections, and with the genetic potential of each cross, estimated from the results of the triple test cross study. Additional random selections from two crosses are being multiplied in order to make more accurate estimates of the genetic potential of the crosses.

As these assessments will have been made in different seasons, a variety trial will be grown annually to estimate seasonal effects. The entries in the trial are the seven parental varieties of the five crosses and Maris Mink.

The investigations into the linkage relationships between several dwarfing genes found in commercial barley varieties and other genes of known location on the seven barley chromosomes are continuing (*Ann. Rep. 1978-79*, 27). Some suggestions of linkage were detected in the results from the F_2 populations raised in 1978 and further crosses have been made to verify and extend these findings.

Investigations into the relationship between electrophoretic pattern and β-amylase activity (*Ann. Rep. 1976-77*, 21) have been completed and the data prepared for formal publication. Electrophoresis may be used as a test to select lines with high diastatic power from certain crosses, and the sd-type electrophoretic pattern could be a useful biochemical marker. Attempts to assign this gene to the relevant chromosome will be made using material from a linkage experiment set up to examine the inheritance of malting quality components.

F_3 progeny from crosses with very high β-amylase activity experimental lines as one of the parents are being assessed for β-amylase activity to provide further information about the inheritance of the character.

A drilled trial comparing spring and winter barley varieties was sown at the Murrays in the autumn (1/11/78) and spring (26/4/79) to provide information for the new winter barley breeding programme. Two spring varieties, Golden Promise and Ark Royal, and one winter variety, Maris Otter, were sown both in the winter and in the spring, allowing direct comparisons to be made. In addition, eight two-row and six six-row varieties were autumn sown and nine other two-row varieties were included in the spring trial. Yield and a number of other agronomic characteristics, leaf area and apical primordium development were followed (this Report page 60) and mature plants were recovered so that the components of yield could be estimated.

The 1978/79 winter was the most severe for at least fifteen years. Although the six-row varieties were more winter hardy than the two-row varieties, no variety was completely hardy and at the end of the winter most plots of all varieties had lost all green tissue above soil level. Golden Promise and Ark Royal were affected more by the severe weather than the winter types, but sufficient plants survived to produce yields of 75 per cent and 71 per cent respectively of Maris Otter, the least hardy winter type.

Rhynchosporium was the most prevalent disease in the winter-sown plots and a late attack of mildew was the only disease which occurred on spring-sown plots. It was apparent that six-row winter types were more *Rhynchosporium* resistant, but also taller, weaker strawed, and earlier than two-row winter barleys. As the mean yield of winter six-row varieties was 16 per cent greater than that of the winter two-row varieties, the yield potential of the six-row model should be studied in more detail. Some high yielding two-row genotypes were noted, particularly Calif and Maris Trojan and two numbered selections from PBI. However, Calif was too susceptible to mildew and the others appeared to be rather late for Scottish conditions, with ears emerging as late as spring-sown Golden Promise. Sonja and Igri appeared to have the earliness required in a winter barley. The autumn-sown plots had a mean yield of 660 gm m^{-2} which was significantly higher than the mean yield of 579 gm m^{-2} of the spring sowing. As was expected Maris Otter gave significantly higher yields from autumn sowing, 620 gm m^{-2}, than spring sowing, 498 gm m^{-2}. Similarly spring sowing gave yields of 609 gm m^{-2} for Ark Royal and 524 gm m^{-2} for Golden Promise both of which were significantly higher than that from autumn sowing at 442 gm m^{-2} and 463 gm m^{-2} respectively.

Barley Physiology

SPRING BARLEY

The collaboration with Dr E. J. M. Kirby (PBI) on physiological studies (*Ann. Rep. 1976-77*, 19 and *1977-78*, 23) was continued in 1979 both by the analysis of data already collected and by new experimental work.

A comparison of plants harvested from plots grown in Cambridge (PBI) and Edinburgh (SPBS) was made to determine how yield components were affected by the differences in the environments. At SPBS the yield of Golden Promise was significantly higher in both 1976 and in 1977, while that of Maris Mink was only significantly higher in 1977. In both seasons the number of ears per plant, grains per ear and weight per grain were higher at SPBS. The weights of individual grains at each node on the main stem were also measured. In 1976 the SPBS grown plants had heavier lower grains, while the upper grains were heavier at PBI. In 1977 grains at all ear positions were heavier at SPBS. On the assumption that primordium size is a factor in determining grain weight the relative difference, between grain weights at the base and tip of the ear in Cambridge and Edinburgh in 1976, can be understood by considering plant development and its interaction with the prevailing weather conditions. At the time at which the mid-ear spikelet primordia were being formed at SPBS there was a large rise in mean air temperature. Such a rise after a prolonged period of low temperature would have caused a rapid increase in the growth rate of tillers and leaves. This in turn would increase intra-plant competition for carbohydrate and have resulted in the formation of smaller primordia towards the tip of the ear.

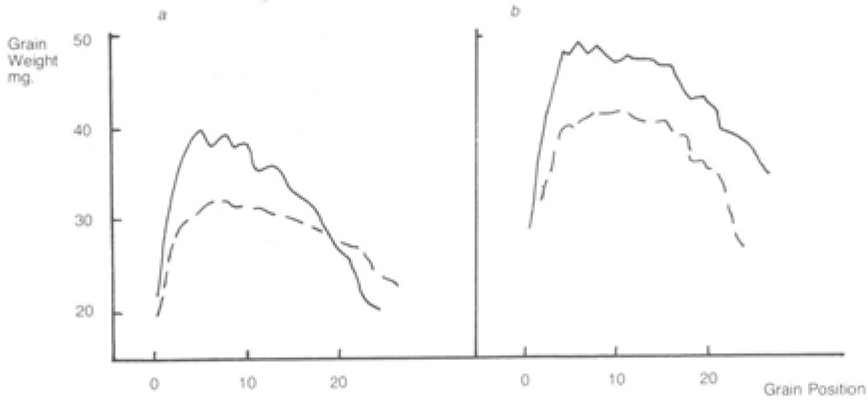


Figure 1. Grain weight at each mainstem ear node of Golden Promise grown in 1976 (*a*) and 1977 (*b*). —— = plants grown at SPBS, — — = plants grown at PBI.

The larger number of ears per plant found at SPBS was due to significant differences in the pattern of tiller development. In both seasons the plants grown at SPBS had a higher proportion of ears on the second and third tillers. A comparison of the grain weights from each tiller with that of the main stem showed that SPBS grown plants had greater grain yields on later formed tillers than those grown at PBI. This is probably due to the lower temperatures experienced at SPBS which result in slower growth rates and less severe intra-plant competition. It might be expected that the same explanation could be advanced for the higher yield of autumn-sown crops.

In 1979 the field experimentation was assisted by Miss Karen Buick, a student from Dundee College of Technology. The aim of the work in 1979 was to collect data to support and extend that gathered in 1976 and 1977. The barley varieties Golden Promise, Maris Mink and Clipper were sown on two occasions at both PBI and SPBS, making four different environments. Plots grown at SPBS received lower accumulated temperature levels at any given time after sowing, combined initially with longer daylengths, than those at PBI. The second sowing at each site received higher accumulated temperature totals and in the earlier stages, longer daylengths at any given interval after sowing. The rates of leaf growth and spikelet primordium initiation were closely related to the accumulated temperature in each of the individual environments. Linear regressions of accumulated temperature, for the exponential periods of increase in leaf and spikelet primordium number, accounted for more than 90 per cent of the total variation. These data are in the process of analysis and will be compared with data still to be obtained from harvested plants.

WINTER BARLEY

The severe winter of 1978/79 caused considerable winter kill in the winter-sown plants. But even at the point at which there was no visible leaf tissue, apical growth continued. The rate of primordium production was followed through the winter until maximum primordium number was reached in early spring. A similar monitoring exercise was carried out on the spring-sown plots. From the emergence of the first leaf until the maximum number of primordia were formed the rate of primordium initiation showed a linear relationship with accumulated degree days in the main stems of the genotypes examined (Table 6). Regression of accumulated day degrees (above

TABLE 6

Regressions of accumulated day degrees and mean primordia numbers in spring- and autumn-sown varieties

Variety	*Sowing*	*Number of samples*	*Regression coefficient ± Standard error*
Ark Royal	Spring	6	0·102 ± 0·004
	Autumn	13	0·059 ± 0·005
Golden Promise	Spring	6	0·099 ± 0·009
	Autumn	13	0·064 ± 0·003
Maris Otter	Spring	7	0·091 ± 0·008
	Autumn	13	0·068 ± 0·005
Calif	Autumn	10	0·065 ± 0·003

0°C for the average of the daily maximum and minimum temperatures from sowing date) and numbers of primordia developed was highly significant for each genotype. Genotypes developed primordia significantly faster from spring sowing than from autumn sowing. Although there were large differences within the groups of spring- and autumn-sown varieties, none was significant. Through collaboration with Professor G. M. Milbourn and Dr G. Russell of the Edinburgh School of Agriculture, it was possible to monitor leaf area development and duration in the same trial. A further investigation of apical development has been started using accurately spaced plants of four two-row varieties sown in the autumn and five sown in the spring.

Barley Breeding

Disease nurseries were established for yellow rust (*Puccinia striiformis*), brown rust (*P. hordei*) and *Rhynchosporium*. In each nursery clumps of test genotypes were grown between rows of a susceptible spreader variety. The spreader was artificially inoculated, in the case of the rusts by a number of different methods (see below). Finely chopped straw from a previously infected crop was spread on the *Rhynchosporium* nursery in the autumn and again in the spring. Over 2,900 entries in the barley collection were assessed for resistance to a simple race of yellow rust (Astrix virulent) and Race UK 1 of *Rhynchosporium*.

Part of the yellow rust nursery was set aside for a comparison of inoculation methods. A susceptible spreader with good mildew resistance was inoculated at G.S.22-29 in one of three ways; (*a*) infected seedlings were transplanted from the glasshouse into the rows of spreader, at 2 m intervals, (*b*) an aqueous spore suspension was injected into plants at 1 m intervals along each row, and (*c*) the spreader was sprayed with a spore suspension during a period of wet weather. Overhead irrigation was applied on days with no rainfall for six weeks following inoculation. An assessment of the level of infection on test clumps of a single variety distributed throughout the nursery was made one week after this. The most severe and uniform epidemic of yellow rust was generated from the infected transplants. The less laborious technique of syringe inoculation was more effective than spraying, which produced the lowest mean infection level and most variable results.

For the second year running (*Ann. Rep. 1978-79*, 29) brown rust failed to develop sufficiently for useful assessments of resistance in the breeding material. Natural epidemics of this disease are extremely rare in Scotland, despite the widespread use of susceptible varieties, and it seems likely that temperature is the factor limiting epidemic development of this pathogen in our nurseries, where high levels of inoculum are introduced. Screening at a warmer location, or under polythene, may be necessary in future. Further multiplication of Race UK2 of *Rhynchosporium* on plots of a susceptible winter barley variety yielded sufficient heavily infected straw to inoculate a separate disease nursery with this race in the autumn, in which breeders' entries will be sown in the spring of 1980.

Powdery mildew (*Erysiphe graminis*), though encouraged by the sowing of strips of a susceptible variety throughout the trials area, developed late in 1979. The exposure of mobile seedling nurseries to detect barley powdery mildew throughout the season at the Murrays indicated that the relative frequency of pathogen virulence for the individual resistance genes Mlh, Mlg, Mlv and Mla_{12} was relatively high (> 50 per cent) in 1978 and 1979. Virulence for Mla_{6} was slighly less common and that for $Mla_{4/7}$ was found in less than 30 per cent of the population in both years. Isolates able to attack Rupee (Mla_{13}), MC 20 (Mlo) and Akka (Mla_{9}) were barely detectable in 1979, though the frequency of virulence on the latter exceeded 16 per cent in 1978.

An increase in virulence on the combination Mlg + Mla_{12}, present in the variety Maris Mink, amongst others, was observed in 1979, and was associated with an increase in the susceptibility of this variety in trials. More unaccountable was the high frequency of virulence for the combination Mlg + Mlv, which exceeded that expected from theoretical considerations by a large margin in both years.

Selection for partial resistance to powdery mildew in the barley collection continued. Six hundred genotypes exhibiting potentially useful levels of resistance were exposed to a severe, natural epidemic in the field. From these, about thirty agronomically useful genotypes with apparently non-hypersensitive resistance were selected for further study in the glasshouse and laboratory. Infection frequency, latent period and spore production on these genotypes are being examined at various developmental stages. In addition, selection for different types of mildew resistance was practised on an unselected population of *Hordeum spontaneum* in the field. Over 80 per cent of the 2,000 individual plants exhibited high levels of resistance to the races prevalent at the Murrays, as detected by the use of mobile seedling nurseries. Seed of a large number of resistant genotypes was collected for further study.

Of the two spring barley varieties entered for National List Trials in 1979 (*Ann. Rep. 1978-79,* 29) SPBS MM39/16 showed the better performance. This variety had early/medium maturity, good disease resistance, and moderate diastatic power. It will continue in National List Trials in 1980. SPBS 69/13/3 was withdrawn after one year of trial owing to its unsatisfactory performance.

In 1979 there was a further increase in the production of new varieties from the spring breeding programmes. Five new National List Trial submissions were made. Of these, SPBS 63/4/1/13 (Armelle × Maris Mink) is a feed variety with good disease resistance while the others have enhanced diastatic power. SPBS 4/200/5/90 (Akka × Midas) and SPBS 213/11/4 (Akka × Maris Mink) both have high diastatic power and are early maturing, while SPBS 648/18/68 and SPBS 648/18/85 (Akka × Maris $Mink^2$) both have moderate diastatic power and very good yield.

The methods used in our breeding programmes have been changed from the F_2 bulk procedure to the pedigree line trial system (*Ann. Rep. 1978-79,* 113). In 1979 genotypes handled by the pedigree line trial methods entered progeny trials for the first time. Consequently the 1980 secondary trial (pre-NLT submission) is made up of material of diverse origin. They include four selections from each of the crosses Akka × Maris $Mink^2$ and Ark

Royal × Trumpf, two selections from Ark Royal × Aramir and one from Tyra × BR69/44. The trial entries are completed by four selections, advanced from the F_4 generation in 1978 via New Zealand, from the crosses MM47 × Guinness 377/1, Rif × Aramir, Porthos × Zoe and Trumpf × Ark Royal.

Nearly 150 stocks from thirty-nine selections will be entered into primary trials and multiplication in 1980 as candidates for NLT submission in 1982. A further fifty stocks from some promising crosses are being multiplied in New Zealand during 1979-80, for inclusion in primary trials in 1980. In 1980 a total of 170 stocks will be multiplied in comparison with 230 multiplied in 1979.

Some 390 selections were entered into pre-primary trials in 1979. A nursery of some 25,000 F_3 progenies was sown together with an F_2 nursery of 172 substantial populations. The use of spreader rows and syringe inoculations in these nurseries helped promote epidemics of yellow rust, but powdery mildew development was rather sporadic.

The low soil pH site established at West Byres Farm, West Lothian (*Ann. Rep. 1978-79,* 30) was used again in 1979 to screen populations for tolerance to acidic soils and a large number of single plant selections was made. A few lines, originally selected from West Byres in 1977, were grown in a yield trial in 1979 and single plants selected in 1978 were grown as progeny rows.

The trial results allowed a direct comparison of the composite-derived lines with lines produced at the F_4 generation via the pedigree breeding method. The range of expression for all the characters measured was very similar in both populations. In particular, if tolerance is confirmed by later screening, it appears that there is no difficulty in combining high yield and tolerance of low pH soils. The progeny rows were heavily selected for mildew resistance, resistance to lodging and shortness of straw, and the surviving lines will be included in 1980 trials. The composite population containing male sterility was grown again in 1979, grain from sterile ears was then grown over winter in a glasshouse.

In certain seasons it has been noticed that some plots in SPBS trials show much poorer growth in the centre than at the edges. This is in contrast to the stress effects noticed elsewhere in which plant growth appears better in the centre of plots. In 1979 a small investigation was initiated to examine the influence of the stress effects on selection procedures at SPBS. An F_7 trial of thirty entries grown in a generalised lattice design of two replicates at each of two sites was chosen for study. At Queenstonbank visible stress effects were especially noticeable, but at the Murrays they were virtually absent. Each plot was subdivided into end (15 cm cut from each end), side (two outer drilled rows) and centre sub-plots. Preliminary comparisons of both trials for the characters yield, thousand corn weight, per cent nitrogen and β-glucan showed marked differences between the sub-plots for all characters. The centre sub-plots gave lower yields per unit area, had smaller grain and lower levels of nitrogen and β-glucan. Some evidence of interactions between sub-plots and trial entries was also found for all characters, suggesting that these results should be interpreted with caution. Analysis of the data continues and a more extensive investigation is planned for 1980.

The Transverse Seeder (*Ann. Rep. 1978-79*, 29) developed in conjunction with SIAE was used to sow a large proportion of the 1979 nurseries. Its performance was not wholly satisfactory with contamination within rows being evident, but the principle has been shown to work. Some detailed modifications are required to enable the machine to operate to acceptable standards of purity. A Monosem spaced plant seeder has been purchased and modified to sow large F_2 populations of spaced plants.

Oat Breeding

Fyne has received a Provisional Recommendation by NIAB for general use in England and Wales. Fyne is derived from a composite cross breeding programme, conducted by Mr Donald Cameron, whose objectives were to produce high-yielding milling-quality oats for the lowland areas of Scotland. The original crosses were made in 1965, the resulting seed mixed and the bulk populations grown under conditions of natural selection at four Scottish sites for five years. Single plants were then selected from these populations and assessed and multiplied over a number of years. Fyne was the most promising of these selections. Yield trials carried out over a number of years have shown that Fyne has high yielding potential. In comparisons with Leanda and Maris Tabard, it has better mildew resistance and intermediate maturity. Its kernel content is as good as Maris Tabard and thousand grain weight is between that of Maris Tabard and Leanda. Although it is taller than these two varieties, it has good standing power. Portmore, the last of the material originating from this programme, has been withdrawn from further trials.

The UK oat crop is being sadly neglected by both farmers and breeders. With a different disease spectrum from wheat and barley and a wider range of adaptability, oats are a useful break-crop. Furthermore, they are a better balanced crop nutritionally and the straw is of better feeding value. It is the aim of the new spring oat pedigree breeding programme to exploit the advantages of oats, regenerate interest in the crop and expand the area devoted to the crop. The main disadvantage of oats is that a high husk content causes a large yield reduction in the grain crop when compared to wheat and barley. The objective of the breeding programme is to produce new oat varieties giving significantly greater yields than barley in the main cereal growing areas of Eastern Scotland. However, to be suitable for Scotland, this attribute must be combined with early maturity, resistance to all causes of grain loss and to powdery mildew (*Erysiphe graminis F. sp. avenae*) and crown rust (*Puccinia coronata*). The quality requirements of the various commercial users of the oat crop are complex, but it is a further aim of the programme to produce oat varieties of high kernel content which are suitable for milling.

The most advanced material in the pedigree breeding programme was sown as paired rows at the F_3 generation in 1979 along with a reasonably large

F_2 population of spaced plants. As sowing of these nurseries was delayed by bad weather, preventative spraying against possible frit-fly (*Oscinella frit*) attack was carried out. Very little powdery mildew developed either on the F_2 or on the F_3 nurseries and consequently selections were based on straw length, straw strength, early maturity and resistance to shedding. Selected plants from the F_3 selections will be sown in progeny plots in 1980 whilst the bulked residual will be sown in a yield trial in a breeding scheme similar to that described for the barley breeding programme (*Ann. Rep. 1978-79*, 113).

Four pair crosses were chosen for a small scale genetic investigation into some quantitative characters of oats (*Ann. Rep. 1978-79*, 31). The basic generations (P_1, P_2, F_1, F_2, B_1 and B_2) of each cross were grown at the Murrays in 1979. For all the crosses each generation was represented by a row of ten plants and these were sown with wheat guards in a randomised complete block experiment of four replications. The plants in each row were scored for a number of developmental characters including height and maturity during the growing season. Each row was harvested intact and will be scored in the laboratory for a number of morphological characters and components of yield.

Cereal Collections

The collections of barley and oat cultivars maintained by the Station now comprise 3,012 and 1,134 entries respectively. The attempt made in 1978 to revitalise the oat collection was frustrated by a severe frit-fly attack. A second attempt in 1979 was successful and high quality seed of most accessions is now available and will enable further evaluation of the collection to continue in support of the oat breeding programme. In this context it is proposed to sow a crown rust nursery for the first time in the spring of 1980.

ARC BARLEY DATA BANK

The barley data bank was set up in 1975 as a collaborative exercise between the three ARS Plant Breeding Stations (PBI, SPBS and WPBS). The bank is maintained at the University of Cambridge computer installation and is used via the Cambridge multi-access system (PHOENIX). Each institute has space within the bank allocated to its own barley collection, and enters data on its own material. These data are available to all institutes and some problems have been encountered through differences in definition of some of the descriptors. These have largely been overcome by the production at SPBS of a document detailing the differences in usage. This has been circulated to those responsible for the data handling at the PBI and WPBS, and will enable meaningful comparisons to be made between data from each section of the bank.

To date, information on 1,200 of the 3,012 varieties of the SPBS collection is available from the bank and data are being entered for the remainder. Hitherto, the bank has been of limited value, chiefly owing to the inadequacy of available data, but a significant improvement is expected when updating is completed.

PROGRAMS

Computer programs have been written in order to streamline the management of the collections. A stock control program is used to retrieve the seed stock status of varieties and may be used to generate input for a program which in turn generates field plans and plot labels. Such plans were used in 1979 to considerable advantage as the elimination of manual listing and copying improved accuracy and allowed increased information to be printed on the plans. Further programs have been developed for manipulation of data whereby disease level and plant maturity scores may be compared with observations from previous years.

HORDEUM SPONTANEUM

In 1977 PBI, SPBS and WPBS collaborated with the Hebrew University of Jerusalem, in the collection of *H. spontaneum* from 213 localities over the whole of Israel. At each site two seeds were taken from a random sample of plants, the number of samples being in proportion to the population size. This resulted in two identical sets of seed, one of which was returned to the United Kingdom. The three institutes embarked upon a joint programme of multiplication of this collection which numbered approximately 54,000 seeds. To date about 18,000 have been grown. The task of growing this material has proved very labour intensive and as sufficient material had been generated to fulfil immediate experimental evaluation, it was decided to halt the multiplication programme. The remaining seeds from the initial collection together with the progenies from multiplication are in store at the PBI and a further phase of multiplication is not envisaged until replenishment of the multiplied stocks is required.

Evaluation of some of this material has begun at SPBS, notably on aspects of mildew resistance (this Report page 62).

DAFS PACKAGE 1

ARC Projects 04001-04004 inc.
04006-8
04013–15 inc.

A. M. Hayter
M. J. C. Asher
R. P. Ellis
R. J. Giles
J. S. Swanston
W. T. B. Thomas
J. Brown
J. C. Penman

POTATO DIVISION

Two clones have been accepted for National List and Plant Varieties Rights Trials in 1980: both are early maincrop varieties with high yield potential; 8911 abc(15) is resistant to *Globodera rostochiensis* race Ro1, and partially resistant to *G. pallida*, the other, 9006 (6), is resistant to potato virus Y, to potato leafroll virus and to tuber blight.

The four clones, entered into statutory trials in 1978 and which have performed satisfactorily according to the limited data available, will return for the second year of trial in 1980, and have been named as follows:—

7169 (10)	Provost
8906 abc(11)	Guardian
8990 (7)	Baillie
7495 (6)	Sheriff

Agreement was reached with colleagues at the Plant Breeding Institute, Cambridge, on both the principle and detail of joint trials procedures for advanced clones from both breeding stations. The first joint trials of first-early and maincrop clones are planned for 1980, and it is expected that the Northern Ireland Plant Breeding Station, Loughgall, will join in 1981. These trials will enable the products of the three public sector potato breeding programmes to be compared before the stage of statutory trials.

Following discussions with the Technical Group of the Potato Processors Association (*Ann. Rep. 1978-79*, 60), all collaborative work on the evaluation of processing quality in our breeding material is being arranged with the Technical Group rather than with individual companies as in the past. This arrangement simplifies communications for us, and ensures that all data on processing quality originating from commercial collaborators, is available to all members of the Association. The 1979 trials were a success and arrangements for the 1980 trials are complete.

The health of all stocks held at Blythbank has shown an encouraging response to intensive roguing and aphicide spray routines. The overall frequency of diseased plants rogued in 1979 was less than 1 per cent, and is now approaching what may be regarded as a realistic irreducible minimum for a breeding operation of this size and diversity.

Following the review of DAFS Package 8, which consists of the projects of the Strategic Breeding Department, all projects have been recommissioned but with a significant change of direction. Work on Neo-Tuberosum, on diploids and on their tetraploid derivatives, as well as on dihaploids, is now wholly concerned with the evaluation of this strategic material as a commercial breeding resource. To this end the routine development of adapted populations has ceased, and work is now concentrated on screening for yield potential, for cooking and processing quality, and for resistance to diseases. This phase of evaluation is a necessary prelude to a systematic and thorough exploitation of this adapted pool of genetic diversity.

There has been significant progress in the past year in the development and adoption of new serological detection methods for potato viruses. In particular an effective antiserum to PLRV has been prepared and its utilisation in the ELISA technique is being studied.

The field trials for screening for reaction to the two spraing viruses TRV and PMTV, were both successful in that high levels of infection were observed. However, good trials are infrequent and the need remains for the development of laboratory or glasshouse tests which can be conducted under controlled conditions.

The improvement of screening techniques for fungal diseases continues to exercise us in relation to gangrene, skin spot, and tuber blight. Notably, progress has been made in developing a screening procedure for detecting differences between varieties in resistance to soft rot.

With regard to potato cyst nematodes, further development work has been carried out on the closed container and seedling tests, and the closed container method has been used in all the routine screening carried out in 1979. In that they permit a shortening of the breeding-selection cycle, both tests have important implications for the breeding programme.

Studies of the way in which the potato host suppresses the formation of cysts by *G. pallida* have implicated various aspects of the biology of the host parasite relationship, including reduced hatching rate, reduced hatching period, reduction in invasion, and the disproportionate development of males. Further work is expected to reveal the relative significance of these different components, from the different resistance sources, to yield suppression in the host and to soil populations of the nematode.

J. H. W. Holden

Commercial Breeding Department

THE 1979 CROSSING PROGRAMME

Nineteen seventy nine proved to be a good year for hybridisations in all categories except for blight resistance breeding where the results were disappointing.

Purposive breeding for first earlies is a minor programme but eight advanced clones were intercrossed and outcrossed to seven first early cultivars, including Maris Bard and Pentland Javelin. Results were satisfactory and selection and assessment are proceeding.

The emphasis in breeding for eelworm resistance was again on combining resistance derived from *Solanum vernei* with that derived from *S. tuberosum* ssp. *andigena*. Gaps left by failed crosses in the 1978 programme were filled. New clones with resistance to *Globodera pallida* derived from *S. vernei* were used, as well as parents with proven breeding records from the same source. These were crossed to parents with resistance from *S. tuberosum* ssp. *andigena*. This programme was as successful as could be expected with 92 per cent of the desired crosses being secured.

The aim in the blight resistance breeding was to utilise as parents, progeny tested clones with good resistance to either or both foliage and tuber blight.

Twelve clones originally used speculatively as parents in 1978 and subsequently confirmed as being resistant to blight were crossed with a proven resistant clone. The latter clone, though previously used as a male parent failed to produce sufficient pollen, with the result that only four out of twelve crosses were successful.

Eighteen advanced blight resistant clones were crossed speculatively with three proven blight resisters. Here too, results were poor with only a quarter of the possible crosses secured.

Seven parents, progeny tested for foliage blight resistance, were intercrossed with some success.

Clones with three combinations of virus resistance, namely virus X and Y resistance; leafroll and virus X resistance; and leafroll, virus Y and virus X resistance, were crossed with Pentland Squire and Maris Piper, as well as with two good blight resistant clones. The cultivars used as pollen parents produced progeny from all combinations attempted, while a 50 per cent success resulted when the blight resistant parents were used as pollen parents.

Twenty four other advanced clones with superior agronomic commercial attributes were crossed with the cultivars Pentland Dell, P. Ivory, P. Squire, Maris Piper and Dr McIntosh. Almost all intercrossing was successful.

VIRUS RESISTANCE

The material in this programme is bred and selected within five lines of breeding for resistance to virus Y derived from different wild species of *Solanum*, and from one line for resistance to leafroll. In the crossing programme for 1979, fifty six parents resistant to viruses X and Y and twenty eight parents with good leafroll and virus X resistance were used. The breeding policy was to cross within lines and to intercross from the virus Y lines to the leafroll line and to cultivars. Records of the fertility in the field of some of the parents coupled with pollen fertility counts by the Cytology Unit staff aided the completion of a crossing programme which successfully yielded seed from approximately 400 crosses. The virus plots at the Murrays were variable with good and poor areas. One localised area, for example, suffered from a fairly severe infection of common scab (*Streptomyces scabies*). Apart from a considerable number of clones propagated as parental material, there were 8,000 single tuber plots; 500 three tuber plots for selection for virus trial in 1980; 340 three plant plots of material in the field exposure trial 1979; 400 twelve plant plots for selection; forty clones at Drochil Castle for assessment; twenty-one clones at the M3 stage and six clones at the M4 stage at the Murrays and in preliminary trials at the regional maincrop trial sites.

POTATO CYST NEMATODE RESISTANCE

The improved techniques for screening for PCN resistance have continued to permit the identification of resistant clones at earlier stages in the breeding programme. However, the attempt to screen tubers taken from seedlings grown in the glasshouse during the winter of 1978-79 proved only a partial success (see Pathology Report, p. 84). Although it was possible to identify some progenies with apparently higher than average levels of resistance, the data was not reliable enough to use as a basis for selection of particular clones at lifting time in the field.

The overwinter screening of the selections from the 1978 three plant plots (second year ex-glasshouse) proved very successful. For the first time it has been possible this year to identify and select for resistance amongst the M1 (third year ex-glasshouse) using this data. Of 409 M1 clones bred for PCN resistance, 180 have been selected with high levels of resistance for further assessment.

Previously, before the development of this early screening method, clones would have been selected without benefit of data on their reaction to eelworm and, inevitably, promising PCN resistant lines would have been discarded without their potential as parents being either explored or exploited.

QUALITY TESTING

All the clones from the commercial breeding programme in the four stages of assessment (M1-M4) at the Murrays and in regional trials, as well as material from the Strategic Breeding Department, approximately a total of 3,000 samples, were screened for cooking quality. Emphasis was placed on scoring samples of the advanced clones from the four regional trial sites. Samples from the four different sites and different types of soil give a good indication of the various cooking qualities. Scoring is now based on a one to nine scale for the following characters: flesh colour, texture, sloughing, after-cooking blackening and also crisp colour; the higher the score the better the quality.

Specific gravities were low during 1979, possibly a result of the cold summer, with the control cultivar Record averaging 1·09. The standard of quality in general has been above average, with clones of poor quality being readily identified.

TRIALS AT THE MURRAYS

Once again a cold wet spring delayed planting which particularly affected the first early material, which was planted about four weeks later than is normally the case. The plots had a good start, but then suffered somewhat from a cold spring and summer as well as from occasional strong winds which damaged leaves and stems. The Wee Murrays field was fairly uniform in soil type with a slight fertility gradient across the plots. The main control cultivar, Pentland Crown, gave a similar yield to that in 1978 in the Longriggs field, with an average yield of 23·6 kg and a range of 17 to 28 kg for a twelve plant plot. The harvest was expeditious due in part to the clement weather, but also to a new lay-out more suitable for mechanical harvesting.

1979 REGIONAL TRIALS

Despite a late start, due to the cold wet spring of 1979, most of the sites provided good data on the performance of our advanced clones in Scotland, Wales and England. Unfortunately a partial failure of nematicide treatment at the Arthur Rickwood EHF maincrop trial site, and damage by herbicide to the first early trial at Trefloyne, meant that data from both these sites was of limited value to decision making.

A total of ten first early clones and five control varieties were grown at four sites; Penrice and Trefloyne in South Wales using seed once grown by our UCW collaborators in 1978; and Cairnside, Wigtonshire and the Murrays. The clone 8906 abc (11) has continued to perform well, equalling or outyielding the highest yielding controls, justifying the decision to submit it for National List Trials in 1979. Clone 7169(10) performed well at Penrice, where, along with 8906 abc (11), it outyielded Maris Bard, but its performance in Scotland was rather disappointing this year. Three less advanced clones performed well and one, 9114 ce (2), was identified as a possible NLT candidate for 1980–81.

The latter clone will be retrialed at UCW using once grown seed in 1980, and 25 Kg seed samples have been supplied from Blythbank for 1980 to provide sufficient seed for larger trials in 1981. By that time, 7169(10) and 8906 abc (11) are expected to have been named and placed on the National List.

Seed tubers of sixteen less advanced clones (M_3, fifth year ex-glasshouse) have also been dispatched to UCW for observation in parallel with the usual trials at the Murrays and Stranraer.

Fully replicated trials of twenty one maincrop clones and three controls (Pentland Crown, Maris Piper and Maris Peer) and unreplicated observation plots of sixty M_4 clones were planted and lifted at all four maincrop regional trial centres in 1979. The data from the Arthur Rickwood EHF site proved difficult to interpret (see above). However, the Gleadthorpe EHF, Terrington EHF and the Murrays sites have produced useful data which has permitted evaluation of the material under trial.

Several clones performed well in comparison with the controls, in particular 8911 abc 15 which outyielded Pentland Crown and Maris Piper at all sites. The clone 9006 (6) also confirmed previous estimations of its potential and on the basis of these and earlier results, the decision was taken to submit both for National List Trials in 1980. Clone 9754 a (15), previously thought to have varietal potential, performed moderately well in yield terms, but a tendency to brittleness of tubers was confirmed and as a result it has been withdrawn from trials.

Decisions on the future of the other 1979 entries have not yet been made, but yield trial data indicate that at least nine may return to trials in 1980.

Ten clones out of sixty in the M4 observation plots have been identified as candidates for replicated regional trials in 1980. Several others will be grown in observation plots again in 1980.

In 1980 the SPBS and PBI advanced clones will be assessed together in jointly organised trials. The PBI have accepted responsibility for three southern maincrop sites, Arthur Rickwood, Terrington and Trumpington, and SPBS for the Murrays and Gleadthorpe. SPBS will also remain responsible for the first early trials at the two sites in South Wales. The trials will be similar to those run previously by SPBS but a slightly larger plot size, plus an additional replicate at each site, allied to the use of more sophisticated statistical designs, should lead to an enhanced quality of data.

These developments should lead to both greater precision and improved predictive reliability of the trials, and will permit a comparison of performance of clones from the two Institutes. In 1981 it is expected that DANI will also join this scheme.

SEED PRODUCTION

A total of 7·2 ha was used at Blythbank and Bordlands and Drochil Castle to produce seed tubers of all clones under assessment, for future assessment or for possible use as parents. Some 41,000 different clones, of which 33,500 were single plant plots and the rest three plant plots up to 700 plant plots of Approved Stocks of NLT candidates, were grown. The late spring delayed planting until mid-May. Despite the late start the plots grew well, particularly at the Bordlands site. The health of the stocks was good, with 0·9 per cent virus infection overall (0·6 per cent PLRV and 0·3 per cent PVY) compared with 1·7 per cent in the previous year. Four clones in NLT and eight potential candidates for submission to NLT received Approved Stock certificates from DAFS. The plants were defoliated at the end of August.

Unfortunately the new potato store at Blythbank was not completed by harvest time. In consequence much of the material had to be transferred and accommodated at Sourhope until December, by when the new store was ready. This additional building has doubled our storage capacity at Blythbank and relieved the pressure on storage space. It is equipped with sophisticated ventilation, air circulation and temperature control systems which will allow adequate control of storage and sprouting.

Twenty valuable clones were cleared in 1979 of virus diseases by heat treatment and meristem culture and will now be grown and maintained in a healthy state at Blythbank.

SUBMISSIONS TO NATIONAL LIST TRIALS

Data on the yield, quality, disease resistance and agronomic characters of three clones were presented to the SPBS National List Trials Committee. The decision of the committee was to submit two clones for Plant Varieties Rights and National List Trials in November 1979. A brief description of the two clones is given below:—

8911 abc (15) was originally considered a potential National List candidate in 1975 but its submission was delayed due to PLRV infection during the epidemic of 1975-76. It is an early maincrop clone, slightly earlier in maturity than Pentland Crown, which it has outyielded substantially at all sites. Its special merits include specific resistance (H1) to *Globodera rostochiensis*, pathotype Ro1, plus a moderate level of resistance to *G. pallida*.

9006(6), the second submission, is also an early maincrop. It has been a consistently high yielding clone, equal to or exceeding Pentland Crown. It possesses a similar degree of resistance to leafroll virus and virus Y as Pentland Crown plus a high level of resistance to tuber blight, and usually has a slightly higher dry matter content.

The four clones entered into statutory trials in 1978 are all proceeding into their second year of trials. Little quantitative data is yet available on their performance in any of the various trials into which they were entered, but preliminary indications and verbal communications are encouraging.

Clone 7495(6), a potential crisping variety, has outyielded Record and equalled or exceeded the same in dry matter content in two independent trials conducted by our collaborators at UCW, Aberystwyth and the Potato Processors Association.

Clone 8906 abc (11) has confirmed its ability to produce a high yield of attractive ware equal to, or more usually exceeding, current leading first-early varieties at an early lift. There are also indications that in addition to its known partial resistance to *G. rostochiensis* and *G. pallida* it is also "tolerant" of PCN infestation, that is to say it is capable of providing a yield at maturity under conditions of heavy PCN infestation while other more resistant but "intolerant" clones have suffered significant yield reductions (Trudgill, pers. comm.).

Clone 8990(7) in a second early trial grown by PBI at Cambridge was somewhat disappointing in yield compared with the control cultivar Estima, but it was the best of all other entries. Its performance elsewhere, however, was satisfactory and in Spain and Majorca was outstanding.

Clone 7169(10) performed well in the SPBS first early trials at Penrice where it outyielded Maris Bard but its performance at the Murrays and in Wigtownshire was disappointing.

Samples of all these clones have been despatched for trial to various collaborators in the UK and overseas by arrangement with NSDO, but to date no data on performance has been returned.

BIOMETRICAL WORK WITH POTATOES

Work has concentrated on the analysis of data from the three uniformity trials grown in 1978 (*Ann. Rep. 1978-79*, 59). Imposition of simulated randomised complete block designs having varying sizes and shapes of plots and blocks allowed more precise field layouts to be identified. It appeared that squatter plots and blocks were preferable to longer, narrower shapes. Indeed, some smaller, squatter plots gave lower coefficients of variation (*i.e.* higher precision) than did other larger, narrower plots. The coefficient of soil heterogeneity was calculated for each uniformity trial. Using these values it was possible to demonstrate that a worthwhile increase in precision should be expected by the use of an incomplete block design. There would appear to be very little to be gained by the use of plots larger than twenty five plants. The greatest precision is likely to result from using the smallest plots and the largest number of replicates compatible with field operations.

Analysis of the 1978 competition diallel data also continued. The purpose of this is to test the need for guard rows in our variety trials. A similar experiment was grown in 1979 using five varieties (Pentland Crown, Pentland Dell, Pentland Hawk, Croft and Maris Piper). This gave twenty five combinations of core and surround and these were grown in five replications. The analyses are not yet to hand. Whilst the pilot experiment of 1977 indicated little competition between different genotypes growing in adjacent drills, the 1978 experiment suggested otherwise (some early work has suggested that competition may depend upon seasonal influences). If the 1979 data confirm that significant competitive effects do exist then we should ideally begin using guard rows in our variety trials. However, as seed is very limited in supply we would first need to establish if the distortion caused by the competition is greater than the precision lost through scoring smaller plots.

COLLABORATION

1. *Industrial Processors*

Samples of 100 tubers of the seventeen clones in SPBS regional trials in 1979 were supplied to the PPA. These were multiplied by them in Yorkshire to provide small bulks of ware. Member companies of the PPA then assessed them for chipping, crisping and dehydration qualities and for storage characteristics. The dry matter of the clones proved to be low, but a few have potential as chippers and were considered to be worth a second year of trial.

One hundred and fifty kg of seed of the NLT submission 7495(6) was grown in trial by the PPA for direct comparison of yield, crisping quality and storage characters with the control variety Record. The results of this trial are awaited following the completion of tests, but were very encouraging in terms of yield and specific gravity.

2. *Overseas*

The trials of advanced clones at La Puebla, Majorca and Valencia, Spain grown for SPBS and NSDO by Luis Matutano S.A. were very successful. In the replicated trials, using both cut and whole seed tubers, clone 8990(7) performed outstandingly, outyielding the other entries including the controls. The clone 8906 abc (11) performed well in terms of yield but in the opinion of our Spanish collaborators it produced a less visually attractive sample than 8990(7). It was decided to resubmit 8990(7) for further replicated trials in 1980 with two other clones, 9735 a (23) and 10533 cc (14), which demonstrated commercial potential in the 1979 preliminary trials. A further ten advanced clones have also been despatched for a preliminary observation trial in 1980.

Small samples of each of the four NLT submissions, 7169(10), 8906 abc (11), 7495(6) and 8990(7) were despatched to France and Germany by arrangement with NSDO in spring 1979, but no data has yet been forthcoming.

NSDO have also arranged trials for the same four clones in Cyprus, Egypt, Algeria and Tunisia and samples have been sent this autumn for trial in 1980.

DAFS Package 7	T. M. W. Davidson	C. J. W. Torrance
ARC Projects 05001-05008 inc.	G. R. Mackay	M. F. B. Dale
	R. J. Killick	G. E. L. Swan

Potato Pathology Department

INTRODUCTION OF NEW SEROLOGICAL METHODS FOR THE DETECTION OF POTATO VIRUSES

Work has continued on the development of the Latex and ELISA tests for detecting potato viruses.

Potato Virus Y (PVY)

Antisera from several sources have been used: Mr W. P. Mowatt (SHRI) kindly supplied serum to a tobacco veinal necrosis strain of PVY, which was assessed for use in the ELISA test. Using a γ-globulin concentration of 1 $\mu g\ ml^{-1}$ and conjugated antibody at 1 $\mu l\ ml^{-1}$ the serum gave good detection of veinal necrosis, common strain and C strains of PVY, but did not differentiate between leaves infected with PVA and healthy uninfected leaves. The ELISA technique has been used in routine screening for resistance, for it is a more sensitive and quantitative test than inoculation of virus on detached leaves of *Solanum demissum*. ELISA has enabled the detection of infection present at levels which are too low to be detected by the *S. demissum* test.

An antiserum to PVY was supplied by Mr W. M. R. Laidlaw (DAFS Agricultural Scientific Services), and was used to sensitise latex for the Latex test. The sensitised latex was more sensitive than the *S. demissum* test, less sensitive than ELISA, but gave more rapid results than both. One hundred clones in the field trial grown at Cambridge to assess resistance to PLRV and PVY were tested with both Latex and ELISA methods. In only two plants did the Latex test give a negative reaction when the ELISA test proved positive.

An antiserum to a common strain of PVY was produced. It had a titre of 1:2048-1:4096 in the ring interface test. Used in ELISA tests the serum gave good detection of the common strain of PVY, satisfactory detection of veinal necrosis strains but poor detection of a C strain of PVY. Leaves infected with PVA again reacted as healthy leaves, giving an absorbance at 405 nm (A^{405}) of less than 0·02 OD units.

Potato Leafroll Virus (PLRV)

Ing. D.Z. Maat (IPO, Wageningen), kindly supplied a little PLRV serum which was used in the ELISA test to monitor virus levels during purification. An antiserum of our own was produced after successful purification of the virus. The highest titre obtained in sera so far tested has been 1:640-1:1280 in Ouchterlony gel diffusion tests, and no reaction to protein of healthy plants is apparent even at a serum dilution of 1:2. Electron microscope titre (determined by Mr I. M. Roberts of SHRI) was between 1:4000 and 1:8000, and the serum had a high avidity for the virus (titre measured by gel diffusion was 1:320-1:640). The sera so far tested have given satisfactory reactions in ELISA tests using a γ-globulin concentration of 1·25 $\mu g\ ml^{-1}$ and conjugated antibody at 2 $\mu g\ ml^{-1}$. Reactions to healthy leaves have an A^{405} of less than 0·04 OD units.

Few difficulties have been encountered in testing leaves for infection with PLRV and PVY with ELISA, except that healthy uninfected leaves that have been allowed to decay somewhat before testing give a relatively high reaction, with an A^{405} of 0·10-0·15 OD units. However, the reliable detection of these viruses in potato tubers has proved difficult because all healthy tubers of the twenty five clones so far tested have given reactions to ELISA which vary considerably between clones: the A^{405} values range from 0·04 to 0·2 OD units, overlapping with readings from infected tubers.

SCREENING FOR RESISTANCE TO POTATO VIRUSES X AND Y

Some 600 clones and 28,000 seedlings of 135 progenies were screened for resistance to potato viruses X and Y for the Commercial and Strategic Breeding Departments. The seedlings were spray-inoculated with the viruses and susceptible individuals eliminated. Plants of about 500 clones were sap-inoculated with PVX and PVY (the common strain of each) to obtain information on their virus resistance. About 100 clones were screened in more detail by graft inoculation with four strains of PVY and two strains of PVX.

FIELD TRIAL FOR RESISTANCE TO PLRV AND PVY

In 1978 a field trial was grown at the Plant Breeding Institute in which four plots of 400 clones were interspersed with infector plants. The tuber progenies were grown on at PBI in 1979 and scored for infection with PLRV and PVY. As in previous years scoring was on the basis of visible symptoms, but this year the Latex test was used in the field to check doubtful plants for Y infection.

Infection levels were low: in the control varieties leafroll occurred in 7 per cent of the plants of Pentland Crown and 25 per cent of Majestic, and PVY occurred in 20 per cent of the plants of Majestic and not at all in Pentland Crown. It was possible to identify some clones as susceptible, but others only as apparently resistant.

A similar trial was grown at PBI in 1979 for scoring in 1980.

THE SPRAING VIRUSES

Tobacco rattle virus (TRV)

The 1978 trial at Tayport (Fife) was very successful; the incidence of spraing symptoms in the tubers from sub-plots of the susceptible control variety Pentland Dell was high throughout most of the trial. In fifty eight sub-plots of Pentland Dell, the incidence of spraing (based on presence or absence in each tuber) ranged from 0 to 75 per cent, with a mean of 28 per cent, and only four sub-plots had no spraing. This meant that resistant clones could be identified with much more confidence than in most years.

Four out of eighteen advanced clones looked very resistant, with little or no spraing in four sub-plots of each clone. Pentland Lustre and Pentland Meteor also appeared to be very resistant, although NIAB has rated them susceptible. This would suggest geographic variation in resistance, possibly due to virus strain specificity, or variation in the nematode vector *Trichodorus spp*. Croft also appeared to be resistant, though it had a high incidence of internal rust spot which could be due to the virus. Croft is rated susceptible by NIAB.

There were also seventy eight less advanced clones in the trial. Eighteen of these had no spraing in either of two sub-plots, and are therefore likely to be resistant.

Potato mop-top virus (PMTV)

In 1978 a trial was grown in a field infested with PMTV at Braco (Perthshire). The presence or absence of spraing in each tuber was recorded for each sub-plot, and sixteen tubers from each sub-plot were grown on and the plants scored for presence or absence of haulm symptoms.

The trial worked well: symptoms occurred in up to 77 per cent of the tubers in each of the twenty seven sub-plots of the susceptible control variety Arran Pilot, and only one sub-plot had no spraing. Haulm symptoms occurred in up to 87 per cent of the plants, and only two sub-plots showed no haulm symptoms. Eight of eighteen advanced clones were identified as susceptible in replicated sub-plots, and six appeared resistant. Twenty of sixty three M3 clones showed no symptoms in single sub-plots, and only one of a further thirteen first-early clones appeared susceptible, ten having no spraing and no definite haulm symptoms.

As well as Stormont Enterprise and Record, which are already considered resistant, Croft, Pentland Meteor and Pentland Lustre looked resistant with no spraing in two sub-plots, although Stormont Enterprise, Record, Croft and Pentland Lustre did show haulm symptoms in one or two plants. Pentland Javelin and Pentland Marble appeared susceptible, and a little spraing occurred in Redskin, Pentland Crown, Pentland Dell, Pentland Hawk, Pentland Ivory, Pentland Raven and Pentland Squire.

APHID COUNTS

A potato aphid survey was carried out in Wee Murrays at fortnightly intervals from 4th July to 29th August 1979. The first date was before spraying began, and the others were three to five days after spraying with pirimicarb. On each occasion fifty whole plants were examined, but only one or two individuals of *Macrosiphum euphorbiae* or *Myzus persicae* were found. Suction trap data obtained by Mrs L. A. D. Turl (DAFS Agricultural Scientific Services) from the Murrays for these dates indicated that few aphids had been caught.

POTATO SPINDLE TUBER VIRUS (PSTV)

Some 250 test samples, each of up to 100 leaflets, were submitted to DAFS Agricultural Scientific Services for testing for the presence of PSTV during 1978/79. All but seven tests from the Commonwealth Potato Collection, which are being re-grown for testing during winter 1979/80, were declared free of the virus.

FOLIAGE AND TUBER BLIGHT (*PHYTOPHTHORA INFESTANS*)

Routine glasshouse assessments of foliage resistance were made on 837 fifth and sixth year selections from the commercial breeding programme, and on ninety two Neo-Tuberosum clones and eleven dihaploids from the strategic breeding department. The fifth year selections included clones resulting from the 1974 crossing programme where the emphasis was on breeding for blight resistance. The levels of resistance found are shown in Table 7. Of 192 sixth year selections, nineteen showed a good level of resistance, scoring six or more on the one to nine scale of increasing resistance, as did nineteen of ninety three Neo-Tuberosum clones.

TABLE 7

Levels of foliage blight resistance in fifth year selections in the Tuberosum breeding programme

Parentage	*No. progenies tested*	*Mean score (1-9 scale of increasing resistance)*
Proven blight resisters × Speculative blight resisters	61	5·1
Proven blight resisters × Neo-Tuberosum (resistance unknown)	52	4·5
Crosses not selected for blight resistance	101	4·6

Seedlings of seventy five progenies of blight-resistant parents were screened in a seed-pan test to identify progenies with a high number of resistant individuals. As in 1978, four categories of disease severity were recognised: less than 10 per cent, 10 to 25 per cent, 26 to 50 per cent and more than 50 per cent of the total amount of foliage infected in the pan of twenty five seedlings, after six days incubation at 15°C. Two pans of seedlings were grown per progeny.

In order to compare results from the seed-pan test with tests on whole plants, two progenies selected from each of the four scoring categories were re-sown and allowed to tuber in 1978, and two tubers from twenty seedlings grown for a whole plant test in 1979. Each plant was given a score on the same one to four scale of decreasing necrotic area used in the seedling test. Table 8 shows the number of plants which fell into each category. This suggests that although the first (least resistant) group appeared more susceptible when

TABLE 8

Levels of foliage blight in adult plants of progenies representative of four seed-pan test scoring categories

Disease category derived from 1978 seed-pan test	*Number of adult plants scoring* 1	2	3	4	*Mean Score*	*Total number of plants tested*
1	18	21	16	15	2·4	70
Increasing 2	11	19	11	20	2·7	61
Resistance 3	6	5	9	46	3·4	66
↓ 4	2	1	4	72	3·8	79

tested as seedlings than as tuber-grown plants, the more resistant progenies were satisfactorily identified by the seed-pan test.

The resistance to tuber blight of fifth and sixth year clones from the general breeding programme was assessed in the usual routine laboratory tests. Among early clones tested, eighty two of 105 fifth year selections and twelve of forty eight sixth year selections showed resistance equal to or better than that of the resistant control variety Wilja.

The level of infection in maincrop clones was again too low to allow more than very susceptible clones to be identified. Inoculation and incubation techniques were examined experimentally in an attempt to explain this failure. Spraying the tubers with inoculum twice, or spraying them with water before inoculation, gave an increased level of blight, but tubers of Pentland Dell lifted at the end of October and inoculated using the normal technique proved considerably more susceptible than at the routine lift in early September, despite increased maturity. In 1980, plots of control varieties will be excluded from the routine blight fungicide treatment to determine if this has any effect on the test.

The 1979 field trial for testing the resistance of advanced selections to foliage and tuber blight was again carried out at Yonderton Farm in Ayrshire. A good level of infection was established in the foliage, and four successive weekly observations in the progress of the disease on the foliage were carried out from 30th July. Of twenty nine early clones, two showed similar resistance to Maris Peer, and thirteen of seventy four maincrop clones were as resistant as Record. Three clones stood out as being particularly resistant at the final scoring, with less than one quarter of the foliage blighted, when foliage of Record was more than three quarters infected. These clones had been rated as resistant in previous laboratory tests.

Levels of infection in the tubers were generally low: the susceptible varieties Pentland Javelin and Pentland Dell had 21 and 18 per cent of tubers blighted respectively. Harvest was delayed because of wet weather and some blighted tubers may have rotted in the ground, leading to underestimation of susceptibility, particularly in early varieties. Of the 103 clones in the trial, eight were more than 20 per cent blighted and four out of five of these had already been rated very susceptible in laboratory tests. Twenty eight clones had been assessed in the field trial in two years, and results for twenty three of them were in good agreement.

Miss J. C. M. Rose, a CASE award student from the University of Glasgow, spent the first of three annual three-month periods in the Department. She is investigating the race non-specific resistance of tubers to blight.

Some factors affecting the laboratory tests for assessing foliage and tuber resistance were studied by Miss S. M. McFarlane, a "sandwich" student from Napier College. A glasshouse whole plant test on ten plants each of Corrie (expected score six on one to nine scale), Majestic (five), Maris Piper (four) and Bintje (three), planted seven, six, five and four weeks before inoculation was carried out in May, July and September. There was a significant difference between the susceptibility of plants of different ages, the youngest plants being the most susceptible. At the first inoculation, susceptibility was greatest on the youngest plants and the remainder exhibited a similar, somewhat lower, level of susceptibility. In July and September the increase in resistance was more gradual and less marked. Age affected susceptibility to the greatest extent in the more resistant varieties, the difference between four and seven week old plants of Corrie being in the order of two scoring categories. Corrie appeared more susceptible in July, with a mean score of 6·0, than in May, when it scored 7·3, and Bintje was particularly resistant in September, with a mean score of 5·2, but the overall level of susceptibility of the other two varieties was similar in all three inoculations.

The effect of the age of the tuber on susceptibility was further investigated, using ten varieties covering a range of susceptibilities (*Ann. Rep. 1977-78*, 51; *Ann. Rep. 1978-79*, 63-65). Delaying inoculation for one, two, four or eight days after harvest gave a reduced level of infection in six of the ten early varieties, the greatest decrease occurring with one day's delay. A decrease in susceptibility of early varieties inoculated at fortnightly intervals between mid-July and mid-September was again observed, confirming last year's findings (*Ann. Rep. 1978-79*, 63-65). The mean level of blighted tubers fell from 63 per cent in mid-July to 45 per cent in mid-September. Similar inoculations were carried out on ten maincrop varieties, but the level of infection was too low for any trend to be observed.

GANGRENE (*PHOMA EXIGUA* VAR. *FOVEATA*)

Routine cornmeal-sand inoculations were carried out in the winter of 1978-79 to assess the resistance of 802 clones from the commercial and strategic breeding programmes. Five hundred and twenty of these clones were fifth year selections, in the first year of testing. As last year, samples of ten tubers only were used, with the object of identifying highly susceptible clones to be discarded. Forty two such clones, with susceptibilities comparable to the highly susceptible control varieties Pentland Envoy and Pentland Falcon, were identified.

A higher than usual proportion of clones was rated resistant in routine tests in 1978-79, for 180 of 254 sixth and seventh year selections scored seven or more on the five point scale of one, three, five, seven and nine. One hundred and ninety eight of these clones had also been tested in 1977-78: the two tests showed satisfactory agreement, for 170 clones received the same or adjacent ratings in both years.

The observation reported in *Ann. Rep. 1978-79*, 66, that an initial period of high humidity is essential for the development of the disease after rolling tubers in a cornmeal-sand culture was confirmed. Three boxes of twenty tubers of Pentland Crown and two of Dunbar Standard were inoculated and stored at 100 per cent relative humidity at 4°C for one, two, four, six or eight weeks before being transferred to 80 per cent relative humidity at the same temperature. The gangrene score after eight weeks (see *Ann. Rep. 1978-79*, 66) was as high after one week at 100 per cent relative humidity as after any of the longer periods. Disease development on tubers held at 80 per cent relative humidity throughout was negligible. A relative humidity of 100 per cent is now maintained for only two weeks in the routine screening test, thus reducing the amount of soft rot observed hitherto.

A comparison between 4°C and 8°C as incubation temperatures for gangrene was again made (see *Ann. Rep. 1977-78*, 66). Three boxes of each of eleven varieties were inoculated and held for ten weeks at each temperature. The overall mean disease score was 3·6 at 4°C and 1·7 at 8°C, the reverse of last year's finding. Pentland Falcon, however, had a higher disease score at the higher temperature (12·7 compared with 7·4).

Sterilising washed tubers of Pentland Crown in 2 per cent formaldehyde before washing them again and inoculating them either by dipping in culture macerate or rolling in cornmeal-sand culture had no effect on the amount of gangrene that developed after eight weeks incubation at 4°C. Tubers inoculated without being washed after sterilisation developed much less gangrene. Dipping was a less effective method of inoculating than rolling: although it is not possible to equate directly the inoculum potential of each type of inoculum, dipped tubers had a mean score of 0·8 and rolled tubers of 3·5 on the nought to twenty four scale (see *Ann. Rep. 1978-79*, 66).

The development of gangrene on tubers of Pentland Crown, Pentland Hawk and Corrie was compared with that on tubers of the same stock deliberately exposed to light and which had turned green. After inoculation by rolling, and incubation at 4°C for eight weeks, normal tubers (three boxes per variety) had a mean score of 4·4 and green tubers (two boxes) were markedly more susceptible, with a score of 10·6.

SKINSPOT (*POLYSCYTALUM PUSTULANS*)

In the 1978-79 screening test of 214 sixth and seventh year clones, tubers were surface-sterilised with 2 per cent formaldehyde solution and inoculated within forty eight hours of lifting. The overall level of infection was high, but there was little difference between resistant and susceptible control varieties, so that clones could not be reliably assessed. However, twenty-seven clones stood out as less susceptible than the controls, and the susceptibility of fourteen of fifteen clones which had been heavily infected in previous tests was confirmed.

In an experimental attempt in the winter of 1979-80 to adjust the level of infection, three boxes of ten varieties were inoculated (with or without sterilising in 2 per cent formaldehyde) with culture macerate diluted to half, one quarter or one eighth strength with tap water. Surprisingly, disease levels were similar at all dilutions, except that very little infection developed on unsterilised tubers. Skinspot did not develop extensively on any of the ten varieties, however, possibly because the tubers available for the experiment carried considerable common scab.

COMMON SCAB (*STREPTOMYCES SCABIES*)

The disease resistance of fifth year selections was assessed in 1978 under polythene tunnels at the Murrays on a site immediately adjacent to that used in 1977. The level of scab was again too low for reliable assessment, the susceptible control variety Maris Piper having only 33 per cent of tubers with more than one sixteenth of the surface scabbed. The uneven distribution of disease within and between tunnels is underlined by the fact that the mean percentage of infected tubers per tunnel, calculated from two plots of twelve control varieties, ranged from five to thirty six. Unless a permanent scab site can be established at the Murrays, with a more even distribution of *S. streptomyces* in the soil, it seems preferable to use larger plots of each clone elsewhere and thus delay screening to a later stage in the breeding programme.

The glasshouse scab test based on the method described by McIntosh (*Potato Res. 13*, 241-7) was extended in 1979 to include 200 fifth year clones. Three pots of each clone gave a total of ten to twenty tubers for assessment, and eleven clones were identified as more susceptible than the most susceptible control varieties (Maris Piper, Arran Victory, Désirée).

A trial of sixth and seventh year selections was carried out in 1978 at both Archerfield and at a new site on Scoughall farm near Whitekirk, East Lothian. There was poor agreement in the results from the two sites. Of the 238 clones in the trials, 123 fell into the two resistant categories, seven and nine, of the five point scale at Archerfield, whereas 183 did so at Scoughall, suggesting underestimation of susceptibility at Scoughall. However, of eighteen clones which obtained a score of one at Scoughall, only eight were similarly rated at Archerfield: two clones obtained a score of five, and four clones a score of seven. These differences may be accounted for to some extent by disease escapes, but possibly other factors are involved, such as locally different strains of *S. scabies*. One hundred and six of the clones had been tested at Archerfield in 1977, but only fifty seven clones received the same or adjacent rating in both years at this site.

DRY ROT (*FUSARIUM SOLANI* VAR. *COERULEUM*)

Thirty two seventh year clones with potential as crisping varieties were tested for susceptibility during the winter of 1978-79. Tubers were inoculated by wounding with a glass rod and rolling in a cornmeal-sand culture, but levels of infection were too low (after twelve weeks incubation) to show differences in susceptibility. A fresh isolate of the pathogen obtained from the East of Scotland College of Agriculture was used on a pilot scale in 1979-80 to confirm the validity of the inoculation technique, and proved very aggressive to the susceptible variety Catriona. In a comparison of the susceptibility of twelve cultivars to both *F. solani* var *coeruleum* and *F. sulphureum*, three boxes of twenty tubers of each variety were wounded with a glass rod, rolled in a cornmeal-sand culture of one or other of the pathogens, and incubated at high humidity for ten weeks at 10°C. The rots produced by *F. sulphureum* were generally larger and somewhat deeper, but the most striking feature of the comparison was the differential reaction of the varieties. Catriona was highly susceptible to *F. solani* var. *coeruleum* and Pentland Ivory was very resistant, whereas these varieties reacted in quite the opposite manner to *F. sulphureum*.

WART (*SYNCHYTRIUM ENDOBIOTICUM*)

In 1978-79 143 clones from the commercial breeding programme and twelve from the strategic breeding programme were tested by DAFS for resistance to wart. Seventy nine per cent of fifty eight virus-resistant clones, 81 per cent of twenty seven other clones from the commercial breeding programme and 64 per cent of fifty eight potential parents were found to be completely or partially resistant. Eight of eleven clones previously tested were given the same rating in both years.

SOFT ROT (*ERWINIA CAROTOVORA* VAR. *ATROSEPTICA*)

Dr W. F. Bourne, a senior member of staff of Lanchester Polytechnic, spent three months in the Department during the year. He was able to use the method of screening developed in 1978 to group a number of varieties according to their susceptibility to soft rot when wounded, point inoculated and incubated at 25°C under nitrogen for six days. Pentland Javelin was consistently the most susceptible of the fourteen cultivars investigated.

POTATO CYST NEMATODE

Screening for resistance

The development of the closed container method for mass-screening potato clones for resistance to potato cyst-nematode has continued. A comparison of this method with the conventional glasshouse rootball test was made, using thirty five clones bred from *Solanum vernei* or *S. tuberosum* ssp. *andigena*. The clones were selected to represent a range of resistance to *G. pallida* (pathotype E) of 10 to 100 per cent susceptibility when compared with the fully susceptible variety Pentland Crown. Significant agreement was found ($r = 0{\cdot}75$, $P < 0{\cdot}001$) between susceptibilities derived from the two methods of testing. This confirms results previously obtained (*Ann. Rep. 1978-79*, 69-70). The results from thirty six Neo-Tuberosum clones were also significantly correlated ($r = 0{\cdot}665$, $P < 0{\cdot}001$). The closed container method has therefore been used for all routine screening carried out in 1979 (3,550 tests). The method has been slightly modified in order to stimulate the production of more extensive root systems: J.I. No. 2 compost was substituted for sand and its moisture level increased to 30 per cent.

Some 830 *ex-andigena* and *ex-vernei* clones were screened for resistance to *G. pallida* (pathotype E) using four canisters per test. In 1978 537 of these clones had been tested in single canisters and had been classified as resistant if less than ten cysts were visible on the root system. In 1979 these clones were retested, and 43 per cent were classified as 15 per cent susceptible or less. Twenty two per cent of those designated susceptible in 1978 were regarded as resistant when retested in 1979. Clearly, however, even the single canister test carried out in 1978 was of value in selecting resistant clones, and such a test would be useful at an early stage in the breeding programme.

Work on the development of a seedling test for resistance has been pursued. Tubers from seedlings tested in 1978 (*Ann. Rep. 1978-79*, 69-70) were subjected to a rootball test. There was a significant correlation between the susceptibility of a progeny when assessed as the mean of individually grown seedlings and as plants grown from tubers developed from those seedlings ($r = 0{\cdot}65$, $P < 0{\cdot}001$). Growing seedlings individually is space consuming, so the feasibility of screening four replications of fifteen seedlings per pot to produce a mean level of resistance for each progeny has been investigated. Results indicate that this method allows detection of significant differences between progenies, and that there is agreement between these results and those obtained when seedlings are grown individually ($r = 0{\cdot}69$, $P < 0{\cdot}05$). Further work to confirm the relationship between the resistance of progeny assessed in this way and from tuber-grown plants is underway. If validated, this test will offer the opportunity of screening progenies for resistance early in the breeding programme and also give useful information on the breeding value of parents.

Hatching and invasion

Tests on the hatching response of *Globodera pallida* to clones of *Solanum tuberosum* and *S. vernei* × *S. tuberosum* continued. Tubers of Home Guard or 8906 abc (11) were planted in J.I. No. 2 potting soil in 23 cm diameter clay pots sunk in sand in glasshouse beds. Two terylene bags, each containing 100 cysts, were buried in each pot. Five pots of each clone were sampled four weeks after the tubers were planted and at four-week intervals thereafter until sixteen weeks. Residual viable eggs were counted and percentage hatch estimated by counting eggs from cysts in bags buried in pots containing soil only. A significantly smaller number of unhatched eggs ($P < 0{\cdot}001$) remained under Home Guard (37 per cent) than under 8906 abc (11) (50 per cent). This difference was apparent after four weeks and remained constant throughout the experiment.

In another experiment the rate of hatch of *G. pallida* was examined over a period of five weeks in pots of Pentland Crown, Home Guard, 8906 abc (11) and 8917 b (3). Tests were conducted as described above, but in smaller pots (10·5 cm diameter) and bags were sampled at weekly intervals. After four weeks the degree of hatch was similar under all clones (59–67 per cent); in the final sample there was no further hatch under 8906 abc (11) and 8917 b (3), whereas Pentland Crown and Home Guard continued to induce hatching to a level of 78 per cent and 73 per cent respectively. The difference between Pentland Crown and the two resistant clones was significant ($P < 0{\cdot}05$).

In a more detailed study of the fate of juveniles after hatching, cysts of *G. pallida* (pathotype E) were soaked for a week in tap water and transferred to potato root diffusate for forty eight hours to ensure a rapid hatch. Seven cultivars over a range of resistances were chosen, and detached sprouts of these clones were rooted in trays of moist sand for a week. Five cysts were then placed by means of a paint brush along the terminal 35 mm of a root of each sprout. The inoculated portion of root was sandwiched between two layers of polyurethane foam and fastened with a hair clip. The sprout was then planted in J.I. No. 2 compost. One week later inoculated sections of root were re-located, stained with cotton blue, and the juveniles were counted (Table 9).

TABLE 9

Mean number of juveniles present in the roots of seven clones with different levels of susceptibility to *G. pallida*. Observations made one week after inoculation

Clone	*Susceptibility* (percentage of Pentland Crown)*	*No. observations*	*No. juveniles/ root*	*S.E.*
Home Guard	100	24	18·2	1·4
Pentland Meteor	100	4	14·8	3·5
Pentland Crown	100	19	7·1	1·6
9806 abc (11)	25	39	4·9	1·1
8912 bc (5)	42	26	4·4	1·4
8891 d (28)	20	33	3·3	1·2
8917 b (3)	9	25	3·0	1·4

* Data from pot tests 1975–78, except for Pentland Meteor which is assumed to be fully susceptible to *G. pallida*.

The clones derived from *S. vernei* contained significantly fewer juveniles in the roots than Home Guard and Pentland Meteor ($P < 0{\cdot}05$), but there was no significant difference between the numbers of juveniles in the roots of Pentland Crown and the clones derived from *S. vernei*.

In a further experiment, roots of Pentland Meteor and 8917 b (3) were infested with cysts stimulated in diffusate as described previously, and were examined after fourteen days. An analysis of variance showed that Pentland Meteor roots not only contained significantly more juveniles than 8917 b (3) ($P < 0{\cdot}001$), but that there was a significant interaction between cultivars and the sex ratio of juveniles, in that roots of Pentland Meteor contained proportionately more females than did 8917 b (3) ($P < 0{\cdot}001$, Table 10).

The technique of Mugniery and Person (*Sciences agron. Rennes 1976*, 217–220) has also been used to study invasion and development. In a preliminary

TABLE 10

Mean number of males and females developing in roots of Pentland Meteor and 8917 b (3) fourteen days after inoculating with diffusate-treated cysts

Clone	*No. roots*	*Mean No./root* *Male*	*Mean No./root* *Female*
Pentland Meteor	4	24·0 ± 3·6	6·5 ± 1·3
8917 b (3)	4	4·3 ± 2·2	0·3 ± 0·5

experiment with Pentland Crown, Désirée, 8906 abc (11) and 8917 b (3), small eye scoops were placed on water agar and allowed to grow. The agar was inoculated adjacent to the roots with hatched juveniles, and invasion and development were observed under the microscope without destroying the plants. Developing females were observed protruding from the roots after sixteen days, and after twenty days counts of females developing in the roots of these clones were respectively eighty two, ninety two, six and four. The proportion of males to females was also very much greater on the roots of the partially resistant 8906 abc (11) than on Pentland Crown or Désirée. These observations lead to the hypothesis that reduced hatching and invasion by juveniles and increased male development may contribute cumulatively to resistance derived from *S. vernei*.

The Nutrient Film Technique, originally developed at GCRI for growing plants in a thin film of circulating nutrient, has been used for growing potatoes infested with potato cyst nematode. Nematodes have successfully developed to maturity on the soilless roots. This technique should complement others in the study of nematode development.

Meristem culture

Considerable success has been achieved in the meristem culture of several clones from a differential series (*Kort et al., Nematologica 23*, 333-339) which will be used to pathotype British potato cyst-nematode populations. By this means plants of 62.33.3 have been cleared of viruses S, X, Y and leafroll and multiplied by node cuttings to produce 400 tubers. Five plants of GLK 58.1642/4 await virus tests, and two plantlets of 65.346/19 have been transferred into compost. It is hoped that these plants will give rise to healthy stocks for use in our research work and to supply nematologists elsewhere in the United Kingdom. A further five clones of the *S. vernei* × *S. tuberosum* group used for research have also been cleared of X, Y and leafroll.

Tolerance and resistance

It is important that resistant cultivars should also be tolerant, as it seems likely that clones which show a large decrease in yield as a result of nematode invasion will have no attraction for commercial growers. Resistant clones derived from *S. vernei* have been supplied to Dr D. L. Trudgill and Miss L. Cotes (SHRI) who are carrying out an investigation into tolerance. It is hoped in due course to develop a test to identify tolerant clones.

In 1978 a walled outdoor plot infested with a population of *G. pallida* (pathotype E) which originally came from Lindley, Lincs, was permanently subdivided into three equal plots. The partially resistant clones 8917 b (3), 8906 abc (11) and the control Pentland Crown were planted. Soil populations are being monitored each year after cropping to detect any increases in the frequency of nematodes able to overcome resistance derived from *S. vernei*.

DAFS Package 7
ARC Projects 0510-05015 inc.

R. L. Wastie
H. E. Stewart
M. S. Phillips
I. B. Majewicz
J. M. S. Forrest
R. M. Solomon
L. A. Wilson

Strategic Breeding Department

This Department deals with "Package 8" which involves the Commonwealth Potato Collection and work with South American cultivated potatoes, both diploid and tetraploid, and with dihaploids of commercial-type potatoes. The Package has recently been reviewed and, while work with the Collection is unaffected, other activities have been modified. The requirement for change was notified after the field plantings had been made and disease-resistance testing arranged, but it influenced the season's pollination programmes. Development work is being discontinued while surveys of yields, disease resistances and other properties are carried out, the purpose being to evaluate the material as a resource for commercial breeding. Work with tetraploids was already largely aligned in this direction, mass-selection having been discontinued, studies of yields in progenies obtained by crossing with commercial breeding lines initiated, and disease-resistance testing expanded (*Ann. Rep. 1978-79,* 72-75); these activities are being developed further while work on establishing a "Mark II" Neo-Tuberosum population with a broader genetic base has been curtailed. Mass-selection in the diploid programme has been discontinued, and in both this and the dihaploid programme emphasis is being placed on obtaining and studying the performance of derived tetraploid material of the kind which could be used in commercial breeding.

THE COMMONWEALTH POTATO COLLECTION

The Collection lines sown in autumn 1978 for final PSTV testing (*Ann. Rep. 1978-79,* 72) were sampled and tested over the 1978-79 winter by the Plant Quarantine Authorities. Evidence of infection was found in one bulk sample involving ten lines, but was not confirmed either in duplicate samples taken at the same time as the original ones and stored in a deep-freeze or on re-sampling. Suspicion was therefore extended to seventy other Collection lines initially sampled at the same time, but tests on duplicates and repeat samples of these also proved negative. Tubers of these eighty lines were replanted in autumn 1979. The remainder of the lines were cleared for PSTV and will be replanted in spring, 1980 for the production of true seed.

A paper on the history and maintenance procedures of the Collection, presented in 1978 to an IBPGR-sponsored training course on gene-bank work, has been included in an IBPGR handbook for future courses.

Forty four seed samples have been distributed during the year, four for use at the SPBS, thirty eight to five other UK centres, and two to Poland.

SOUTH AMERICAN CULTIVATED TETRAPLOID POTATOES

Last year, mean yields were reported for a set of Neo-Tuberosum × Tuberosum progenies (*Ann. Rep. 1978-79*, 73-74). Studies have subsequently been extended to the individual clones composing the progenies, the tubers being passed through riddles to determine their size-distribution. The mean yield of tubers over 1½" per clone per progeny ranged, over the eighteen progenies in the experiment, from 60 to 125 per cent of that of Pentland Crown. Only three progenies did not include at least one clone as high yielding as Pentland Crown, and eleven of the twelve clones in the best progeny outyielded Crown.

A further experiment was planted in 1979, using small pot-grown tubers. It compared fifty four genotypes of each of four classes of material. Analysis of the data is incomplete but mean yields were highest in Neo-Tuberosum × Tuberosum progenies, next-highest in Neo-Tuberosum intercrosses (c. 85 per cent of Ntb × Tbr), a Tuberosum intercross was poorer (c. 75 per cent), and Neo-Tuberosum selfed progenies were low yielding (c. 50 per cent).

A pollination programme, aimed mainly at obtaining arrays of progenies suitable for investigation of yield inheritance, was conducted. In addition to the crossing of Neo-Tuberosum onto Tuberosum female parents, intercrosses and selfings were done within the parental groups, and some reciprocal crosses of Tuberosum onto Neo-Tuberosum female parents were made to check whether maternal factors influence yield. This seed will be sown, but other seed from Neo-Tuberosum intercrosses aimed at providing progenies for selection of superior clones will be stored for future use. Only limited work was done on completing the securing of the second generation of the expanded "Mark II" Neo-Tuberosum population, and this seed will be stored.

The use of Neo-Tuberosum in the cultivar breeding programme was reviewed in *Ann. Rep. 1977-78*, 56-57. Subsequently, four clones derived from pollinations over the 1969-1971 period have attracted special attention; 9242 a (30) was entered to the 1978 Regional Trials while 9245 ab (24) and

10469 a (2) were in the 1979 trials; the former two and 9250 ab (2) have been grown in trials in Spain. Due to the PSTV scare, pollinations done in 1972 were abortive (the seedlings discarded) and none were done in 1973. In 1974 Neo-Tuberosum was used extensively, and from this batch 171 clones have survived three years of selection in the field, a higher proportion than in the earlier batches from which 125 reached this stage from a comparable total number of seedlings. Small-scale use of Neo-Tuberosum continued up to 1977 but no Neo-Tuberosum parents were used in 1978 or 1979.

In the replicated 1978 "assessment" planting of Neo-Tuberosum clones and control varieties two early-maturing clones gave similar yields to Pentland Javelin and Craigs Royal. The mean yields for fifty one early-maincrop, twenty seven maincrop and twelve late clones hardly differed and were comparable with those of Pentland Crown and Croft. Some clones were markedly higher yielding than the average, and seventeen significantly outyielded Pentland Crown while four significantly outyielded Maris Piper and Majestic which, in this planting, gave higher yields than Pentland Crown. About half the clones were comparable with the controls in tuber size and size distribution, others having smaller average sizes or greater variation in size. The tubers were scored on a range from one = excellent in appearance to five = bad, control means ranging from one for Pentland Crown and Pentland Javelin to 3·25 for Majestic; about 10 per cent of the individual Neo-Tuberosum plots scored one and 50 per cent two with only about 10 per cent scoring less than three. Forty clones were classed as being within the commercial range in yield, tuber size and size variation, and in appearance, or as being excellent in appearance and not far outside the range in other respects. Normally only these would have been retained, but as surveys of disease resistances and other properties are in progress most of the others were also replanted in 1979.

Another, different, batch of clones was grown in a replicated planting in 1979 but processing of the data is incomplete.

Maturities in Neo-Tuberosum clones have hitherto been assessed only by observation of senescence when grown for autumn harvesting, but in 1979 some clones with apparent early maturity were grown as "earlies" and harvested in July. There was a single three-plant plot of each clone and two such plots of Pentland Javelin, Craigs Royal and Home Guard. Yields of the controls ranged from 400 to 860 g per plant, and their mean tuber weights ranged from 50 to 110 g. Of the twenty eight Neo-Tuberosum clones ten gave over 500 g per plant, the best giving 1,050 g. Many bore excessively numerous and small tubers but four of the ten high yielders had tubers averaging 50 g or more. One, Gl.77B/54, with a yield of 670 g, and oval shallow-eyed white tubers averaging 60 g, was judged worthy of reassessment while the top-yielder, Gl.76B/13, with bronze-red but rather flat tubers averaging 50 g, may also be of interest.

Preliminary potato cyst eelworm resistance tests, using pathotype E, were done on 117 clones derived from the same twenty three parents as the forty three clones tested last year (*Ann. Rep. 1978-79*, 75), and on eighty six other clones mostly of unknown parentage. Eighty five per cent appeared less susceptible than Pentland Crown, 42 per cent having less than 40 per cent and 6 per cent having under 10 per cent of Pentland Crown's susceptibility. It appeared that low susceptibilities among the 117 clones stemmed mainly from six of the twenty three parents (Gl.71/96, /101, /112, /125, /128 and /175), mean scores in clones derived from these ranging from 28 to 40 per cent, based on from five to twenty three clones. Resistance was not uniform within a progeny; as an extreme example, two clones from the cross Gl.71/96 × Gl.71/148 scored 2 and 101 per cent.

Further investigations have been made of the nature of the resistance to virus Y derived from certain Neo-Tuberosum clones (*Ann. Rep. 1978-79*, 74). It appears that the resistances derived from clones Gl.71/96, /112 and /179 resemble that derived from Gl.71/190 in being operative against a range of related viruses, yet not conferring full immunity in all cases. (The report last year of resistance deriving from Gl.71/172 was a misprint for Gl.71/179).

Collaborative work with Golden Wonder Ltd. is in hand for evaluation of the crisping qualities of seven Neo-Tuberosum clones. Their comments on samples crisped immediately after harvest are favourable but the results of crisping after storage are awaited. Freeze-dried powders have been sent to the University of Minnesota for protein assessment, results being awaited.

Attempts at flavour evaluation have commenced. At the SPBS similar though slight variation was found in Neo-Tuberosum clones and commercial controls. Fifteen samples were sent to the Food Research Institute for more detailed study. These consisted of ten Neo-Tuberosum clones which in SPBS tests had appeared normal and three Neo-Tuberosum clones together with the varieties Home Guard and Arran Consul in which slight differences had been found. At the FRI, a trained taste panel of nine persons assessed each sample and from their collated descriptions it appears that they found nothing unusual in the flavours of the five samples which our tasters differentiated but slight differences in some of the others. These results suggest that definition of flavour differences in Neo-Tuberosum will be difficult.

SOUTH AMERICAN DIPLOIDS AND TUBEROSUM DIHAPLOIDS

Changes were introduced in the layout of evaluation plots at the Murrays in 1979 to permit small-scale mechanical harvesting and these led to larger bulk tuber samples being obtained, allowing data to be collected on the percentage of "ware" yield (*i.e.* that composed of tubers selected between 40 mm and 80 mm riddle sizes). Data for two tetraploid hybrid progenies, obtained by crossing diploids with tetraploids, and for Pentland Crown control plots, is given in Table 11.

Each F_1 hybrid clone was represented by a three plant plot (0·6 m spacing) in the A and B replicates at the Murrays. Additional three plant plots were set out at Rosewarne Experimental Horticulture Station in Cornwall and are

TABLE 11

Yield, "ware" yield and mean tuber weight in two 4x hybrid progenies (Tuberosum × Phureja)

Progeny	No. of clones	Replicate	Mean yield/plot in kg	% Yield "ware"	Mean tuber weight in grammes
AP64	9	A	9·0	75·3	123·7
		B	8·4	79·3	105·2
		C	7·5	—	123·0
AP65	11	A	6·7	75·1	117·8
		B	5·8	82·2	112·5
		C	6·7	—	107·9
CONTROL (P. Crown)		A	6·0	69·5	158·4
(10 plots)		B	3·9	72·8	175·7

designated "C" in Table 11. The F_1 hybrids produced a higher yield of somewhat smaller tubers than Pentland Crown in both the Murrays replicates, and a higher proportion of the yield was of marketable size. The Murrays replicates were some distance apart and conditions in replicate B were rather adverse; the hybrids withstood these conditions rather better than the control cultivar. The mean performance of the AP64 progeny was not quite as good as the Rosewarne site although satisfactory yields were obtained. AP64 and AP65 have the same seed parent (Pentland Dell), but different diploid pollen parents.

It is important for the proper utilisation of diploid germ-plasm that a sufficient number of improved clones should be involved in the production of tetraploid hybrids. In 1979 four hitherto unused diplandroid-producing Phureja selections were crossed with Tuberosum cultivars, which included Pentland Squire and Désirée for the first time. Approximately 1,800 seeds were produced and the seedlings will be screened for tetraploidy in 1980. P. Squire was six times more fertile in such crosses than Désirée, but Désirée was the only one of the six cultivars used as parents which gave a useful seed-set with the elite diploid DB171(24). It appears therefore that, to be sure of obtaining 4x hybrids from a desired diploid, a large enough range of 4x partners must be tried. The other constraint in the interploidy crossing programme lies with the ability of superior diploid selections to produce chromosome-doubled pollen grains (diplandroids). A survey of 386 Phureja/Stenotomum clones from the pedigree crossing scheme and the mass-selection clone museum gave an overall 12·3 per cent of clones producing diplandroids, frequencies in individual progenies ranging from 0 to 70 per cent. Crosses are being initiated at the diploid level with the aim of transferring the "diplandroid" character to a wider range of improved material.

Facilities have been made available for surveys of resistance to pathogens not previously sought in the diploid stocks and, in December 1979, 185 clones of the group Phureja/Stenotomum were submitted for testing for potato cyst nematode resistance using the "canister" method. Fifty six clones from the mass-selection population were submitted as an initial survey for sources of resistance to Potato Virus Y (PVY). Replicated PVY resistance tests are also being conducted on twenty five clones from the pedigree breeding programme, together with tests for Potato Virus X resistance. Assessments of leafroll and scab resistance are also being initiated while testing of gangrene and blight resistance is being extended.

In routine cooking tests of Phureja/Stenotomum material, texture is usually found to be "floury" or "intermediate" and after-cooking darkening is rarely a problem; however, some degree of anthocyanin pigmentation was observed in the flesh of about 16 per cent of clones tested. The range of flavours in diploid material appears to be wider than in commercial potatoes, but is very difficult to quantify.

Five clones with distinctive flavours, some liked and others disliked at the SPBS, were sent to the Food Research Institute for assessment. Results from the FRI panel did not agree with those from the local panel on acceptability of flavours and textures. For instance, the clone HBX21(19) was regarded as completely unacceptable at the SPBS owing to a "burnt" flavour, but at the FRI the same "burnt" comment was accompanied by fair acceptability. The FRI panel did, however, confirm the existence of a pleasant "nutty" flavour identified in some diploids at the SPBS. Lack of agreement at the two Institutes on textures was almost certainly a consequence of different cooking techniques, and it is probable that flavour and texture interact in such trials. The FRI reported that it was easier to obtain agreement within their panel on texture than on flavour.

An attempt was made this year to increase the number of eelworm (*Globodera* spp.) resistant dihaploids available. Using the inducer clone IVP48, 360 seeds were obtained from crosses with nine eelworm resistant tetraploids. On past experience, these may be expected to give approximately seventy five dihaploids.

Male fertile dihaploids have been very rare in the Pentlandfield collection, but the pollen stainabilities (with iodine) of several of the dihaploids produced in 1978 were high. Most of these came from one tetraploid, a highly virus resistant clone with several species in its ancestry. Of thirty nine dihaploids from this tetraploid nine had over 30 per cent stainable pollen, including four over 60 per cent. Male fertile dihaploids may be particularly important if it is intended to transfer as much of the dihaploid genotype as possible to tetraploid hybrids by means of unreduced gametes.

In 1978, 765 seeds were obtained from 1,333 pollinations made, in either direction, between fifteen dihaploids and three tetraploids. Of these, 391 were sown and produced 158 plants. Among the dihaploids were two which had set seed very infrequently when crossed onto diploids; they gave thirty one and forty five seeds respectively in crosses with tetraploids. Sixty eight seeds were also obtained from 726 pollinations between four tetraploids and five colchicine-doubled dihaploids, and these gave rise to thirty five plants. All the 193 plants raised were tetraploid, though often aneuploid. They will be grown in multiplication plots in 1980 to provide material for disease resistance testing.

The production of seed from dihaploid × tetraploid crosses was much lower in 1979 than in previous years. This was due chiefly to poor flowering of the dihaploids and low male fertility of the tetraploids. For an estimated 600 pollinations only forty seeds were set.

In this year's eelworm resistance screening programme six new dihaploids were found to have good resistance to pathotypes A and E and two others showed good resistance to pathotype E alone. Two of these resistant clones had fairly high pollen stainabilities and may therefore prove useful for crossing.

Two foliage blight resistant dihaploids showed no apparent change in the level of resistance when their chromosome numbers were doubled using colchicine.

Pentland Crown, a dihaploid obtained from it (PDH 7), and two chromosome-doubled derivatives of the dihaploid were compared in two Latin Square experimental designs. In neither of the trials did the dihaploid differ significantly from its chromosome doubled derivatives in tuber yield, mean tuber number per plant, or mean tuber size ($P > 0{\cdot}05$). Pentland Crown was significantly higher yielding than the other material in both trials ($P < 0{\cdot}01$). It also had a higher mean tuber number per plant and mean tuber weight than the other material, though the difference was significant ($P < 0{\cdot}05$) for each character in only one of the two trials.

Observations on the limited amount of colchicine-doubled dihaploid material at Pentlandfield so far show that little improvement in fertility results from the doubling. A slight increase in female fertility, shown by improved seed set, has been found in the case of one female-fertile dihaploid but a doubled sterile dihaploid is also sterile.

DAFS PACKAGE 8
ARC Projects 05016-05020 inc.

D. R. Glendinning
C. P. Carroll
M. J. De Maine

STRATEGIC PATHOLOGY UNIT

Mechanisms of Field Resistance to Potato Blight and Variability of the Pathogen

Studies of the effect of times of lifting and inoculation on the incidence of blight in tubers were continued, primarily to determine the reasons for the differences noted between the trials conducted in August 1977 and in September 1978 (*Ann. Rep. 1978-79,* 84). Five varieties were involved and the tubers were inoculated following lifting at fortnightly intervals during August and September. Analysis of the results is not complete but, as in 1977, an effect of lifting date on the incidence of infection is indicated. With the exception of Stormont Enterprise (the most resistant variety used) the incidence of infection was highest in tubers lifted during the first part of August. Stormont Enterprise showed a low level of infection throughout.

As in previous studies (*Ann. Rep. 1976-77,* 47 and *1977-78,* 68) there was considerable development of thread-like lesions. They always developed among tubers of the resistant varieties (Pentland Ivory and Stormont Enterprise) but were only associated with more mature tubers of the susceptible varieties (King Edward and Majestic). Although *Phytophthora infestans* can be isolated from such lesions their significance as sources of infection has yet to be established.

Samples of skin, taken from tubers at the different times of lifting and inoculation were preserved for study of features which could be associated with the resistance or susceptibility observed in the tests.

Further attempts were made to increase infection in leaves of clones with high levels of field resistance to blight. Inoculum consisted of a compatible race of *P. infestans*, isolated from leaves of each clone after repeated culture on the same clone throughout a growing season, then maintained on agar. No increased infection was observed following repeated culture of the isolates on the same clones over a further growing season. It was noted that with some clones it was not always possible to maintain isolates by transferring them repeatedly on leaves of the same clone but infection was successful if intermediate passages were made through other clones. One clone was particularly interesting in that only the lower leaves of its plants were susceptible.

It is recognised that a reasonable forecast of a clone's field resistance to blight can be obtained from tests of adult plants, under suitable conditions in the glasshouse. Progeny tests using such plants require much space and time; therefore, exploratory tests were made to examine whether comparable results might be obtained from tests of small (circa 10 cm) seedlings whilst still in seed trays. Additional seedlings of families which had already been assessed from larger plants were used. The results obtained from the seedlings were not comparable with those from the adult plants. Indeed, the family expected to show the least resistance as assessed from adult plants was the most resistant in the seedling test. A number of seedlings from certain families which showed a marked resistance have been retained for further study of their reaction as adult plants.

1979 was a "blight" year and samples of blighted material from varieties with no R genes were obtained through the Plant Pathology Advisers in East and West Scotland. With one exception, the samples yielded common, simple races of *P. infestans*, e.g. race 3 and race 4. However, from one very mature and unsprayed crop of the variety Epicure, grown from home saved seed, on the Isle of Arran, several isolates of the highly complex race 1, 2, 3, 4, 5, 7, 8, 9, 10, 11 were obtained. It is of interest that no race of comparable complexity was recognised elsewhere even although varieties with R genes which could support these races now occupy a comparatively high acreage in commerce. Previously such races were widely distributed when crops of Pentland Dell were grown without protective sprays. It would appear that in the present situation where all varieties are now sprayed against blight, the R genes have a role in suppressing *P. infestans*. Therefore, the retention of R genes in breeding stocks would seem desirable.

DAFS Package 7
ARC Projects 05028
05029

J. F. Malcolmson

SERVICE UNITS

Cytology

The routine work of the Cytology laboratory is mainly concerned with cytological screening of plant breeding material for the Brassica and Strategic Potato Breeding Departments. Collaboration with these departments on research projects has also continued this year. In addition a small number of plants from the barley breeding programme have been screened for haploidy.

Routine work for the Brassica Department included mitotic counts of artificially synthesised *Brassica napus* plants and mitotic and meiotic counts of advanced hybrid material originating from *B. campestris* × *B. napus* crosses. Notably, five swede and twenty-six oilseed rape plants with 2n = 38 were identified among club-root resistant material derived originally from *B. napus* (swede and oilseed rape) × *B. campestris* (turnip) ECD04 hybrids, backcrossed to the *B. napus* parent.

The three disomic addition lines of *B. campestris* with an additional pair of *B. oleracea* chromosomes, each isolated last year from different selfed monosomic addition lines (*Ann. Rep. 1978-79*, 89), were smaller, less vigorous and later flowering than twenty one chromosome plants from the same parent. The twenty two chromosome plants produced few flowers and failed to set seed after thirty five bud self pollinations, while related twenty one chromosome plants set seed on bud selfing and sib crossing. The parental monosomic addition lines varied in fertility and disomic addition line plants were only found in progenies from lines with low fertility; this may be related to the failure of the disomic addition lines to set seed this year. In meiotic studies of one of these lines the twenty two chromosomes paired perfectly to form eleven bivalents in 93 per cent of 127 metaphase I cells examined, 3 per cent of cells contained a quadrivalent and 4 per cent two or four univalents. Despite the high level of pairing of the additional *B. oleracea* chromosomes, segregations at metaphase II other than 11:11 and lagging chromatids at telophase II were found in many cells in both this and another of the disomic addition lines. It seems likely that some of the gametes would not transmit the extra *B. oleracea* chromosome.

Routine pollen fertility estimates were made of 200 potato clones from the commercial breeding programme and 500 clones from the diploid/dihaploid programme. Twenty five plants, derived from two dihaploid clones treated with colchicine in 1978, were checked for ploidy this year but full results of cytological screening are not yet available.

Fewer plants (eighty seven) from the dihaploid production programme were screened for chromosome number this year and only eighteen dihaploids were found. This is a lower frequency of dihaploid induction than in recent years. Mitotic counts were made of the progeny of tetraploid × dihaploid crosses with the dihaploid as either male or female parent; all 189 progeny were tetraploid hybrids. One hundred and ninety two new tetraploid hybrids were identified in 208 plants from tetraploid × élite diploid crosses. In theory, tetraploid hybrids could be produced by direct crossing of dihaploids with diploids if both parents were able to form 2n gametes. Seed was available from crosses between a dihaploid, known to produce 2n female gametes, and two diplandroid producing diploids. The only plant which gave tetraploid counts out of 307 plants checked for chromosome number was a chimaera and also contained diploid tissue. It is unlikely to be hybrid in origin. A study of female meiosis in diploid and dihaploid potatoes has been started to see if the mechanisms of 2n gamete formation are analogous to those occurring in male meiosis.

J. A. Fantes

Photography and Illustration

Requests for both illustrative and photographic services have continued to increase. A large proportion of the demand lies in preparing demonstrations of work in connection with the Annual General Meeting of the Society. The illustrations are used thereafter as part of the semi-permanent display of aspects of the Station's work, now transferred to wall-mounted boards in the multi-purpose room.

Responsibility for supervising the work of the unit was passed to the Information Officer during the year. Specified daily "consulting hours" have now been established for members of staff, the remainder of the day being devoted entirely to planned work in hand.

Additions to the photographic facilities during the year consist of a Mamiya 645 1000S large format single lens reflex camera, a Bowens "Illumitran" slide copier with inbuilt contrast control and electronic flash, and a Pelling & Cross copying stand. The latter is a versatile addition to our range of equipment.

G. Cruickshank

Statistics and Computing

The routine work of this unit consists of providing a card punching service, the generation of trial designs and the analysis of results, providing liaison between members of staff and ERCC and ARCUS, and advising on computing and statistical problems.

During the past year there has been a considerable increase in the amount of computing carried out at the Station. The number of jobs run, using ERCC facilities, rose by 34 per cent to 4,100. CVT and Genstat are now the most commonly used statistical packages.

A Decwriter II terminal and a Hazeltine Visual Display Unit were purchased to provide more efficient access, via our dial-up line, to EMAS and a second, faster line has been ordered to help cope with the increasing volume of work.

The section has benefited considerably by the presence of a sandwich student for six months. Among other things, this enabled a small suite of interactive programs to be written for the Institute's own computer, a Wang 2200.

An introductory course to the Wang was provided throughout the year, of which a number of staff took advantage.

The Wang continues to be used by the Chemistry Department for data logging and increasingly by other staff for small data processing jobs.

Considerable effort has been spent reviewing the latest micro-electronic data terminals and computers to see how these might facilitate the capture and processing of both field and laboratory data at SPBS. Recent changes in the service provided by ERCC with respect to these terminals mean that this review will have to continue into next year before any decisions can be taken.

The section co-operated with the Commercial Breeding Department of the Potatoes Division in looking for a suitable Data Base System to hold details of the clones used in their program. We were pleased to accept the offer by ARCUS to write such a system into their CVT package, and look forward to using this next year.

J. W. McNicol

BREEDING FOR RESISTANCE TO VIRUS DISEASE OF THE POTATO (*SOLANUM TUBEROSUM*) AT THE SCOTTISH PLANT BREEDING STATION

T. M. W. Davidson

Historical Review

The history of the potato has been well recorded from its establishment in Europe to its becoming a staple food. The impact of the cultivation of the potato on the social history of Britain has been great, particularly with respect to the upheavals caused by crop failure upon a dependant peasantry. The scourge of the potato in the nineteenth century was late blight (*Phytophthora infestans*), annually unpredictable but savage and awesome in times of epidemic. More insidious but also chronic and debilitating in effect was the condition known as "degeneration" attributable to the common virus diseases. Due to ignorance of the causitive agent as well as of any remedial action virus diseases spread in crops and fresh sources of infection multiplied. One practical solution applied to combat degeneration was to raise new varieties from seed. These whether from natural selfing or from hybridisation had the advantage of being free from virus infection at least for a time. A few varieties did indeed last and remained popular for decades. This was no doubt due to relative resistance to, or tolerance of, the common virus diseases. The variety Myatts' Ashleaf is a case in point. Introduced to Scotland in 1853 it was still being grown to some extent in the early years of the twentieth century. The raising of the new varieties became a kind of cottage industry in the second half of the nineteenth century when a bewildering number of new varieties were introduced as well as old varieties masquerading under new names. The argument on the cause of degeneration proved of interest to students of the potato for fully 150 years. As late as 1921, Salaman in a comprehensive review of the literature on the subject finally laid the blame for degeneration where it rightly belonged, at the door of viruses (Salaman 1921).

Among the first to use wild species of *Solanum* as a source of new "blood" was an American, Goodrich. He obtained a small quantity of South American potatoes from which in 1851 he selected the most promising and named it Rough Purple Chile (Goodrich, 1855). From this selection he obtained progenies of natural selfs and was able to select a cultivar he called Garnet Chile. Albert Bresee, another American, later selected the variety Early Rose from a natural self of Garnet Chile. Early Rose was used extensively as a parent by breeders in Britain. About the same time as Goodrich was selecting Garnet Chile and in the wake of disastrous epidemics of blight William Paterson of Dundee made a collection of varieties from around the world.

From them he collected natural berries and raised seedlings from which he selected Paterson's Victoria. This cultivar which was reputed to be resistant to the strain of blight then current, became one of the most famous in the history of the potato in Britain in its own right, and more particularly as the ancestor of most of the improved varieties at the turn of the century and beyond. The end of the nineteenth century was to see the high point for cultivars in terms of yield and quality. Archibald Findlay (1905), who more than others contributed cultivars of note is quoted as having said "I would not give a farthing for any potato if I could not trace its descent from Victoria", and also "no man will by distribution of mere wealth . . . do what Paterson has done for mankind". One of the first to seek a scientific approach to potato breeding was Dr John Wilson of St Andrews University. From 1912 until his death in 1919 Wilson attempted to breed for resistance to blight as well as other objectives. He hybridised successfully four wild species, *S. maglia*, *S. commersonii*, *S. demissum* and *S. etuberosum* as well as a wild form of *S. tuberosum* from Mexico. Of the seven or so varieties stemming from his short career three, namely Templar, Bishop and Crusader, were reasonably successful. Templar and Crusader were reputed to be leafroll resistant. It is of interest to note also that in tests carried out recently assessing resistance to strains of virus Y Crusader showed an appreciable resistance, particularly to some strains of the virus. After Wilson's death his records and stocks of seeds and clones were acquired to form the basis of potato breeding and research at the newly founded Scottish Society for Research in Plant Breeding. In the first decade of potato work at this station the emphasis was on the continuation of Wilson's work in breeding for resistance to blight. Throughout this time the effort was disrupted to a greater or lesser degree by ravages of virus disease. In one year it was inferred by the amount of leafroll present in plants from true seed derived from a leafroll infected parent that the disease had been transmitted through the seed! (*Ann. Rep. 1927*, 23). In 1926 the Cambridge Potato Virus Research Station was established under the direction of R. N. Salaman. This marked a significant development in research into the nature of potato viruses, their modes of spread and into ways of maintaining healthy seed stocks. At the Scottish Plant Breeding Station (SPBS) were two virologists of note, namely K. M. Smith and F. Bawden, who were to be in the van in the new field of potato and plant virological research in its period of rapid development. It was against this background of research into the characteristics of potato viruses and their strains that investigational work began and was carried on at the SPBS. The main line of investigation was the testing of self-fertile varieties for their reaction to viruses classed as mild mosaic, severe mosaic and leafroll. The presence or absence of visible expression of the disease was taken as susceptibility or resistance. The extreme types, *i.e.* the most resistant and the most susceptible, were used to secure seed progenies to test whether such resistance was inherited on Mendelian lines. From this developed the most significant pre-war work on viruses at the station. A study of the comparative reaction of varieties and seedlings to artificial infection with the common viruses showed some to respond with lethal necrosis. Progenies obtained and tested from lethal crossed with non-lethal parents showed that the reaction was controlled by a single dominant gene for viruses X, A, B and C and that the genes for resistance to viruses X and A were linked. The effectiveness of this resistance in the field was confirmed from infection data from field inspections of varieties endowed with one or more of these major genes compared with varieties without them (Cockerham, 1939). This led to the realisation that the necrotic response to virus infection was most important from the economic point of view. As a result of this work when the second of the varieties bred by the Society, Craig's Defiance, went on the market, it was known to be field-immune from viruses X, A, B and C. Bred from cultivars Pepo and Epicure, Craig's Defiance was not the first variety to have this combination of major genes for resistance. In the case of the others, four in number of which Crusader and Harbinger were the most notable, their spectrum of resistance was the result of chance, unsuspected but nevertheless contributing to their value as cultivars (Cockerham, 1943). A search for a source of resistance to virus Y was attempted in the current varieties looking for a lethal-necrotic response to artificial infection. Although some varieties did show some response they proved to be more or less susceptible in the field. With regard to leafroll virus no necrotic response was detected or expected but certain varieties and seedlings were known to be more resistant than others. One observation made at the time was that in breeding for leafroll resistance the seedlings most resistant to leafroll were found to have poorer agronomic characters than the less resistant. Salaman (1921) had also found this to be the case some years before.

Breeding for Resistance to Virus X

Cockerham (1954) found that there is a pattern of relationship between the strains of virus X and genes controlling the hypersensitive response to them. In the case of virus X only two genes had been found in cultivars, Nx tuberosum and Nb tuberosum. By using cultivars representing the four possible gene combinations of the two genes Cockerham found that the strains could be grouped into four according to whether or not an hypersensitive reaction was induced following inoculation of each strain to each of the host plants. The group strains, considered the least developed since they had the narrowest host range, could be controlled by the presence of either of the two genes in a cultivar, the group two strains by the Nb tuberosum and the group three by Nx tuberosum. Cockerham postulated that there ought to be strains belonging to group four which would activate neither of the two genes. In field conditions with cultivars with these genes singly or together the group four strains might be expected to be the dominant and most favoured group. For reasons unknown group three is the commonest group of strains found in the field, group two is very rare now and group one probably not to be found in the UK. Only two strains of group four have been known to exist, one X[a] (Bawden and Sheffield, 1944) which no longer exists was described as an aberrant strain of X and the other is extant. It derived from a group two strain on *S. andigena* CPC 2971 which was graft transmitted to the cultivar Pentland Beauty that became systemically infected. The new strain was found on test to belong to group four but with affinity to group two from which it had arisen (Cockerham and Davidson, 1963). Rozendaal (1966) construed this as a case of strain mutation on the filtering effect of specific resistance to the introduction to the host by graft inoculation of a strain of the virus to which the host has specific resistance. The ubiquity of group three strains in the field as opposed on the one hand to group two strains of parallel evolution and on the other to group four strains which have never appeared or become established in the field must depend on factors other than hypersensitivity to them in a proportion of cultivars. It is probable that, under natural condition of spread in susceptible cultivars, group three strains are the most infective. The disappearance of virus X from stocks is in part due to the certification regulations for seed stocks as well as to the abundance of cultivars with resistance to virus X. Of the fifteen commercially available varieties bred by the SSRPB nine have the Nx tuberosum gene, six have the Nb tuberosum gene and one is immune to all strains of virus X. It is noteworthy that the source of Nx tuberosum in British varieties stems from Paterson's Victoria. Craig's Defiance is only three crosses removed from Victoria and Craig's Snow-white and Craigs Royal only four (Ross, 1951). The breeding policy with regard to resistance to virus X continues to be the use of genes conferring resistance in a non-specific manner. Thus immunity from virus X was preferred. There are two major independent genes conferring immunity from all strains of virus X designated Rx andigena and Rx acaule. Rx andigena is derived from *S. andigena* and found in CPC 1673 and USDA 41956 (Schultz and Raleigh, 1933). Rx acaule is derived from *S. acaule* in CPC 379 and 44/1016/10 (Ross, 1954). Being major genes and segregating in a disomic manner they were readily incorporated into breeding lines where successive progenies may be monitored for X-immunity and susceptibles eliminated. Nearly all the virus Y and LR resistant lines of breeding are also immune from virus X.

Breeding for Resistance to Virus Y

Three types of resistance to virus Y have been identified and occur in cultivars by hazard or design.

1. Specific resistance to one or more groups of strain.
2. Resistance to infection.
3. Comprehensive resistance to all strains including extreme resistance. (Resistance-breaking strains may occur but are unlikely to be found in the field.)

1. SPECIFIC RESISTANCE TO ONE OR MORE GROUPS OF STRAINS OF VIRUS Y

As long as cultivars are grown with susceptibility to some or all strains of virus Y the groups of strains present in the field will tend to be those with the largest host range. The gene-strain relationship is stable but subject no doubt to gradual evolutionary change. Major changes do not appear to have occurred as a result of mutation but by introduction of strains from one isolated environment to another. Such was the introduction of Y^N strains from South America into Europe. In Table 12 is shown the resistance or susceptibility of possible genotypes to possible strains, a stable situation in the field prior to the introduction of Y^N strains.

TABLE 12

Expected genotype-strain response of cultivars inoculated with strains of virus Y
N = hypersensitivity; S = susceptibility
The bracketed group of strains is hypothetical

Host Genotype	*Strains of virus Y in group* (CA)	Y^c	*Virus A*	Y^o
Recessive	S	S	S	S
Na_{tub}	N	S	N	S
Mc_{tub}	N	N	S	S
Na_{tub} Nc_{tub}	N	N	N	S

Of the four possible groups of the virus three were known to have been present in the field. These three were "C" strains of Y^c group, strains of virus A and strains of the Y^o group. The most primitive group of strains (CA), since its range of hosts is limited to cultivars recessive for the genes Na tuberosum and Nc tuberosum confirming resistance to Y^c and to virus A, may or may not have been present in the field but it has not been recorded.

In 1948 among material collected by the SSRPB for use in their breeding programme was a clone from Australia, 11-79 (Hutton), which was to have a profound effect on the resistance to virus Y of SSRPB varieties. This clone was bred from the cultivars Katahdin and Snowflake both of which were reputed to show a necrotic response when inoculated with virus Y (Hutton, 1951). Cultivars tracing their resistance from 11-79 are not completely resistant to the Y^o group of strains but show a high degree of resistance to them in the field. The degree of resistance differs a little from variety to variety under the same conditions of natural infection. Of the seven SSRPB cultivars with 11-79 in their parentage five have inherited resistance to virus Y and two have none. One other SSRPB cultivar (Pentland Marble) with similar resistance to virus Y has Katahdin in its ancestry. By using the response of genotypes to strains of virus Y with this gene (or genes), designated for convenience "Ny", and with Na tuberosum and Nc tuberosum the number of possible genotypes is eight with the number of groups of strains eight also when the Y^N group of strains is included (Table 13).

TABLE 13

Expected genotype strain response in cultivars inoculated with strains of virus Y
N = hypersensitivity; S = susceptibility
The bracketed groups of strains are hypothetical

	Strains of virus Y in group							
Host Genotype	*(Y^oCA)*	*(Y^oC)*	*(Y^oA)*	*(CA)*	*Y^o*	*Y^c*	*Virus A*	*Y^N*
Recessive	S	S	S	S	S	S	S	S
N_{atub}	N	S	N	N	S	S	N	S
N_{ctub}	N	N	S	N	S	N	S	S
"Ny"	N	N	N	S	N	S	S	S
N_{atub} N_{ctub}	N	N	N	N	S	N	N	S
N_{atub}"Ny"	N	N	N	N	N	S	N	S
N_{atub}"Ny"	N	N	N	N	N	N	S	S
$N_{atub}N_{ctub}$"Ny"	N	N	N	N	N	N	N	S

When a collection of strains of virus Y was examined by inoculation to cultivars of the eight genotypes shown in Table 13 almost all could be classified into one of the four groups Y^o, Y^c, virus A or Y^N. Of the two strains which did not conform one, Rs188, a strain from *S. andigena* (CPC 188) (Horvath, 1967), induced a necrotic response on all genotypes. The virus could be recovered apparently unchanged from certain genotypes in which the necrotic response was not complete. Another strain, "Sheffield", fitted well into the (CA) group (Davidson & Butzonich). Although the use of specific resistance to virus Y in breeding is valuable it is limited particularly with regard to Y^N strains. The performance in the field of varieties with the "Ny" gene has been found to be better than is indicated by inoculation tests with Y^N strains, as mechanical inoculation does not mirror natural infection.

2. BREEDING FOR RESISTANCE TO INFECTION WITH VIRUS Y

Field-resistance to virus Y of a high degree was noted in *S. phureja*, clone CPC 979. A breeding line was established from seed, germinated in colchicine agar from an intercross of two seedlings of CPC 979 selfed. Field resistance to virus Y was thought to be of considerable value as there was reason to believe that it was not subject to the same possibility of breakdown as major-gene resistance. The difficulties in this line of breeding have been the dissipation of resistance following out-crossing as well as the need for recurrent and successful field trials to monitor the level of clonal resistance to aid selection.

3. BREEDING FOR COMPREHENSIVE RESISTANCE TO ALL STRAINS OF VIRUS Y

The main breeding effort against virus Y by the SSRPB has been concentrated on forms of resistance which would confer complete protection from all strains of virus Y. Potential sources of comprehensive resistance to virus Y were found in *S. demissum, S. microdontum, S. chacoense* and *S. stoloniferum*.

(*a*) Breeding line derived from *S. demissum*

Infection with virus Y of selfed seedlings of *S. demissum* carrying the gene Ny_{dms} usually resulted in systemic invasion of the test plant and its death from necrosis. Similar effects had been observed in material derived from *S. microdontum* also carrying a gene (Ny_{chac}) conferring comprehensive resistance to virus Y. In the latter case it was found that by placing the Ny gene in a background of field resistance to virus Y derived from CPC 979 (see above) the necrotic effect was restricted to the production of local lesions only at the site of infection. A breeding line was established from a cross between *S. demissum* (CPC 4) and *S. phureja* (CPC 979).

(*b*) Breeding lines derived from *S. microdontum* and *S. chacoense*

Although begun separately and maintained as independent lines from *S. microdontum* (CPC 51a) and *S. chacoense* (CPC 51b) these lines must be regarded as similar since they both depend upon a common gene (Ny_{chac}) for their resistance to virus Y. As mentioned in (*a*) above a suitable background was required to moderate the function of the Ny gene in *S. microdontum*. With *S. chacoense* on the other hand an effective background was apparently already present and the line was started from colchicined seed of seedlings of CPC 51b in direct crosses with cultivars. However a *S. phureja* (CPC 1311) with no field resistance to virus Y did figure in the parentage of the colchicined seed.

(*c*) Breeding lines from *S. stoloniferum*

First breeding with *S. stoloniferum* began in 1955 with three clones, CPC 2092, 2093 and 2094, in direct crosses with cultivars. The material proved unsatisfactory because it reacted in a lethal or semi-lethal manner to infection in the field and this line of breeding was terminated. At a later date it was found that the three clones concerned each carried the gene Ry^{rna}_{stol} which is specific in effect (Cockerham, 1970). A second start was made with material received from Cologne supplemented with triple hybrid material derived from (*S. acaule* (CPC 379) × *S. stoloniferum* (CPC 284)) × a cultivar. Later material was received from the John Innes Horticultural Institute with resistance from *S. stoloniferum* of the same extreme type and was incorporated into this breeding line.

4. BREEDING LINE FOR RESISTANCE TO LEAFROLL

The character of leafroll resistance is an arbitrary quality which can only be established upon the basis of exposure to infection of a relatively large number of plants in trial with suitable control varieties (Davidson, 1973). Breeding for the character is largely empirical in that no accurate forecast of the results can be made except that the chances of success are greatest if both parents are themselves classifiable as leafroll resistant. The material for this line is derived from British, European and American varieties and clones possessing more than average resistance to leafroll. In the material which formed the basis of the leafroll breeding line were the cultivars Southesk, Shamrock, Apta, Imperia, Schwalbe and International Kidney as well as clones from America, Poland and Germany. Clone 44/1016/10 (Ross) derived from *S. acaule* was used extensively as a source of immunity to virus X as well as for its leafroll resistance. Leafroll resistant clones have been used extensively as outcross parents for the virus Y resistant lines to transmit leafroll resistance and immunity to virus X into those lines. Leafroll resistance was also found in material derived from *S. andigena* and particularly from *S. demissum* following field trials. All clones after initial selection are subjected to at least one year of field trial from which apparently resistant material can be retrialled and proven resistant material can be used as parents or as potential cultivars (*Ann. Rep.* 1979). Most characters for virus resistance and for leafroll resistance in particular are to some extent proportionally associated with "wild" characters such as poor tuber shape, size and yield. This antipathy of leafroll resistance and commercial characters makes the selection of good commercial clones with leafroll resistance difficult to achieve. The necessity to have field trials to assess leafroll resistance extends the time scale for selection by some years.

New sources of leafroll resistance are becoming available from the tropics where breeding stations, of necessity, grow their material in conditions of intensive natural infection and where resistant material is readily identified simply by its remaining healthy while under propagation. One such is the new cultivar Serranna bred and selected in Argentina (Davidson, 1978).

Following years when the spread of the common aphid-borne viruses reaches epidemic proportions the value of resistance to these viruses is self evident. It is unlikely that virus-resistant clones will be grown for this feature alone without that they also measure up, from the commercial aspect, to the performance of current cultivars. The greater the desire for virus resistance in cultivars the greater would be the emphasis on this character as opposed to the purely commercial, but it is usual in the UK that commercial attributes are a paramount requirement for success in the selection of a new cultivar. In the selection of virus-resistant parents every effort has been made to breed for commercial characters without sacrificing resistance. Many resistant clones have good commercial characters and a few have reached the final stages in the selection system. More and possibly better commercially sound material from the virus-resistance breeding programme is in selection from which will come future parental clones and some to continue on their own merit with potential as future cultivars.

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VARIETIES BRED BY THE STATION

The following are commercially available in Britain:

Stubble-turnip
Appin

Horticultural kale
Pentland Brig

Oats
Fyne*†
Etive*

Potatoes
Craigs Alliance†
Craigs Royal
Red Craigs Royal†
Pentland Beauty
Pentland Crown†
Pentland Dell†
Pentland Hawk*
Pentland Ivory*†
Pentland Javelin*†
Pentland Lustre*
Pentland Marble*
Pentland Meteor*
Pentland Raven*
Pentland Squire*†
Croft*

Varieties marked * have been granted Plant Breeder's Rights and licences to reproduce and sell stocks have been issued. The rights are held jointly by the Society and the National Seed Development Organisation and applications for licences should be made to the Executive Officer, NSDO Ltd., Newton Hall, Newton, Cambridge.

Varieties marked † are on the NIAB Recommended List.

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ALLISON, M. J., and BORZUCKI, R. (1979). *In vitro* estimates of forage crop digestibility. *Agricultural Research Council Annual Report, 1978-79*, 41–42.

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Erratum, Annual Report 1978-79:

PHILLIPS, M. S., and WILSON, L. A. (1979) should read

PHILLIPS, M. S., WILSON, L. A., and FORREST, J. M. S. (1979).

LIST OF PROJECTS

The work described in this Annual Report has been commissioned by DAFS under the following package numbers. (ARC project numbers are also shown.)

DAFS Package	*ARC Project*	
1		**To provide improved cereal varieties suitable for production and utilization in Northern Britain**
	04001	Collect, assess and maintain oat and barley genotypes of use to breeders. Use computer-based data systems.
	04002	Survey physiological characters related to crop performance in barley and oats and construct breeding models.
	04003	Study inheritance of cereal performance characters. Design procedures to maximise and exploit variability.
	04004	Evaluate techniques for choosing parents and selecting offspring. Design data handling system for breeders.
	04005	Test cereals locally from this and other institutes. Explore potential of unfamiliar crops.
	04006	Survey virulence genes in pathogens of oats and barley. Design strategies for disease resistance breeding.
	04007	Study mechanisms of partial resistance of oats and barley to *Erysiphe* and their use in resistance breeding.
	04008	Improve methods to establish oat and barley disease nurseries. Assemble virulence genes of main pathogens.
	04009	Study biochemical components of barley and oat grains related to malting, feeding and processing quality.
	04010	Develop and automate small-scale tests for malting, distilling, brewing and milling quality.

DAFS Package	*ARC Project*	
	04011	Study enzymic, hormonal and other biochemical factors affecting cereal development performance and yield.
	04012	Investigate inheritance of biochemical components of significance in breeding oats and barley.
	04013	Breed malting and feed barley cultivars.
	04014	Breed spring oat cultivars.
	04015	Produce pure seed stocks of new cultivars. Investigate diagnostic features of oats and barley.
	06001	Study of trial designs and field management for plant breeding.
4		**To provide improved varieties of swedes and forage brassicas for livestock feeding**
	03001	Exploit interspecific and intergeneric crosses as sources of variation for brassica and radicole breeding.
	03002	Develop and apply screening tests for useful and harmful biochemical components in brassicas and related spp.
	03003	Collect, assess and maintain genetic material of use to brassica breeders.
	03004	Agronomic, physiological, biochemical and genetic investigations to formulate brassica breeding objectives.
	03005	Identify and maintain S-alleles in brassicas. Study their strength and dominance relations.
	03006	Survey virulence genes in pathogens of brassicas. Design and initiate strategies for resistance breeding.
	03007	Improve methods for assessing brassica diseases and for estimating yield losses caused by them.
	03008	Assemble and test genetic sources of resistance to diseases of brassicas. Produce improved parents.
	03009	Breed F_1 hybrid and inbred swede cultivars.
	03010	Breed rape cultivars from natural and artificial genotypes of *Brassica napus* and related species.

DAFS Package	*ARC Project*	
	03011	Breed kale and fodder cabbage cultivars.
	03012	Breed turnip cultivars especially for Scottish uplands.
	03013	Breed brassica and radish catch crops for late sowing and autumn grazing. Breed fodder radish cultivars.
	03014	Breed radicole cultivars as substitutes for rape from hybrids of *Raphanus* and *Brassica*.
	03015	Test and multiply brassica, radish and radicole cultivars.
7		**Potato breeding and related pathological and genetical studies**
	05001	Breed maincrop potato cultivars for quality, disease resistance and yield for fresh use and for processing.
	05002	Breed early potato cultivars for early yield and quality in relation to fresh use, crisping and canning.
	05003	Maintain and multiply healthy breeding and experimental stocks. Develop and apply improved health control procedures.
	05004	Screen breeding material for cooking and processing quality. Develop and use improved screening techniques.
	05005	Evaluate advanced potato selections in field trials in Scotland, England and Wales.
	05006	Study biometrical genetics of potato characters and devise improved breeding schemes.
	05007	Research into design and predictive efficiency of potato field trials and into G × E interactions.
	05008	Evaluate potato selection procedures and devise improvements for application in breeding programme.
	05009	Establish and manage computerised data bank on clones under selection in potato breeding programme.
	05010	Study biology of potato cyst eelworm including host parasite relationships and the nature of resistance.

DAFS Package	ARC Project	
	05011	Assess potato breeding material for resistance to potato cyst eelworm. Improve screening techniques.
	05012	Assess potato breeding material for resistance to and infection with viruses X, Y and leafroll.
	05013	Assess potato breeding material for resistance to soil-borne viruses. Improve screening techniques.
	05014	Study the biology of common scab, gangrene, skin spot and dry rot.
	05015	Assess potato breeding material for resistance to fungal diseases. Improve screening techniques.
	05028	Study mechanisms of genetic variability in *Phytophthora infestans* and the evolution of new pathogenic types.
	05029	Study mechanisms of quantitative resistance to potato late blight and identify resistant parental material.
8		**Commonwealth Potato Collection and related genetic/breeding studies**
	05016	Manage the Commonwealth Potato Collection of Latin American origin. Liaise with the Dutch/German gene bank.
	05017	Breed Neo-Tuberosum potatoes from Andigena origin for use in breeding cultivars.
	05018	Evaluate Neo-Tuberosum potatoes as parental material for use in breeding cultivars.
	05019	Breed diploid potatoes and evaluate as potential parents for diploid and tetraploid cultivars.
	05020	Produce, breed and maintain collection of dihaploid potatoes. Use dihaploids to enhance disease resistance.
9		**New Crops**
	06002	Studies of the contribution which plant breeding may make to the development of crops new to Scotland.

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
Institute of Animal Physiology	Babraham, Cambridge CB2 4AT
Institute for Research on Animal Diseases	Compton, Newbury, Berks. RG16 0NN
* Food Research Institute	Colney Lane, Norwich NOR 70F
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 GU24 0NF
* 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 NOR 70F
Long Ashton Research Station	Long Ashton, Bristol BS18 9AF
National Institute of Agricultural Engineering	Wrest Park, Silsoe, Beds. MK45 4HS
National Institute for Research in Dairying	Shinfield, Reading, Berks. 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 Disease Research Association . .	Moredun Institute, 408 Gilmerton Road, Edinburgh EH17 7JH
* Hannah Research Institute	Kirkhill, Ayr 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	Pentlandfield, Roslin, Midlothian EH25 9RF

* There has been collaboration during the year between these institutes and the SPBS.

REPORT

to the

FIFTY-NINTH
ANNUAL GENERAL MEETING

of

THE SCOTTISH SOCIETY
FOR RESEARCH
IN PLANT BREEDING

24th July 1980

by the

BOARD OF DIRECTORS

BOARD OF DIRECTORS

1979/80

Trustees

H.M. SECRETARY OF STATE FOR SCOTLAND, Scottish Office, New St Andrew's House, Edinburgh EH1 3TB.
JOHN ARBUCKLE, O.B.E., Barony Cottage, Newburgh, Fife KY14 6HL.
W. ANDREW BIGGAR, C.B.E., M.C., B.Sc., F.R.Ag.S., Magdalene Hall, St Boswells TD6 0EB.
G. B. R. GRAY, Smeaton, East Linton, East Lothian.
JAMES GRAY, O.B.E., T.D., Dalrannoch, Bridge of Allan, Stirlingshire FK9 4PP.

Chairman of Directors

JOHN ARBUCKLE, O.B.E, Barony Cottage, Newburgh, Fife KY14 6HL.

Vice-Chairman

JAMES GRAY, O.B.E., T.D., Dalrannoch, Bridge of Allan, Stirlingshire FK9 4PP.

Ordinary Directors
1977

G. CLAPPERTON, Sherriffhall Mains, Dalkeith EH22 1RX.
A. J. CLARK, B.Sc., Cast Farm, Leuchars, Fife.
G. H. MILLAR, West Foulden, Berwick-on-Tweed, Berwickshire TD15 1UL.
A. PATTULLO, M.C., J.P., Littleton of Airlie, Kirriemuir, Angus.
J. M. ROY (Gordon Innes Ltd.), 69 Bogie Street, Huntly, Aberdeenshire.

1978

M. DOUGLAS HENDERSON, Carse Farmhouse, Aberfeldy, Perthshire PH15 2JQ.
W. S. KING, Tighnadarroch, Pencaitland, East Lothian (deceased).
A. GORDON PORTER, J.P., East Scryne, Carnoustie, Angus.
J. RICHARD ROBERTSON, Mains of Gallery, Montrose, Angus.
G. A. STORRAR, M.C., B.Sc.(Agric.), J.P., Rossie, Auchtermuchty, Fife.

1979

G. GAMMIE, Westerton of Pitarrow, Laurencekirk.
Mrs B. A. GORDON, B.Sc., Rosefarm, Cromarty.
Prof. J. L. JINKS, D.Sc., F.I.Biol., F.R.S., Department of Genetics, University of Birmingham, Birmingham.
A. D. KAY, Esq., B.Sc., Easter Pitscottie, Cupar.
J. McFARLANE, Kames, East Mains, Leithholm, Coldstream.
Prof. D. H. N. SPENCE, Department of Botany, University of St Andrews, St Andrews.

Directors Co-opted

W. H. M. GILL, Rosskeen, Invergordon, Ross-shire.
Sir DAVID LOWE, C.B.E., D.Sc., F.R.S.E., F.R.Ag.S., Elvingston, Gladsmuir, East Lothian.
DEREK A. J. RANDALL, The Miln Marsters Group, King's Lynn, Norfolk PE30 1PA.
C. G. SPENCE, Biel, Dunbar, East Lothian.

Directors nominated by H.M. Secretary of State for Scotland

Professor G. R. DICKSON, B.Sc.(Agric.), Ph.D., F.I.Biol., School of Agriculture, The University, Newcastle-upon-Tyne NE1 7RU.
J. M. TODD, B.Sc., A.I.C.T.A., F.I.Biol., Department of Agriculture and Fisheries for Scotland, Agricultural Scientific Services, East Craigs, Edinburgh EH12 8NJ.
Professor M. M. YEOMAN, M.Sc., Ph.D., Department of Botany, University of Edinburgh, King's Buildings, Mayfield Road, Edinburgh EH9 3JH.
Sir MAURICE YONGE, C.B.E., D.Sc., F.R.S., F.R.S.E., 13 Cumin Place, Edinburgh EH9 21X.

COMPOSITION OF COMMITTEES

1. Standing Committee—Finance

J. ARBUCKLE, *Convener*.
W. A. BIGGAR.
G. CLAPPERTON.
Prof. G. R. DICKSON.
G. B. R. GRAY
J. McFARLANE.
A. PATTULLO.
A. G. PORTER.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*)

2. Brassica Research Committee

Prof. G. R. DICKSON, *Convener*.
G. GAMMIE.
A. D. KAY.
Sir DAVID LOWE.
A. G. PORTER.
Prof. M. M. YEOMAN.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

3. Cereals Research Committee

A. PATTULLO, *Convener*.
Prof. J. L. JINKS.
A. D. KAY.
Sir DAVID LOWE.
D. A. J. RANDALL.
J. RICHARD ROBERTSON.
C. G. SPENCE.
Prof. M. M. YEOMAN.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

4. Potatoes Research Committee

J. McFARLANE, *Convener*.
G. GAMMIE.
W. H. M. GILL.
Mrs B. A. GORDON.
M. D. HENDERSON.
J. M. ROY.
Prof. D. H. N. SPENCE.
J. M. TODD.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

5. Farm Advisory Committee

G. CLAPPERTON, *Convener*.
A. J. CLARK.
W. S. KING.
G. H. MILLAR.
C. G. SPENCE.
G. A. STORRAR.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

ADMINISTRATION

Membership

At 31st March 1980 the total membership was 321, comprising 229 Life Members and 92 Annual Members. Five new members were elected during the year, and nine died or resigned.

Meetings

The Board of Directors met on five occasions during the year, these being:—

5th April 1979
7th June 1979
26th July 1979
15th November 1979
15th February 1980

The Finance Committee, Research Committees and Farm Advisory Committee met during the year on the dates shown below:—

Finance Committee	7th January 1979
Brassica Research Committee	25th October 1979
Cereals Research Committee	1st November 1979
Potato Research Committee	22nd November 1979
Farm Advisory Committee	13th May 1979

Board of Directors

Messrs J. M. Fell, W. H. M. Gill, C. G. Spence, Dr J. B. D. Herriott, B.Sc., Ph.D., and Sir David Lowe demitted office as Ordinary Directors at the Annual General Meeting held on 26th July 1979, in accordance with the provisions of the Society Rules.

New Ordinary Directors elected at the Annual General Meeting were Mr G. Gammie, Mrs B. A. Gordon, B.Sc., Prof. J. L. Jinks, D.Sc., F.I.Biol., F.R.S., Messrs A. D. Kay, J. McFarlane and Prof. D. H. N. Spence.

Messrs W. H. M. Gill, C. G. Spence and Sir David Lowe were co-opted as Directors, in accordance with the Rules, during the course of the year. Mr D. A. J. Randall was also co-opted during the year to fill a vacancy in the number of elected Directors which had been carried over from 1978.

The Board has regretfully to record the death of Mr W. S. King, Tighnadarroch, Pencaitland, East Lothian, on 22nd December 1979. Mr King, who was well known and respected in the East Lothian agricultural community, joined the Society in 1949 and was elected as a member of the Board in 1978.

The undernoted Ordinary Directors are due to retire from the Board at the 1980 Annual General Meeting:—

Mr G. Clapperton, Sheriffhall Mains, Dalkeith EH22 1RX.

Mr A. J. Clark, B.Sc., Cast Farm, Leuchars, Fife.

Mr G. H. Millar, West Foulden, Berwick-on-Tweed, Berwickshire TD15 1UL.

Mr A. Pattullo, M.C., J.P., Littleton of Airlie, Kirriemuir, Angus.

Mr J. M. Roy (Gordon Innes Ltd.), 69 Bogie Street, Huntly, Aberdeenshire.

Robert L. Scarlett, C.B.E., C.D.A., S.H.M., V.M.H.

Robert Scarlett of Sweethope, Musselburgh, died in June 1979 at the age of ninety one. He had enjoyed a long association with the SSRPB which he joined in 1935. First elected to the Board of Directors in 1938 he served as its Vice-Chairman from 1962 to 1966 and was appointed by the Secretary of State as a Trustee of the Society in 1964. He retired from this position in 1977.

Robert Scarlett was very well known in agricultural and horticultural circles and had been a member of many committees and representative bodies in both industries. For some years he was Chairman of the Registration Committee of DAFS, which examined and approved new potato varieties, and which among others, registered Craigs Snow White, Craigs Alliance and Craigs Royal.

In addition to his interest in potatoes, which included practical breeding of his own, he was actively engaged in all aspects of horticulture including fruit and flower production.

FIFTY-EIGHTH ANNUAL GENERAL MEETING

MINUTE OF PROCEEDINGS AT THE FIFTY-EIGHTH ANNUAL GENERAL MEETING OF MEMBERS OF THE SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING, held at Pentlandfield, Roslin, Midlothian, on Thursday, 26th July 1979.

Mr John Arbuckle, O.B.E.
Barony Cottage, Newburgh, Fife, presided.

Minutes. The Minute of the 57th Annual General Meeting, held at the Scottish Plant Breeding Station on Thursday, 27th July 1978, having been circulated prior to the meeting, was taken as read and was approved and signed.

Apologies. Apologies for absence were intimated by the Secretary.

Annual Report and Accounts. The 58th Annual Report of the Directors embodying the audited accounts for the year ended 31st March 1979 which had been distributed to the members before the meeting was submitted by the Chairman.

After a brief speech the Chairman proposed and Mr James Gray, O.B.E., T.D., Dalrannoch, Sunnylaw, Bridge of Allan, Stirlingshire, seconded the adoption of the Report and Accounts. This was carried unanimously.

Election of Directors. The proposal by Mr J. M. Todd, B.Sc., A.I.C.T.A., seconded by Mr W. Andrew Biggar, C.B.E., M.C., was unanimously adopted to elect to the Board of Directors the following members:—

Mr G. Gammie, Westerton of Pitarrow, Laurencekirk.
Mrs B. A. Gordon, B.Sc., Rosefarm, Cromarty.
Professor J. L. Jinks, D.Sc., F.I.Biol., F.R.S., Department of Genetics, University of Birmingham, Birmingham.
Mr A. D. Kay, B.Sc., Easter Pitscottie, Cupar.
Mr J. McFarlane, Kames, East Mains, Leithholm, Coldstream.
Professor D. H. N. Spence, Department of Botany, University of St Andrews, St Andrews.

Appointment of Auditors. On the motion of Mr G. A. Storrar, M.C., B.Sc.(Agric.), J.P., Rossie, Auchtermuchty, Fife, seconded by Mr A. Pattullo, M.C., J.P., Littleton of Airlie, Kirriemuir, Angus, Messrs Brown, McDonald and Fleming were appointed Auditors of the Society.

This concluded the business of the meeting.

The Chairman opened the informal part of the meeting by inviting Dr R. C. F. Macer, the Station Director, to present his report on the work and activities of the Station during 1978-79.

The Director in introducing the Annual Report stated that the absence on the platform of a representative of the Department of Agriculture and Fisheries for Scotland allowed him more time to give his report. He did not intend to comment in detail on the content of the Annual Report presented to the Society. However, he did wish to emphasise certain aspects of the achievements of the past year, to say something about the present situation at the Station, and to take a brief look at future needs.

As far as the past year was concerned, the Chairman would be referring to the uncertainties generated by the proposals of the Working Party. These had a most disruptive influence at the Station and he said he would be failing in his duty as Director if he did not inform members of the Society of the three main effects:—

1. The effect on morale of staff—both directly and indirectly.
2. The distraction of effort from the work programme by time used in discussion and documentation, and by the effects of the embargo on staff recruitment.
3. The drying-up of new Capital Investment at the Station; only some on-going projects had continued—a potato store at Blythbank and one glasshouse, the latter to a reduced specification.

The first two were self-explanatory; the third needed some explanation. A comparison of the notes to the accounts, on pages 172 and 173 of the Annual Report, with those of earlier years showed the effects clearly. The planned Capital Expenditure for the present year allowed for a further fall. Despite this a major new piece of equipment would soon be installed in the Chemistry Department. The effect on long-term planning was a very worrying feature as it was known to be extremely difficult to make up for an interruption in the flow of a capital investment programme and particularly so at a time of severe financial restraint. It was, of course, prudent to impose an embargo on staff replacement for a short period during the deliberations of the Working Party, but this had been in force for a year.

Despite the difficulties the main activities of the Station had continued to develop in many directions. One indication of this was the submission for National List testing in 1979 of eight potential new varieties—two barleys, two swedes and four potatoes. Another was the building of the new potato store at Blythbank for the joint use of the Plant Breeding Institute and SPBS.

The new analytical tool for the Chemistry Laboratory was an advanced scanning infra-red spectrometer. It would allow the very rapid assessment of many crop quality components and would revolutionise the screening of breeding material for many quality factors. The presence of this equipment at the Station, the first of its kind to be provided for the Agricultural Research Service, was a measure of the respect in which the Chemistry Department was held.

The year had seen the establishment of formal links with the Potato Processors' Association for the commercial assessment of advanced selections for processing quality. Changes had been negotiated in the Rules of the British Association of Plant Breeders, in which a Board member, Mr Derek Randall, had played a leading role, which now allowed state-funded institutes to become members. SPBS had done so and could now make its voice heard through this Association. The Association had held its AGM at Peebles and members visited Pentlandfield and the Murrays, thus helping to provide an even better understanding between the private and state sectors of the plant breeding industry in the UK.

Breeders from the Brassica and Cereals Department had each spent several months in New Zealand. The Station's association with New Zealand was flourishing and, once again, cereal material multiplied there during the winter was growing well at the Murrays.

The Department of Agriculture and Fisheries for Scotland had reviewed the commissioned potato research at the Station during the year. The Director was pleased to say that all the work had been re-commissioned.

The Director then commented on the present situation. The Station, in company with all Government-funded organisations, had been instructed to reduce current expenditure; provision had been made to meet this imposition. The scale of the cuts was such that they could not be met without damage to the Station's research programme. The nature of much of the expenditure, on fuel for transport and glasshouse heating, for example, was showing the greatest cost increases and these had to be met within "cash limits". There was also a need to restrict recruitment. The Director said he must be quite explicit about this matter. Reduced expenditure and fewer staff meant reduced and less efficient research—nothing less. Cuts made now in expenditure affecting long-term projects would, inevitably, have consequences lasting into the next century and could affect the food supplies of future generations.

This led the Director to look to the future and to identify the requirements that would be placed upon crop production. He said the Working Party was established to provide the framework within which this research could be done for the next fifty years in Scotland.

In world terms, at present, and despite frequent comment to the contrary, food *production* was not a major problem. Total production could be doubled or trebled with existing technology and resources (of both advanced and peasant agriculture). However, food, fibre and fodder demands would increase (and become less available to the UK) and input resources (water and energy) would become more scarce during the next half-century. In the UK it seemed highly probable that the oil resource would have been exhausted and it would be necessary to become more dependent on our own agricultural production. The Direct said it was crop production upon which all else depended, either directly as a food source, or as the base of a food chain. Furthermore, it might become necessary to develop crops specifically as sources of fuel or once again to provide more fibre for clothing.

To meet these demands in a cool northern climate it was necessary *now* to continue and even to expand conventional arable agricultural research and plant breeding. This view had been accepted by the Working Party.

However, the needs went beyond this. The Director felt we should now be attempting to develop a more diverse range of crop plants capable of producing high yields and specific qualities with lower requirements for high energy-demanding inputs—for example, nitrogen—and developing the cultural practices to exploit such new genetic material.

In conclusion the Director thanked the staff for their support and work during a difficult year and he formally welcomed new members of staff. He paid tribute to the services of Mr H. C. M. McLeod, the Society's Secretary and Treasurer, who had resigned during the year to take up an appointment with the Hill Farming Research Organisation. Mr McLeod had held office for six years during which time many developments had taken place at the Station. He also thanked Mr P. P. Bonnington for serving as Acting Secretary in the period prior to Mr Love's appointment.

The Director also thanked the Chairman for the immense amount of time and interest that he had devoted to the Station's affairs, and Mr James Gray, Vice-Chairman, and members of the Board of Directors for giving unstintingly of their time during the year.

Finally, the Director thanked Dr F. J. W. England who had acted as senior editor for the Annual Report. He and his colleagues on the editorial board had put in a great deal of work and this had been reflected in both the size and the content of the report.

The Chairman thanked Dr Macer for his report on the past year's activities and went on to say that, as usual, he wished to make his own report to the meeting as Chairman of the Board of Directors.

Mr Arbuckle said that on this normally happy occasion he must sadly refer first to the loss which had been suffered by the Society and, indeed, by agriculture as a whole, by the death of Mr Robert Scarlett. Until two years ago, Mr Scarlett had been a member of the Board and a Trustee of the Society. Mr Scarlett was well known in the UK for his active interest in many branches of agriculture and agricultural research. There were many people in Scotland, including himself, who owed him a debt. He joined the Society in 1935 and was elected to the Board soon after, later becoming Vice-Chairman. He had served the Society well for over forty years and until almost his ninetieth birthday.

The Chairman then said that he was pleased to be able to report on the work of the Board of Directors and to refer to some aspects of the work of the Station. Earlier in the day he had visited the Murrays, the principal centre for field experimentation and trials used by the Station staff. He had seen, as members would have done, the plots of brassicas, cereals and potatoes, as well as the farm crops. All were of a high standard and he was pleased to be able to congratulate staff on the appearance of the farm as a whole and on the experimental material in particular. Having said that, it was unfortunate to have to record that after nearly nine years' occupation of the farm, and three years after designing replacements, the old steading building remained in a dilapidated state. If the Murrays was to be regarded as a research centre of international standing they must be removed, or renovated, and proper facilities provided.

The work of the Station, some of which was on display at Pentlandfield, showed that staff had continued to give their attention to the scientific aspects of plant breeding research as well as to the breeding of new varieties. The demonstrations were both interesting and relevant to crop improvement. Their clear presentation was an aid to understanding and Mr Arbuckle congratulated the staff who planned and executed them to such a high standard. One of the ways in which the Society fostered agricultural research was by promoting direct contact between farmers and scientists, so he hoped that members of the Society, and their guests, would take the opportunity to study the demonstrations and to meet the staff.

When addressing the Society last year Mr Arbuckle had referred to the changing and exciting times in which we now lived. He now said that perhaps he should have said "challenging" for some of the changes with which we were now confronted were hardly those of our choice. He was thinking of the increased costs which must be met for fuel, equipment, rates and "value added tax" which had come at a time when Government economies were also sought. This situation was bound to create great difficulties for the Director and staff who were required to seek ways of making economies while still maintaining the programme of research. The bulk of the Station's finances were drawn from the Department of Agriculture and Fisheries for Scotland—a fact which the Chairman acknowledged on behalf of the Society.

The past year had been a difficult one for all concerned, and especially for the staff, due to the uncertainties over the future of the Station. Mr Arbuckle recalled that he had announced last year the setting up of a Working Party by the Department of Agriculture and Fisheries for Scotland to examine the future of state-funded plant breeding and arable crop research in Scotland. The Working Party, of which he had been a member, reported to the Department in December 1978 and recommended that the work of the Scottish Plant Breeding Station and that of the Scottish Horticultural Research Institute should be combined in a new crops institute at Mylnefield, near Dundee, where the Scottish Horticultural Research Institute is now sited. Since then there had been numerous meetings of the Board, between Board members and staff, and with Department of Agriculture and Fisheries officials. After much discussion concerning the land and facilities available at Mylnefield and the need for new buildings, the welfare of staff and the financial implications, the Board of Directors had accepted in principle the proposals made in the Working Party Report. The Secretary of State's decision was awaited.

Mr Arbuckle said he would have liked to have been able to announce the outcome of these discussions but, unfortunately, the matter remained unresolved. He recognised that the uncertainty over the siting of future crop breeding in Scotland was detrimental to the work of this Station. It was unsettling for staff, precluded capital investment and inhibited the establishment of work for which continuity of site was important. He, personally, very much regretted this situation and had made repeated representations to DAFS without avail. He felt that he had to say that in his opinion both DAFS and the staff side of the Whitley Council had been dilatory in this matter and had contributed to the present unsatisfactory position.

Many assurances had been given to staff to the effect that, should the proposals be adopted, the facilities available for their work would be maintained and, indeed, enhanced and that there would be opportunities for continued employment for most, if not all staff at the new site. The Department had provided as many safeguards as possible for staff jobs but he could not give an absolute assurance that all staff would find employment at the new site. Every effort would be made to accommodate other staff in the neighbourhood of Pentlandfield. It was his view that the Working Party proposals were as relevant today in the new economic circumstances, and after the change of Government, as when they were made last year, and that they still provided the best solution to the Station's problems. They offered exciting possibilities for the future of arable crop breeding and research. He believed that the long-term gain for agricultural research would outweigh the short-term disruptions and personal inconveniences which must inevitably occur.

There was one consequence of the discussions about amalgamation with the Scottish Horticultural Research Institute that could be reported. There had been a growing realisation that closer ties between that Institute and our own Station would be beneficial for both. One way of fostering this collaboration would be to form a joint Board responsible for the management of both Stations. Therefore, a meeting had been arranged earlier in the month between representatives of both Boards. An agreement had been reached on how a single Board might be set up. This agreement, which had been submitted to DAFS, had yet to be approved by the Boards and then would need to be sanctioned by the Secretary of State for Scotland.

The Chairman expressed his thanks to all members of the Board of Directors who, in the year, had been called on more frequently than usual, and especially to Mr James Gray, the Vice-Chairman, for his special help. He also thanked the retiring members of the Board for their service willingly given, namely Mr J. M. Fell, Mr W. H. M. Gill, Dr J. B. D. Herriott, Convener of the Brassica Research Committee; Sir David Lowe, Mr C. D. Scott and Mr C. G. Spence, who were appointed in 1976, and Mrs B. A. Gordon, Mr J. McFarlane and Mr D. A. J. Randall who were co-opted last year.

Two members of the Potato Breeding Department, Dr Tom Davidson and Mrs Rosalind Hine, would soon be retiring. The Chairman offered them both his and the Society's good wishes.

The Chairman then thanked the Director and all the staff of the Scottish Plant Breeding Station at Pentlandfield and at the Murrays upon whose enthusiasm, hard work and scientific integrity the Station's international reputation depended. The breeders of the new varieties depended on the research scientists around them and all were beholden to the administrative, technical and farm staff for support.

The Tenth SSRPB LECTURE:

MODIFYING PLANTS WITHOUT BREEDING, WITH PARTICULAR REFERENCE TO POTATOES

Delivered on the 17th April 1980, by

Professor J. K. A. BLEASDALE, B.Sc., Ph.D., F.I.Biol.
Director of the National Vegetable Research Station

It may seem provocative that I have chosen to speak on how to modify plants without breeding to an audience whose common interest is plant breeding. My choice of subject was more innocently arrived at as I have little knowledge of plant breeding and could not venture to inform you of new horizons in this subject. However, I have some knowledge of plant breeders and I find that they often tend to believe that only breeding can achieve agriculturally desirable modifications to plants. More specifically, they frequently fail to recognise how much induced environmental responses in plants can aid them in their breeding or usefully overcome shortcomings not easily circumvented by breeding.

It is possible to show that the modification of plants without breeding now makes a significant and increasingly sophisticated contribution to all phases of vegetable production and the first part of my talk will be concerned with this. In the second part I will deal exclusively with the potato crop where new work is revealing considerable opportunities for modifying the performance of existing cultivars.

As a platform of common ground on which I can build, I would remind you that the modification of plants without breeding is commonplace and was possibly amongst the first steps that man took in arriving at a recognisable agriculture. For example, the main technique for controlling flowering in temperate biennial vegetables, such as carrot and parsnip, is to sow the seed in the spring and avoid the cold stimulus of the winter. This gives the maximum amount of growth of the edible organs and it seems likely that this trick of collecting seed and controlling sowing date was amongst the first measures taken by primitive man in domesticating some wild species. Modern man cuts his lawns, trims his hedges and prunes his roses. No breeder has yet produced a substitute for these mechanical modifications of growth but plant physiologists have almost achieved this with the use of plant growth regulators. I need hardly remind you that the rewards for producing a lawn grass that did not need cutting are incentive enough for us to be sure that breeders have tried. Thus, even relatively primitive methods of modifying growth can produce desirable modifications to plants that are not attainable even with the sophisticated breeding knowledge we have today. To illustrate this theme further I will now cite examples in vegetables ranging from seed to storage.

MODIFYING VEGETABLES

Seeds. Engineers have developed precision seed drills to space seeds at required intervals and reduce or eliminate thinning. The mechanisms of these drills only work well when the seeds are of a uniform size and are smooth and spherical. The modification of seed shape by breeding would be difficult but seed pelleting has been developed to make those seeds of irregular size and shape into the amenable ball-bearings which one sometimes supposes were used for the design work on the drills.

Because of our cool springs, British celery cultivars have to be particularly resistant to the cool stimulus which must precede bolting. It is unfortunate that the genes that confer this desirable character are either the same or are closely linked with those which confer a high degree of dormancy on the seed (Thomas, 1978). It has proved possible to overcome this dormancy either by spraying the seeding plant with hormones or by treating the seed with hormones (Thomas and O'Toole, 1980; Thomas, Biddington and Palevitch, 1978).

Seed dormancy induced in lettuce is commonly a factor affecting establishment in the field. Cultivars differ in the temperature that has to be exceeded before dormancy is induced but all the temperatures lie within the range likely to be encountered in the field. The problem can be overcome by sowing pre-germinated seed as by this stage dormancy is no longer induced by high temperature. I will refer later to the technique we have developed for sowing pre-germinated seed.

Vegetable propagation. Tissue culture techniques are being widely used to propagate ornamental plants that will not breed true from seed. In vegetables it has similarly been used to overcome the genetical shortcomings of material, notably in asparagus, and more recently the potential has been demonstrated in rhubarb. It has also proved useful in arresting further inbreeding depression in the parental material of F_1 hybrid Brussels sprouts and has been used in cauliflower breeding as an aid in selection against defects in the curd.

Vegetative growth. The control of the size of the marketable parts of many vegetables by the control of spacing and period of growth has been the subject of much of my own research (Bleasdale, 1973). Extremely close spacings can produce "new" vegetables such as mini-cauliflower (Salter, 1971) or leaf lettuce (Gray, 1972 and 1973). Such control of size only partially overcomes the variability in size normally found in crops. This variability needs to be reduced to increase the proportion of a crop falling within the narrow size limits often demanded.

It has become evident that genetic uniformity as represented in inbreeding crops such as lettuce and in F_1 hybrids, does not reduce the phenotype variability as much as one might suppose or hope. Even in regularly spaced and genetically uniform crops such as lettuce, there is variation in growth which leads to a spread of harvest which, in turn, increases costs. It has been shown (Gray, 1976) that much of this variation is caused by the spread of emergence of the seedlings. It is now clear that the allocation of equal areas to each seedling does not ensure uniform plants as the earlier seedlings take more than their allocated space. Thus, in crops where inter-plant competition is severe because close spacings are employed, differences in the time of emergence have an increasing effect on the variability of plant size as the growing season progresses. The technique of fluid-drilling pre-germinated seed can reduce the spread of emergence and increase the crop uniformity.

Recent work has shown that hormones can alter the proportion of assimilate allocated to the edible root in carrots (Barnes, Thomas and Currah, 1979) and radish (Thomas, 1980). A mathematical model of the control mechanism suggests that breeders could aspire to giving us more carrot and less tops. If they cannot do this, then it is clearly possible by other means.

Flowering. It has seemingly proved impossible to breed a cauliflower cultivar with such synchrony of maturity that a single harvest can be made. However, with certain cultivars it has been shown that the cold treatment of transplants (Salter and Ward, 1972) will give a much more synchronous flower (curd) initiation and hence a more uniform maturity, making it possible to envisage a single destructive harvest by machine (Wheeler and Salter, 1974).

The modification of plants by controlling their environment is commonly practised to speed breeding programmes or to synchronise the flowering of types required for crossing. In this instance, we can justly claim to be modifying plants for breeding.

Fruiting. Work at Wellesbourne has recently shown that the outdoor tomato crop is viable in the southern parts of the UK, provided new techniques of production and appropriate cultivars are used. Part of the technique involves the use of ethephon to induce a more synchronous ripening than normal. However, recent work, reported by Maugh (1974), suggests even greater possibilities. He reports that Henry Yokoyama of the United States Department of Agriculture's Agricultural Research Service, has shown that certain chemicals, designated bio-regulators, can depress specific genes to give better quality, particularly manifest as colour, flavour and nutritional quality in some fruit. One class of bio-regulator induces the formation of carotenoids and enhances fruit colour. Thus it seems possible to envisage the chemical switching of genes giving us more control of ripening.

Senescence. Growth regulators and/or storage conditions can hasten or delay senescence. The most striking examples of recent time are arising from the wider application of controlled atmosphere storage as originally developed for apples. Green mature tomatoes can be stored for weeks and then control ripened to extend the season of availability of field-grown crops (Thomas, Gray and Drew, 1977).

Cabbage can be stored for months without loss of its green colour (Isenberg and Sayles, 1969). This is an appropriate point to acknowledge that my presentation is unduly biased towards the physiological modification of plants. A pathologist could, however, present an equally convincing case as they have modified the response of plants or the susceptibility of our crops to pathogens. This has been particularly true for potatoes to which I now direct your attention as we examine how a crop physiologist views the possibilities and prospects for modifying the crop without breeding.

MODIFYING POTATOES

My own work on the potato crop was concerned with spacing and the control of size, particularly for the production of tubers suitable for canning. Briefly, this led to the concept that the number of stems, counted shortly after emergence was complete, was a satisfactory measure of plant population. In many ways the eye on a tuber could be likened to the seed of other vegetable crops in that when planted only some grew to give plants. The problem remains, as it does in the other vegetables, of finding a germination test that would predict the emergence in the field. However, certain truths became self-evident, such as there being more eyes on a given weight of small tubers as compared with larger ones. This has in turn led to much more precise recommendations of planting rates, as differences in seed size and cultivar effects on the number of eyes per tuber are taken into account.

Because it would have made potatoes more akin to the other vegetables with which I worked, I considered the possibility that crops should be grown from true seed. In the early 1960s this seemed impossible as breeders generally maintained that true-breeding lines could not be established. The economic advantages of crops from true seed seemed to me to be considerable and I was disappointed that there seemed little prospect of progress. The position is now very different. It is reported that 12,000 hectares of potatoes from true seed are grown annually in China. The potential for the Western World and particularly for the tropics is thought to be large and public and private breeders are now involved. The question remains as to whether crops could be grown from true seed in the UK and, if they were, would they be seed crop or ware crops. We believe that the work we have done on outdoor tomato production has relevance as we have devised a cheap way of raising transplants which involves fluid-drilling to overcome the high temperature requirement of the initial stages of germination. It seems probable that cheap potato transplants could be raised in the same way and, given this, our growing season may be long enough and warm enough to give acceptable yields. I will readily admit that this would not be a case of modifying plants without breeding but rather modifying plants because of breeding for the ability to breed true from seed.

The conventional crop grown from tubers is genetically uniform but even when no disease factors enter into it we all know that different batches of seed will grow and yield differently. Some of these differences can be attributed to differences in seed size and/or the viability of eyes. Clearly it is desirable that we should understand how to control and optimise the performance of seed tubers and recent work done collaboratively between Dr David Wurr at Wellesbourne and Mr Eric Allen at Aberystwyth has begun to show us how this can be done.

Their experiments have been concerned with the effects of physiological age on crop yield. However, physiological age is a rather imprecise concept so they relate yields to the length of the longest sprout at the time of planting. This, in turn, they showed could be related to the number of day degrees > 4°C encountered between the end of dormancy of the seed tuber and it being planted. The end of dormancy was defined as the time when a sprout 3 mm in length had been produced and was shown to vary with planting date and variety (Table 14).

TABLE 14

Effect of date of planting of the seed crop on end of dormancy (appearance of 3 mm sprout) in progeny tubers

Date of planting	*Arran Comet*	*Désirée*	*Vanessa*	*Dunluce*
2nd April	9th Sept.	23rd Oct.	22nd Nov.	22nd Sept.
24th April	18th Sept.	15th Nov.	10th Dec.	21st Sept.
14th May	1st Oct.	10th Dec.	27th Dec.	4th Oct.

(From Allen *et al*, 1980)

The relationship between yield and the number of day degrees > 4°C has been observed in only a limited number of experiments, typical results being shown in Figure 2. The relationship between day degrees > 4°C and the number of tubers produced (Figure 3) and the seed yield can be even more striking and significant. It would appear that the seed producer should be concerned to minimise seed age by using low storage temperatures until planting.

The indications are that increases in physiological age, as measured by the criteria given, result in:—

(*a*) Earlier plant emergence.
(*b*) Earlier tuber initiation.
(*c*) Fewer tubers being set in most varieties.
(*d*) Smaller final plant size in some varieties and consequently lower tuber bulking rates.
(*e*) Increased susceptibility to water stress.
(*f*) Increased requirement for N applications.
(*g*) Earlier senescence in most varieties.

It follows that if temperature conditions in a seed store vary from place to place the tubers from that store will vary in physiological age and that within the crop, which is genetically uniform, various degrees of variation of the types listed above will be encountered. At present there is no doubt that large

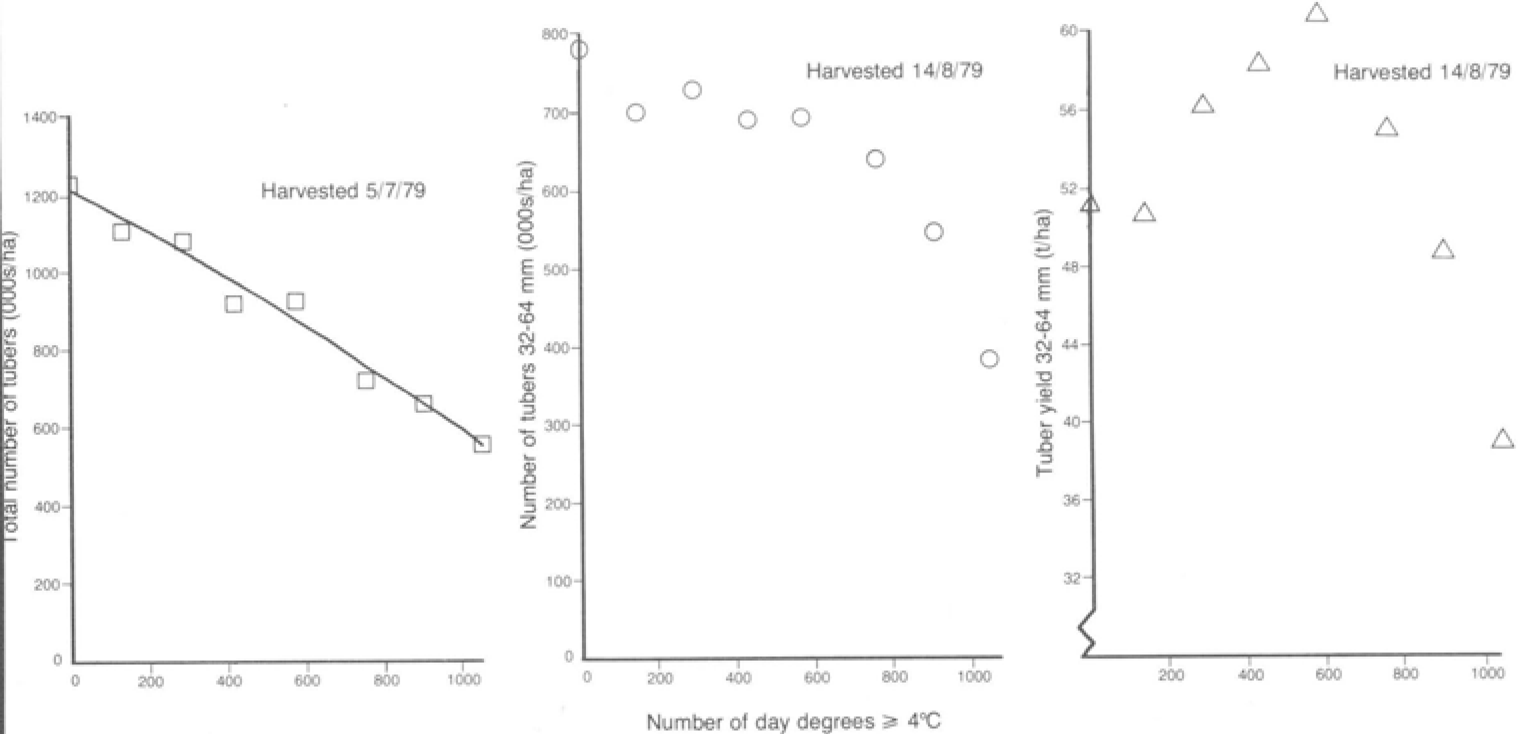

Figure 2. The effect of temperature prior to the planting of seed tubers of cv. Arran Comet, on subsequent numbers of tubers produced at two harvest dates and on the yield of seed-size tubers (reproduced from Allen *et al.*, 1980).

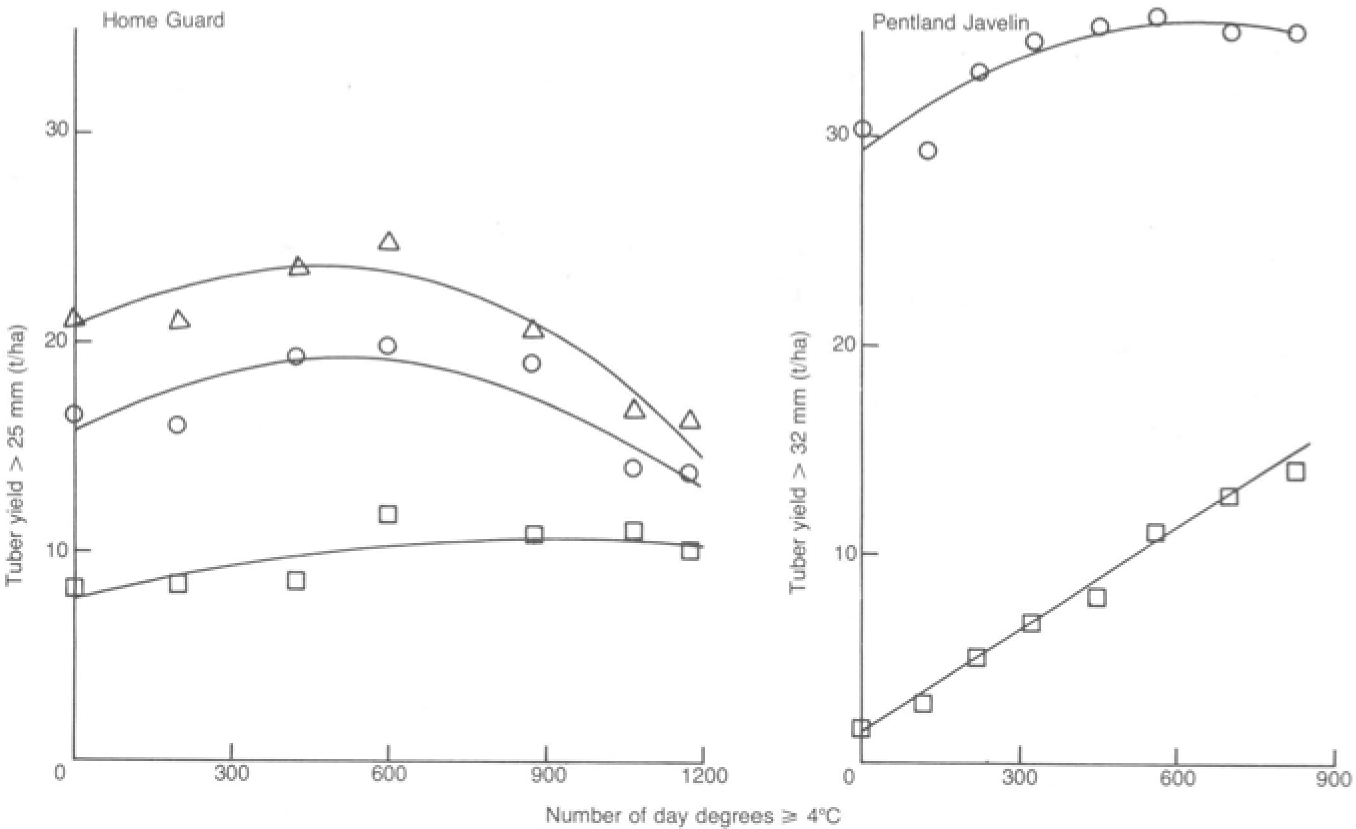

Figure 3. The effect of temperature prior to the planting of seed tubers, on their subsequent yield. Left cv. Home Guard; right cv. Pentland Javelin (reproduced from Allen *et al.*, 1980).

spatial temperature differences exist in most commercial seed stores and there can be little doubt that this contributes to between plant variability in performance. As a first step growers should invest in a few fans which would run continuously to climate temperature gradients in stores. The improved uniformity of crops should adequately compensate for the costs but, and perhaps more importantly, it should also pave the way for more sophisticated control of the conditions of seed tuber storage.

In the past seed producers have been rightly preoccupied with ensuring that their seeds were free from disease. The pathologist has dominated the scene showing them how they can keep their seed potatoes free from disease. I believe that the time has come for positive action to improve on the freedom from disease that we have by increasing the fitness of the seed for the task ahead. This is where the physiologist takes over and he is already revealing promising possibilities. He will, however, need the same response and encouragement as has traditionally been afforded the pathologist if he is to contribute as significantly to improving potato production.

There is no doubt that we can go further in modifying plants without breeding but I will readily admit, especially in this company, that we do not seek to compete with the breeder but, through collaboration with him, to complement the basic contribution that he makes to improving our crops.

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ABSTRACT OF ACCOUNTS

INCOME AND EXPENDITURE ACCOUNT

for year ended 31st March 1980

1979					
		Income			
		Department of Agriculture and Fisheries for Scotland—			
	£936,360	Maintenance grants		£1,035,000	
	—	Transfer from unexpended maintenance grants brought forward at 1st April 1979		12,216	
£936,360					£1,047,216
100		Annual subscriptions			91
978		Other income			1,429
£937,438					£1,048,736
		Less *Expenditure*			
	£511,899	Scientific and technical staff salaries, wages and National Insurance contributions		£ 606,796	
	17,073	Implements and apparatus		15,893	
	54,311	Other research expenditure		66,109	
	7,526	Staff recruitment and training		7,583	
	51,885	Additions to fixed assets (see note 1)		46,555	
	100,555	Property and buildings (see note 2)		116,251	
	43,110	Travel and transport		42,990	
	58,043	Administration and office expenses (including salaries etc. £46,581; 1979 £37,208)		72,107	
	14,982	Pensions and supplementation		17,355	
		The Murrays Farm—			
	50,576	Net operating cost	£37,792		
	34,116	Improvements	3,974		
			£41,766		
	(34,116)	*Less* capital grants from Department of Agriculture and Fisheries for Scotland	3,974		
				37,792	
909,960					1,029,431
£ 27,478		Unexpended balance of maintenance grant carried to Balance Sheet (see note 3)			£ 19,305

BALANCE SHEET

as at 31st March 1980

1979				
		Fixed Assets (see note 4)		
	£904,311	Heritable property	£953,036	
	219,553	Capital equipment	295,582	
£1,123,864				£1,248,618
		Current Assets		
	£ 80	Stock	—	
	5,402	Sundry debtors and deposits	£ 3,612	
	55,063	Cash and bank balances	65,488	
60,545				69,100
£1,184,409				£1,317,718
		Less *Current Liabilities*		
	£ 552	Sundry creditors	£ 1,858	
	59,501	Department of Agriculture and Fisheries for Scotland— Unexpended maintenance grants (see note 3)	66,590	
60,053				68,448
£1,124,356				£1,249,270
		Represented by		
£1,012,671		Funds as at 1st April 1979		£1,124,356
		Add grants received from the Department of Agriculture and Fisheries for Scotland—		
	£ 74,726	Capital works	£ 48,725	
	36,959	Capital equipment	76,589	
	£111,685		£125,314	
	—	*Less* sale of fixed asset	400	
111,685				124,914
£1,124,356				£1,249,270

JOHN ARBUCKLE
Convener, Finance Committee.

NOTES TO INCOME AND EXPENDITURE ACCOUNT AND BALANCE SHEET

(Year ended 31st March 1980)

1. Additions to fixed assets—

Apparatus and equipment	£ 27,494
Safety equipment	233
Library books etc.	4,417
Motor vehicles	13,340
Furniture and fittings	1,071
	£ 46,555

2. Property and buildings—

Rates, taxes, insurance	£ 24,644
Power, light, heat	64,618
Property alterations	836
Property repairs	12,455
Edinburgh Centre of Rural Economy	13,226
Land improvement	472
	£ 116,251

3. Unexpended maintenance grants—

Balance brought forward at 1st April 1979	£ 59,501
Less transfer to Income	12,216
	£ 47,285
Add addition during year	19,305
	£ 66,590

4. Fixed assets as at 31st March 1980—

	Cost	*Less charged to Revenue Ac.*	*Net*
Heritable property	£ 953,036	—	£ 953,036
Capital equipment	295,582	—	295,582
	£1,248,618		£1,248,618
Implements and tools	84,411	£ 84,411	—
Vehicles	43,862	43,862	—
Laboratory apparatus	135,037	135,037	—
Furniture and fittings	27,589	27,589	—
Library books	29,033	29,033	—
	£1,568,550	£319,932	£1,248,618

FUNDS AND BEQUESTS

INCOME AND EXPENDITURE ACCOUNT

for year ended 31st March 1980

1979				
		Income		
		Gross interest and dividends on investments (see note 1)—		
	£1,006	Narrower range	£1,028	
	1,178	Wider range	1,494	
£2,184				£2,522
77		Interest on bank deposit accounts		259
639		Profit on realisation of investments		—
50		Life subscriptions		82
75		Donations		178
£3,025				£3,041
		Less *Expenditure*		
	£ 7	Registrar of Friendly Societies	£ 9	
	141	S.S.R.P.B. lecture	129	
	80	Retirement presentation	75	
	388	Travel grants and travelling expenses	—	
	—	Research grants	299	
	180	Donations	180	
	—	Revaluation of investments	64	
	107	Hospitality	207	
	165	Bank charges	119	
1,068				1,082
£1,957		Net revenue carried to Balance Sheet		£1,959

FUNDS AND BEQUESTS

BALANCE SHEET

as at 31st March 1980

1979		*Narrower range*	*Wider range*	
	Assets			
	Investments at cost or valuation (see note 2)—			
£16,570	Life Membership Subscriptions and Donations Fund	£ 8,319	£10,248	£18,567
2,856	W. J. Reid and James Munro Bequests	2,059	749	2,808
729	Dr Wilson Memorial Fund	365	347	712
2,097	J. C. Thyne Bequest	1,049	1,048	2,097
£22,252				£24,184
725	Recoverable income tax		£ 768	
2,712	Bank of Scotland—current and deposit accounts		2,486	
			£ 3,254	
(220)	*Less* sundry creditors		10	
				3,244
£25,469				£27,428

	Represented by	*Funds at 1st April 1979*	*Net revenue for year*	
£18,731	Life Membership Subscriptions and Donations Fund	£18,731	£ 1,403	£20,134
3,338	W. J. Reid and James Munro Bequests	3,338	215	3,553
870	Dr Wilson Memorial Fund	870	50	920
2,530	J. C. Thyne Bequest	2,530	291	2,821
£25,469				£27,428

FUNDS AND BEQUESTS

NOTES TO INCOME AND EXPENDITURE ACCOUNT AND BALANCE SHEET

1. Full details of gross interest and dividends received are given in the appended schedules.
2. Full details of the investments appertaining to each Fund are given in the schedule. Movements during the year were as follows—

	Book value	*Sale proceeds*
Realisations		
W. J. Reid and James Munro Bequests—		
Narrower range—		
£215·00 English and International Trust Ltd. 7% Conv. Loan Stock 1986	£259	£259
Dr Wilson Memorial Fund—		
Narrower range—		
£35·00 English and International Trust Ltd. 7% Conv. Loan Stock 1986	£ 51	£ 51
Purchases		
Life Membership Subscriptions and Donations Fund—		
Narrower range—		
£1,000·00 14% Exchequer Stock 1984	£998	—
Wider range—		
£1,000·00 14% Exchequer Stock 1984	£998	—
W. J. Reid and James Munro Bequests—		
Wider range—		
260 ord. 25p shares English and International Trust Ltd.	£219	—
Dr Wilson Memorial Fund—		
Wider range—		
42 ord. 25p shares English and International Trust Ltd.	£ 35	—
Transfers from wider to narrower range		
W. J. Reid and James Munro Bequests—		
£58·00 City of Westminster 13% Red. Stock 1981	£ 77	—
£212·00 Agricultural Mortgage Corporation Ltd. 7¾% Debenture Stock 1991/93	142	—
	£219	
Dr Wilson Memorial Fund—		
£52·00 Agricultural Mortgage Corporation Ltd. 7¾% Debenture Stock 1991/93	£ 35	—

APPENDIX

Investments as at 31st March 1980

LIFE MEMBERSHIP SUBSCRIPTIONS AND DONATIONS FUND ("B" ACCOUNT)

	Book value	*Market value as at date*	*Gross interest/ dividends for year to date*
(Narrower range)			
£1,581·10 6½% Funding Stock 1985/87	£ 1,508	£ 1,123	£ 103
£2,359·35 8¾% Treasury Loan 1997	2,254	1,581	206
£1,000·00 14% Exchequer Stock 1984	999	957	—
£450·00 City of Westminster 13% Redeemable Stock 1981	445	432	59
£4,039·00 Agricultural Mortgage Corporation Ltd. 7¾% Debenture Stock 1991/93	3,113	2,383	313
	£ 8,319	£ 6,476	£ 681
(Wider range)			
£1,000·00 14% Exchequer Stock 1984	£ 998	£ 957	—
£450·00 City of Westminster 13% Redeemable Stock 1981	445	432	£ 58
£3,660·00 Agricultural Mortgage Corporation Ltd. 7¾% Debenture Stock 1991/93	2,722	2,159	284
413 ord. 25p shares Guardian Royal Exchange Assurance Co. Ltd.	714	929	72
1,980 ord. 25p shares Royal Bank of Scotland Group	864	1,644	113
690 ord. 25p shares Shell Transport and Trading Co. Ltd.	1,373	2,277	407
388 ord. £1 stock units Imperial Chemical Industries Ltd.	751	1,397	115
1,420 ord. 25p shares Claverhouse Investment Trust Ltd.	795	1,321	121
913 ord. 5p shares London and Manchester Assurance Co. Ltd.	1,586	1,397	102
	£10,248	£12,513	£1,272
"B" ACCOUNT TOTAL	£18,567	£18,989	£1,953

W. J. REID AND JAMES MUNRO BEQUESTS ("C" ACCOUNT)

	Book value	*Market value as at date*	*Gross interest/ dividends for year to date*
(Narrower range)			
£1,359·29 6½% Funding Stock 1985/87	£ 1,334	£ 965	£ 88
£689·00 Agricultural Mortgage Corporation Ltd. 7¾% Debenture Stock 1991/93	498	407	53
£215·00 English and International Trust Ltd. 7% Convertible Loan Stock 1986	—	—	8
£228·00 City of Westminster 13% Redeemable Stock 1981	227	219	30
	£ 2,059	£ 1,591	£ 179
(Wider range)			
£215·00 English and International Trust Ltd. 7% Convertible Loan Stock 1986	—	—	£ 8
521 ord. 25p shares English and International Trust Ltd.	£ 479	£ 432	11
90 ord. £1 stock units Imperial Chemical Industries Ltd.	198	324	27
£72·00 City of Westminster 13% Redeemable Stock 1981	72	69	9
	£ 749	£ 825	£ 55
"C" ACCOUNT TOTAL	£ 2,808	£ 2,416	£ 234

DR WILSON MEMORIAL FUND ("D" ACCOUNT)

		Book value		Market value as at date		Gross interest/ dividends for year to date
(Narrower range)						
£276·60 6½% Funding Stock 1985/87	£	266	£	196	£	18
£143·00 Agricultural Mortgage Corporation 7¾% Debenture Stock 1991/93		99		84		11
£35·00 English and International Trust Ltd. 7% Convertible Loan Stock 1986		—		—		1
	£	365	£	280	£	30
(Wider range)						
£39·00 Agricultural Mortgage Corporation Ltd. 7¾% Debenture Stock 1991/93	£	28	£	23	£	3
£35·00 English and International Trust Ltd. 7% Convertible Loan Stock 1986		—		—		1
85 ord. 25p shares English and International Trust Ltd.		87		71		2
133 ord. 25p shares Guardian Royal Exchange Co. Ltd.		232		299		23
	£	347	£	393	£	29
"D" ACCOUNT TOTAL	£	712	£	673	£	59

J. C. THYNE TRUST ("E" ACCOUNT)

		Book value		Market value as at date		Gross interest/ dividends for year to date
(Narrower range)						
£1,060·00 City of Westminster 13% Redeemable Stock 1981	£	1,049	£	1,018	£	138
(Wider range)						
£1,060·00 City of Westminster 13% Redeemable Stock 1981	£	1,048	£	1,018	£	138
"E" ACCOUNT TOTAL	£	2,097	£	2,036	£	276
TOTAL INVESTMENTS		£24,184		£24,114		£2,522
						(10·43% on invested capital)

AUDITORS' REPORT

In our opinion the Income and Expenditure Accounts and Balance Sheets set out on pages 140 to 147 which have been prepared on a historical cost basis give a true and fair view of the state of affairs as at 31st March 1980 and of the income and expenditure for the year ended on that date.

BROWN, MACDONALD & FLEMING
Auditors.

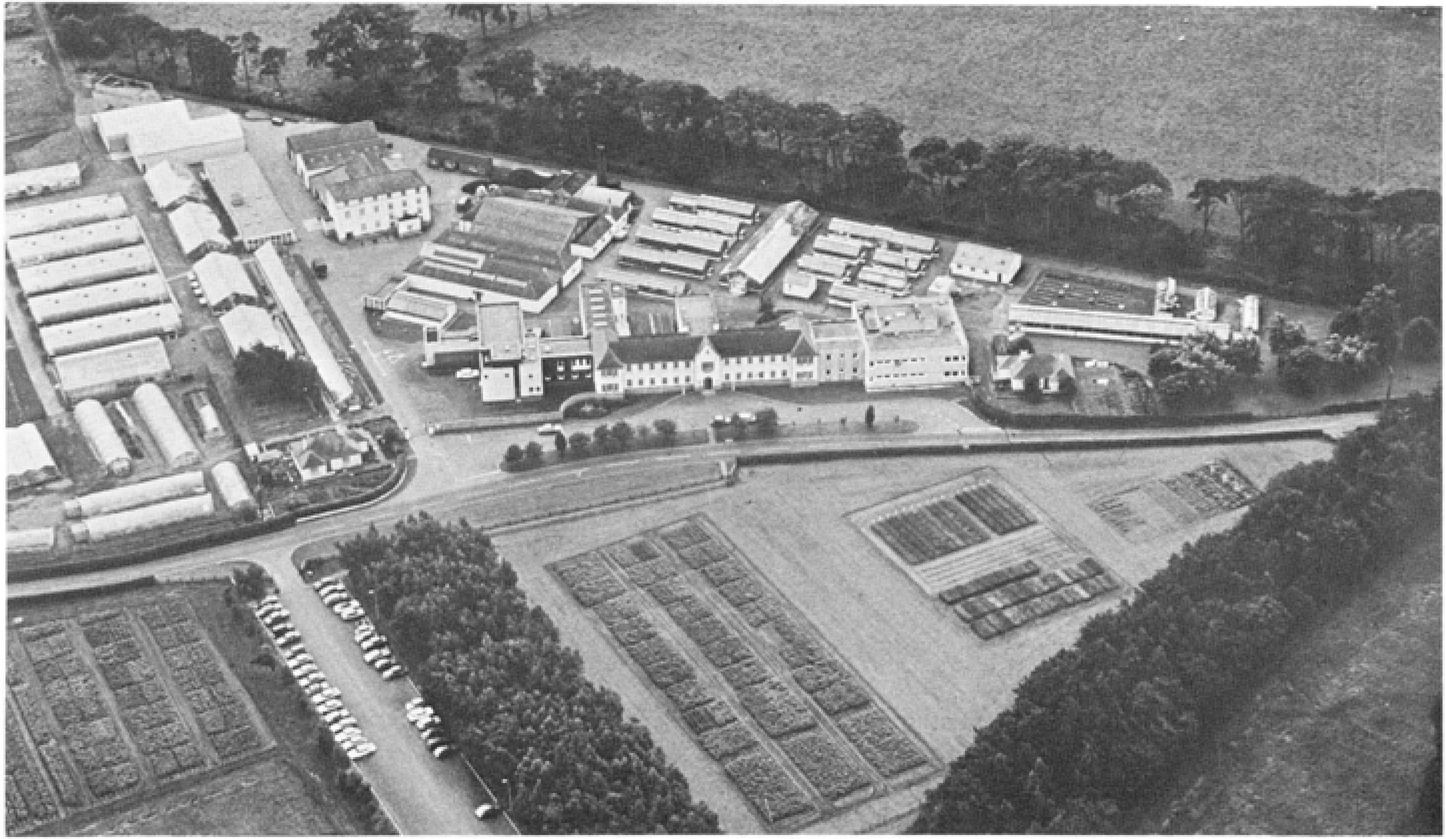
16 Alva Street, Edinburgh.
23rd May 1980.

THE SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING AND THE SCOTTISH PLANT BREEDING STATION

The Scottish Society for Research in Plant Breeding was founded in 1920 with the dual aims of conducting scientific investigations into plant breeding and of breeding crops for Scottish agriculture. Membership of the Society is open to any interested person whether farmer, merchant, scientist or other, in or out of Scotland (see p. 149 for application form). Its management is vested in a Board of Directors which is partly elected by the members and partly nominated by the Secretary of State for Scotland, and its principal activity is to look after the affairs of the Scottish Plant Breeding Station.

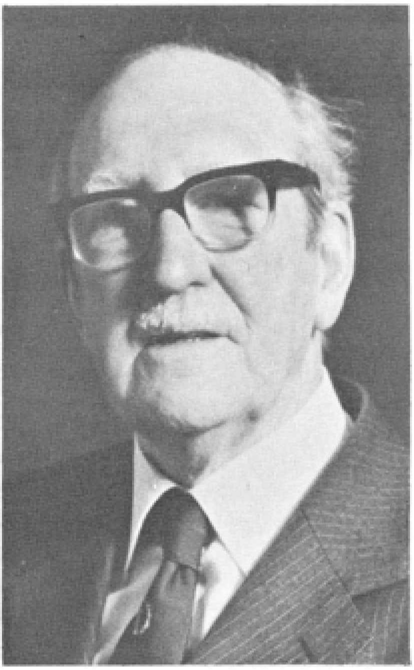
The Station is now financed from public funds granted by the Department of Agriculture and Fisheries for Scotland under scientific advice from the Agricultural Research Council. It was for thirty three years at Craigs House, Corstorphine, and moved to new premises, Pentlandfield, on the Bush Estate of the Edinburgh Centre of Rural Economy in 1954. In addition to laboratories, glasshouses, and some land at Pentlandfield it now has land and facilities at its experimental centre, the Murrays, in East Lothian (see maps on cover). Field trials are also grown at other sites in Scotland, Wales, England and New Zealand.

The Station is now largely concerned with brassica, cereal and potato crops. Its resources are directed approximately equally towards the elucidation of fundamental aspects of these crops and the breeding of new varieties. It has scientific links with the Edinburgh School of Agriculture, the ARC Unit of Statistics, the Edinburgh Regional Computing Centre, and is a component of the Agricultural research Service.



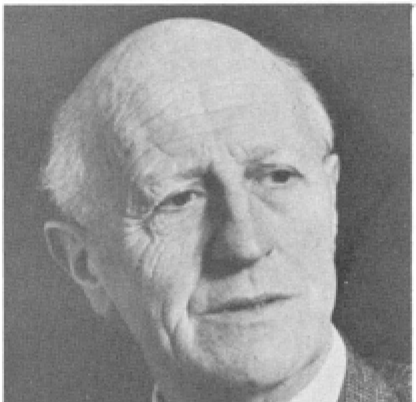
VIEW OF PENTLANDFIELD, SUMMER 1980

Dr R. C. F. MACER



Mr J. GRAY

Mr J. ARBUCKLE



Mr W. A. BIGGAR