SCOTTISH PLANT BREEDING STATION

REPORT

April 1976 to March 1977

And the Report of the

SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING

PENTLANDFIELD, ROSLIN, MIDLOTHIAN EH25 9RF
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Report of the Scottish Plant Breeding Station

Report of the Scottish Society for Research in Plant Breeding

STAFF LIST

(In post 5th March 1977)*

Director: R. C. F. Macer, M.A., Ph.D., F.I.Biol.

FORAGE DEPARTMENT

Head: R. N. H. Whitehouse, M.A.

PSO: M. J. Allison, B.Sc., Ph.D.
F. J. W. England, B.Sc., Ph.D.
A. M. Hayter, B.Sc., Ph.D.
I. H. McNaughton, M.A., D.Phil.

SSO: S. Gowers, B.Sc., Ph.D.
G. R. Mackay, M.Sc.†

HSO: J. E. Bradshaw, M.A., M.Sc., Ph.D.
I. M. Chapman, B.Sc.
R. P. Ellis, B.Sc., Ph.D.†
Miss I. K. Munro, B.Sc.
Miss C. L. Snell, M.Sc.
W. T. B. Thomas, B.Sc., Ph.D.
Miss C. J. Williamson, B.Sc.

SO: R. Borzucki, H.N.C.
I. A. Cowe, H.N.C.†
R. J. Giles, B.Sc.†
M. S. Phillips, B.Sc.
J. S. Swanston, B.Sc., L.I.Biol.
R. B. W. Williamson, H.N.C., L.R.I.C.
A. Young

ASO: J. Brown, O.N.C.
Miss F. M. Bruce, O.N.C.
Mrs D. J. Barclay
S. J. Cormack
D. M. Farrer
R. S. Hird
K. Ireson
D. D. Mathieson
Miss J. E. Middlefell
J. B. McGregor, S.D.A.
R. McHale, O.N.C.
Miss C. M. MacParland
Miss D. C. Page
J. J. Rolls, B.A.
J. A. Scott
Miss D. Watt
Miss E. A. Young
G. R. Young

Experimental Workers: Miss S. A. Byiers
Mrs I. Davidson
G. R. Drabble
Mrs E. B. Hoy
Mrs M. H. McGuigan
Miss L. A. MacPherson
Mrs J. Speirs
Mrs M. H. Tulloch
Miss E. Vallery

POTATO DEPARTMENT

Head: J. H. W. Holden, B.Sc., Ph.D.

PSO: T. M. W. Davidson, B.Sc., Ph.D., N.D.A.
D. R. Glendinning, B.Sc.
Miss J. F. Malcolmson, B.Sc., Ph.D., M.I.Biol.

SSO: C. P. Carroll, M.Sc.
R. J. Killick, B.Sc., Ph.D., M.I.Biol.
A. W. Macarthur, B.Sc.†
R. L. Wastie, M.A., Ph.D., F.I.S.P.†

HSO: J. M. S. Forrest, B.Sc., Ph.D.†
Miss H. E. Stewart, H.N.C., M.I.Biol.
C. J. W. Torrance, H.N.C.

ASO: G. J. Bleazard
P. W. Gettings
Miss P. H. McVeigh
Miss S. Mann, O.N.C.
Miss F. Mathison
Miss S. Milligan
J. C. Penman, H.N.D.
Mrs J. M. Spence
G. E. L. Swan
A. C. Wilkinson
Miss L. A. Wilson, H.N.D., L.I.Biol.

* See page 7 for explanation
† See page 13

SO: P. G. N. Digby, B.Sc.
M. J. De Maine, B.Sc.
Mrs J. A. Fantes, M.A.†
Miss R. M. Ford, B.Sc.
Mrs L. E. M. Gray, B.Sc., A.I.M.L.S.
Miss R. M. Solomon, B.A., M.Sc.

Experimental Workers: Mrs S. A. Bell
M. P. L. Campbell
Mrs M. M. S. Dugan
Mrs E. M. Wann

FIELD AND WORKS

Head: D. W. Speed, B.Sc.

Technical Officer: A. E. Hamilton, O.N.C.

Craftsmen: J. Mellon
G. Stevens
W. J. Warburton

Caretaker/Handyman: T. K. Purves

Handyman: J. G. Butt

Groundsman/Driver: A. E. Cochrane

Storekeeper: R. G. Gray

Experimental Workers: W. G. Robertson
Mrs J. Turner

ASO: T. G. Archibald

Grieve: W. Dick

Agricultural Workers: R. Cameron
N. Carnochan (Tractorman)
J. Currie
D. Goodall
J. Hutchinson
H. Jamieson
A. Knox
M. McPartland
M. Paolozzi
Miss V. Purves
J. Russell
R. Simpson
G. Wilson
W. Wilson (Tractorman)

THE MURRAYS

G. R. White, B.Sc. (Superintendent)
T. Gifford (Tractorman)
J. Ramsay (Vermin Control)‡
D. Ritchie (Tractorman)
R. C. Tait (Tractorman)

ADMINISTRATION

H. C. M. McLeod (Secretary)
P. P. Bonnington (Assistant Secretary)
Mrs A. Fulcher (Clerical Officer)
Mrs M. M. Inglis (Clerical Officer)
Miss S. McLeod (Clerical Officer)
Miss I. M. Hayes (Director's Personal Secretary)
Mrs J. E. Heritage (Shorthand Typist)
Mrs C. M. Leith (Shorthand Typist)‡
Mrs M. J. G. Purves (Shorthand Typist)‡
Mrs J. B. P. Stevenson (Shorthand Typist)
Miss G. Lightbody (Clerical Assistant)

New Appointments since 5.3.77 (to 31.3.77)
ASO: Miss D. J. Fullerton
Librarian: Miss B. Hay, A.L.A.

† See page 13
‡ Part-time

DIRECTOR'S REPORT

R. C. F. MACER

The year 1976-77 has in many ways been an eventful one for the Station. The appointment of a new Director is a rare event, and there have only been four previous Directors since the inception of the Station in 1921. It provides a natural opportunity to review the objectives and the priorities of the research programme at the Station as well as the organisation and the administration of the work with which it has been entrusted. In the year under review, however, such an appointment also coincided with the receipt of the report of the Visiting Group which was entertained at the Station in September 1975, with the publication of recommendations of the JCO Boards (at the end of the first three-year phase of their existence), and with the completion of "rationalisation" discussions with our sister institutes—the Plant Breeding Institute, Cambridge and the Welsh Plant Breeding Station, Aberystwyth. As a consequence, it has been necessary to devote a considerable amount of time to considering and assimilating the information which has been received at the Station and adjusting the research programme and organisation to meet the needs of a changing situation. The whole review has been undertaken during a period of extreme financial stringency in which a "no-growth" policy in scientific research is being applied as national policy. In this part of the Annual Report it may be helpful to re-state the objectives of the Station and to indicate how these fit into the overall pattern of research and development in the United Kingdom.

The main objective of the Station remains that of "conducting scientific investigations into plant breeding and of breeding plants for Scottish Agriculture" which was the intention of the Scottish Society for Research in Plant Breeding at the time of its foundation in 1920. This complies completely with the ARC policy on state-aided plant breeding, and the work is now fully commissioned by the Department of Agriculture and Fisheries for Scotland (DAFS). In the past the Station's work has been involved with potatoes, brassicas, cereals and grasses, with an emphasis on potatoes. This is reflected in the success of the "Pentland" varieties which occupy more than 50 per cent of the United Kingdom ware potato acreage and are becoming of increasing interest abroad, particularly in the Mediterranean region. The review article (page 66) written by Dr J. H. W. Holden outlines the Station's potato research achievements and describes the present and possible future programmes.

The recent JCO Board reports have identified priority areas for research. These have been taken into account in the "rationalisation" discussions. It has now been decided that the Station should terminate all work with grasses and with clovers. Breeding work with these crops will be concentrated at

Aberystwyth where special emphasis will be placed upon the varietal requirements for Scotland. Evaluation programmes will be established by DAFS to screen the Aberystwyth material for suitability for use in Scottish conditions. The needs of Scottish Agriculture will thus be served by harnessing the expertise and extensive facilities at the Welsh Plant Breeding Station, and this is likely to be more effective in producing varieties than the relatively modest programme at Pentlandfield could have been. The complete phasing-out of the grass programme by 1980 (with a major run-down by 1978) will enable a greater concentration of effort on the other crops, and work will be intensified on barley, oats and brassicas. For these crops the Station will serve the needs of other parts of the United Kingdom which have ecological and climatic requirements similar to Scotland. The potato programme will be continued, and further strengthened as soon as financial conditions allow.

There will be other less substantial consequences of rationalisation, all of which are designed to enable the Station to pursue more directly its main strategic research objectives and its variety production programmes. The evaluation of wheat and field beans produced by our sister Stations, especially for northerly latitudes, will be continued and ultimately increased. Regrettably, it will not be possible, for the time being, to continue to work with potential new crops for Scotland (the Plant Exploration Unit). A "watching brief" for new crops and for new promising material will be maintained.

To meet the new demands being placed upon the Station certain changes in organisation were introduced at the end of the year under review. The two large Departments (Forage and Potatoes) which have formed the basis of the organisational structure of the Station in the past have been given Divisional status, thus enabling three Departments to be formed in each. Mr R. N. H. Whitehouse has been designated Head of the Forage Division and Dr J. H. W. Holden, Head of the Potato Division. I have asked Dr I. H. McNaughton, Dr A. M. Hayter and Dr M. J. Allison to head the new Brassica, Cereal and Chemistry Departments in the Forage Division and Dr T. M. W. Davidson, Dr R. L. Wastie and Mr D. R. Glendinning to head the new Breeding, Pathology and Strategic Breeding Departments in the Potato Division. In addition to improving the effectiveness of the research and breeding programmes, this structure should facilitate the handling of the increasing load of administrative work resulting from legislation controlling Plant Variety Rights and National List Testing procedures, and from the more central control of research planning and reporting and the more complex management procedures being imposed upon us. A new Agronomy Division, headed by the Director with a single Department led by Dr F. J. W. England, who has transferred from grass breeding, has been established to co-ordinate the Station's experimental field work and the research related to it. The trials work, and the evaluation of novel material and potential varieties of established crops, is of the greatest importance and Dr England will have a special responsibility in this area. An Administrative Division has also been formed. The new management structure is shown on page 9. For convenience, and because most of the work described in this Report was completed before the new structure came into effect, the Staff List (page 4) is laid out in the way it has operated during the year under review.

The experimental station at The Murrays, near Pathhead, has been further improved during the year. The new storage facilities completed in the spring of 1976 have been of the greatest benefit. Much more needs to be done to bring this farm, which we entered in 1971, up to the standards needed by a large plant breeding organisation. A major drainage scheme was started in February 1977 and thirty-four hectares were re-drained by the end of March. Ultimately, the whole 134 hectares will be re-drained. A design study was made for a new steading and research buildings. Building will be delayed and now, inevitably, spread over a number of years.

At Pentlandfield the new east wing was occupied during the year. The additional laboratory and study space has eased some of the pressures on accommodation. The new lecture room has enabled larger scientific meetings to be held, and the canteen and recreation area have much improved the facilities available to staff. In addition, temporary accommodation has been erected at Pentlandfield to provide additional space and further reduce the overcrowding in some of the laboratories. In the short-term this should allow our research work to proceed efficiently.

We learned with regret of the death, on the 16th October 1976, of Dr George Cockerham who was on the staff of the Station from 1929 to 1969. He contributed greatly to the work of the Station and was a pioneer and leading authority on potato viruses and resistances to them; his publications are major milestones in this field. His contributions to potato breeding are reflected in the significant virus resistances of several SPBS varieties and of other breeding material from which further varieties should yet emerge. A fuller appreciation of his work was published in our 1968-69 Report, on his retirement.

I should like to thank Mr D. R. Glendinning and his colleagues on the Editorial Committee who have collated the material for this Report and who have seen it through the Press.

In conclusion, I should like to express my appreciation to Dr J. H. W. Holden who was acting Director during the summer of 1976 and to Mr R. N. H. Whitehouse and Mr H. C. M. McLeod who so ably assisted him during this period. Also, I should like to acknowledge the help given to me by the Board of Directors and by all the staff in settling in at the Station and in taking up the duties of Director.

OUTLINE MANAGEMENT STRUCTURE

(Introduced 7th March 1977)

DIRECTOR
(Dr R. C. F. Macer)

DIVISIONS	FORAGE (R. N. H. Whitehouse)	POTATOES (Dr J. H. W. Holden)	AGRONOMY (Dr R. C. F. Macer)	ADMINISTRATION (Dr R. C. F. Macer)
Departments	Cereals (Dr A. M. Hayter)	Breeding (Dr T. M. W. Davidson)	Agronomy (Dr F. J. W. England)	Administration (H. C. M. McLeod) *Secretary*
	Brassicas (Dr I. H. McNaughton)	Strategic breeding (D. R. Glendinning)		
	Chemistry (Dr M. J. Allison)	Pathology (Dr R. L. Wastie)		

Units

Strategic Pathology
(Dr J. F. Malcolmson)

Library
(Miss B. Hay)

INFORMATION CONCERNING STAFF AND VISITORS

Director

Dr R. C. F. Macer (Deputy Chief Scientific Officer) joined the staff as Director on 1st September 1976.

He continues to serve as a member of the Cereals Committee and Diseases Working Party of the Joint Consultative Organisation. He was invited to become a member of the Arable Crops and Forage Board and to become chairman of the Cereals Committee for the period up to September 1979.

He attended the Fourth European and Mediterranean Cereal Rusts Conference at Interlaken, Switzerland, in September 1976 and a symposium on problems of pest and disease control in Northern Britain at Dundee University in March 1977, where he chaired the first session on cereals and grasses.

Staff

A. A. "Sandy" McFarlane retired after forty-seven years service with the SSRPB, having started work in the potato glasshouses with Dr Black in 1929 at the Ainville substation, Kirknewton.

Dr A. M. Hayter was promoted to Principal Scientific Officer, A. E. Hamilton to Professional and Technical Officer grade III and R. Borzucki to Scientific Officer.

New appointments made during the year included: Dr W. T. B. Thomas (Higher Scientific Officer); P. G. N. Digby (Scientific Officer); Miss D. J. Fullerton, P. W. Gettings, Miss S. Milligan, Miss P. H. McVeigh, J. C. Penman, J. J. Rolls and A. C. Wilkinson (Assistant Scientific Officers); W. G. Robertson (Experimental Worker grade V); T. Purves (Caretaker/Handyman); J. Mellon (Mechanic); R. Cameron, D. Goodall and Miss V. Purves (Agricultural Workers); R. G. Gray (Storekeeper); Mrs M. J. G. Purves (Shorthand Typist), Miss B. Hay (Librarian).

Resignations included: Mrs G. McConnell (Scientific Officer, part-time); S. Cormack, D. Fleming, Miss F. Hadden, S. Millar and A. Watt (Assistant Scientific Officers); Mrs J. Sutherland (Photographer); R. Cameron, A. Hunter, J. Hunter and J. Roddie (Agricultural Workers); W. Beirne (Caretaker/Handyman).

Visiting Research Workers and Students

Dr I. P. Butzonitch from Balcarce Agricultural Research Station, Argentina, worked with Dr T. M. W. Davidson and Miss R. Solomon on potato viruses from April until September 1976. Mrs L. Snee from the North London Polytechnic worked as a sandwich course student with Miss C. J. Williamson, studying seedling development in relationship to field performance in *Poa* ssp. until July 1976.

Visitors

There were numerous visitors throughout the year. They included: Sir Williamson Henderson, F.R.S., Secretary of the ARC; Dr G. W. Cooke, C.B.E., F.R.S., Chief Scientific Officer, ARC Headquarters; Professor H. R. Klinck of McGill University, Montreal; Professor E. T. Bingham of the University of Wisconsin; Mr Jorgen Larsen of Carlsberg Laboratory, Copenhagen; Dr Kang Kwun from Korea; Dr W. M. Tahir of FAO, Rome; Messrs Kehoe, Dowley and O'Connors of the Agricultural Institute, Carlow; Dr de Bokx of the Institute of Phytopathological Research, Wageningen; Professor Watkin Williams of Reading University; K. G. Proudfoot of the Canadian Department of Agriculture, Newfoundland; P. J. Prins of the Roodeplaat Agricultural Research Station, S. Africa; Zwi Herzoy from the Plant Protection Division of the Ministry of Agriculture, Israel; Dr J. Szirtes from Hungary; Professor Cooper, Director of the Welsh Plant Breeding Station; Professor Russell of Newcastle upon Tyne University; Professor R. Plaisted of Cornell University, USA; Dr E. J. Allan, University College of Wales, Aberystwyth; H. Maunder, Executive Officer, New Zealand Potato Board; Mrs Susan Cross, Gartons Agram Ltd., Southport; G. W. Herd from Rhodesia; Dr Yamagata, Abteilung für Pflanzengenetik, München; Gordon Claridge, New Zealand Potato Grower; and Dr MacFarlane Smith of Rothwell Plant Breeders.

There were visits by several parties of students accompanied by staff of the universities of Aberdeen, Edinburgh, University College of Wales and a party of forty visitors from Finland led by Dr Varis.

Visits abroad

Dr J. M. S. Forrest attended the XIII International Symposium of Nematology in Dublin, at which he presented a paper on screening for resistance to pathotype E of the white potato cyst nematode.

Dr M. J. Allison visited Denmark and Sweden to discuss analyses of whisky worts with Dr Enevoldsen of Carlsberg and work on starch synthesis with Dr Doll at Riso.

Dr F. J. W. England, Dr S. Gowers and G. R. Mackay attended the Eucarpia Fodder Crops meeting at Roskilde in Denmark, where the former two presented papers.

Dr A. Hayter returned from DSIR, Gore, New Zealand in April 1976 after spending three months selecting and harvesting barley; Dr R. Ellis left for New Zealand in January 1977 to carry out this year's selections.

Dr J. W. H. Holden presented a paper at a joint EAPR/Eucarpia meeting in Sweden and R. N. H. Whitehouse attended a symposium on the use of induced mutations for improving disease resistance in crop plants at IAEA in Vienna, in January 1977.

Dr T. M. W. Davidson visited Spain in March 1977, at the request of the NSDO, to advise on the multiplication of potato stocks on the Spanish mainland and in Majorca, where certain SPBS varieties such as Pentland Squire are gaining popularity.

Visits, Conferences and Lectures within the UK

Dr T. M. W. Davidson and Miss R. M. Solomon attended a meeting on viruses and plant breeding at SHRI in July 1976, at which the former introduced a session with a short paper. Mrs J. A. Fantes attended a Chromosome Conference in Kew in July. Dr J. H. W. Holden attended a PMB potato demonstration workshop at Nottingham in September and delivered talks to PMB farmers potato meetings at Perth and Montrose and to overseas potato merchants at Pentlandfield as part of a PMB organised Scottish Tour. Dr R. L. Wastie gave a paper on screening for resistance to storage diseases and Dr F. J. W. England one on selection for winter survival in Italian ryegrass at the AAB meeting in Edinburgh in July. Drs J. E. Bradshaw, R. P. Ellis and A. M. Hayter attended a Eucarpia meeting on cereals and physiology in Cambridge in December. Dr F. J. W. England and G. R. Mackay attended the winter meeting of the British Grassland Society on Forage crops as complements to grass in London in December.

Members of staff gave several talks to external bodies including seminars by G. R. Mackay on rape breeding and on the breeding of brassica forage crops to students and staff of Lanchester Polytechnic, Coventry and the School of Agriculture, University of Newcastle respectively. Dr I. H. McNaughton, Dr A. M. Hayter and A. W. Macarthur each contributed a talk on the maintenance of breeders' stock seed to the students of the post-graduate course on seed technology at Edinburgh University.

Miss C. L. Snell spent three days at WPBS studying the techniques for production of doubled haploids in barley. R. N. H. Whitehouse attended a UKSE meeting in London in April, an ARC/BAPB Committee at WPBS in May, an ARC Cereal Breeders' Conference at PBI in July, the JCO working party on the use of mixtures and a Royal Society discussion meeting in November.

Courses attended

Dr M. J. Allison, R. McHale and I. A. Cowe attended various courses on the use of the Technicon Auto Analyser (AA II), on Column Chromatography, the Technicon InfraAlyser and High Performance Liquid Chromatography. Dr J. E. Bradshaw and M. S. Phillips attended a course in Applied Plant Pathology at ESCA. R. N. H. Whitehouse took part in an SADC seminar on development. G. Stevens attended courses on the use of fire extinguishers and on special welding techniques. R. C. Tait and D. Ritchie are both attending the Agricultural Training Board apprentice training scheme.

Several members of staff attended routine courses on safety, technical report writing and ARC JAR interviews. M. P. L. Campbell, Miss R. M. Ford and C. J. W. Torrance passed the DAFS potato roguers course at East Craigs.

New Qualifications

Miss L. A. Wilson was admitted as a Licentiate of the Institute of Biology. J. C. Penman gained an HND in biology. Miss S. Mann and R. McHale successfully completed the ONC in biology. J. A. Scott passed a crop inspector course at East Craigs.

Subsequent Promotions

With effect from 1st April 1977, A. W. Macarthur and R. L. Wastie were promoted to PSO; J. M. S. Forrest and R. P. Ellis to SSO; I. A. Cowe, R. J. Giles and Mrs J. A. Fantes to HSO.

G. R. Mackay was promoted to PSO on 1st May 1977, on transfer to the Breeding Department of the Potato Division.

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 best thanks.

(a) Agricultural Research Council Institutes

There has been direct collaboration during the year with the thirteen ARC Institutes marked with asterisks in the list on p. 103.

(b) Other official bodies

Agricultural Development and Advisory Service: Gleadthorpe, Terrington and Arthur Rickwood Experimental Husbandry Farms; Rosewarne Experimental Horticulture Station; Swansea, Derby, and Beverley.
Broom's Barn Experimental Station, Higham, Bury St Edmunds.
Department of Agriculture and Fisheries for Scotland, Scientific Services, Edinburgh.
Department of Scientific and Industrial Research, Crop Research Division, New Zealand.
Edinburgh Centre of Rural Economy.
Forestry Commission Northern Research Station, Roslin.
Institute of Terrestrial Ecology, Unit of Tree Biology, Edinburgh.
National Institute of Agricultural Botany, Cambridge and Cockle Park.
National Seed Development Organisation, Cambridge.
Plant Pathology Laboratory, Harpenden.
Potato Marketing Board, London.
Royal Botanic Garden, Edinburgh.
Swedish Seed Association, Svalöf.
Zentralinstitut für Genetik und Kulturpflanzenforschung, Gatersleben, D.D.R.

(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 and Department of Botany.

Heriot-Watt University, Department of Brewing and Chemistry.
Newcastle upon Tyne University, School of Agriculture.
North of Scotland College of Agriculture, Aberdeen.
Stirling University, Department of Biology.
University College of Wales, Aberystwyth.
West of Scotland College of Agriculture, Ayr.

(d) **Industrial Collaborators**

Bayer (UK) Ltd., Bury St Edmunds.
Brewing Industry Research Foundation, Redhill, Surrey.
Dalgety Agricultural Research, Timaru, New Zealand.
Golden Wonder Ltd., Broxburn, W. Lothian.
Miln Marsters Group, Chester.
Moray Firth Maltings, Inverness.
Pan Brittanica Industries Ltd., Waltham Cross, Herts.
Pentlands Scotch Whisky Research Ltd., Edinburgh.
Rank, Hovis, McDougal Ltd., Cupar, Fife.
Rothwell Plant Breeders Ltd., Lincs.
Scottish Agricultural Industries Ltd., Edinburgh.
Sinclair McGill (Scotland) Ltd., Ayr.
Spillers Newgrain Ltd., Morton Mill, Essex.
Suttons Seeds Ltd., Reading, Berks.
Technicon Instruments Ltd., Houndmills, Basingstoke.
Twyford Seeds Ltd., Adderbury, Oxfordshire.

(e) **Individuals**

J. Black, Drochil Castle, Peeblesshire.
G. Finlay, Shanwell Farm, Tayport, Fife.
A. S. Graham, Ravensneuk, Penicuik, Midlothian.
J. S. Graham, Queenston Bank, North Berwick, E. Lothian.
J. F. MacBrayne, West Byres, Ormiston, E. Lothian.
A. MacIntyre, South Ledaig, Argyll.
W. McCrone, Cairnside, Kirkcolm, Stranraer, Wigtown.
R. Miller, Tullochgorum, Inverness-shire.
W. H. Porter, West Scryne, Carnoustie, Angus.
J. Riddell, West Peaston Farm, Ormiston, E. Lothian.
R. G. Robinson, Christchurch, New Zealand.
R. Rowe and Sons, Over Ardoch, Braco, Perthshire.
G. A. Storrar, Rossie, Auchtermuchty, Fife.
R. Trotter, Ormiston Mains, Ormiston, E. Lothian.
A. B. Turnbull, Home Farm, Penrice, Glamorgan.
A. R. Wilson, Brightmony, Auldearn, Nairn.

LIST OF ABBREVIATIONS

Organisations:

AAB	Association of Applied Biologists.
ADAS	Agricultural Development and Advisory Service.
ARC	Agricultural Research Council.
BAPB	British Association of Plant Breeders.
DAFS	Department of Agriculture and Fisheries for Scotland.
DSIR	Department of Scientific and Industrial Research (New Zealand).
EAPR	European Association for Potato Research.
ESCA	East of Scotland College of Agriculture.
IAEA	International Atomic Energy Agency.
JCO	Joint Consultative Organisation.
NIAB	National Institute of Agricultural Botany.
NSDO	National Seed Development Organisation.
NVRS	National Vegetable Research Station.
PBI	Plant Breeding Institute (Cambridge).
PMB	Potato Marketing Board.
RRI	Rowett Research Institute.
SADC	Scottish Agricultural Development Council.
SHRI	Scottish Horticultural Research Institute.
SPBS	Scottish Plant Breeding Station.
SSRPB	Scottish Society for Research in Plant Breeding.
UCW	University College of Wales.
UKSE	United Kingdom Seeds Executive.
WPBS	Welsh Plant Breeding Station.

Others:

APZ	Code-name of an SPBS swede breeding line.
CPC	Commonwealth Potato Collection.
ECD	European Club-root Differential.
EMAS	Edinburgh Multiple Access (Computer) System.
JAR	Job Appraisal Review.
RvP	Name of a ryegrass cultivar.
VTSC	Virus Tested Stem Cutting.

INDEX OF SCIENTIFIC AND TECHNICAL REPORTS

The research programmes of the agricultural research institutes supported by public funds (see p. 103) are co-ordinated by the Agricultural Research Council. The work of the Forage and Potato Departments is therefore divided into approved projects the reference numbers of which are given below.

Service Units:

FORAGE DEPARTMENT

Barley genetics (ARC 1)

A trial was carried out to investigate methods for measuring and predicting malting quality, and for choosing parents for the malting quality breeding programme. Collaborative physiological studies were undertaken on barley development. Methods of applying mass selection to composite cross populations were investigated. Work continued on the barley collection.

In 1976 a trial containing twenty-five varieties was grown at the Murrays, the second in a series to investigate the methods now available for measuring and predicting malting quality in barley. The 1975 trial (*Annual Report 1975-76:* 7), which contained twenty-eight varieties, has now been micro-malted using the method of Whitmore and Sparrow (*J. Inst. Brew.*, **62**, 397) and a full analysis has been made of components of malting quality. In addition, a number of small-scale tests, including the sedimentation test (Palmer, *J. Inst. Brew.*, **81**, 71), the rate of water uptake, nitrogen content, β-glucan content and milling energy, have been made on the raw grain. Field characters including yield have also been recorded. The data have only received preliminary analysis so far, but indicate that the best predictions of malting quality would be obtained from the measurement of milling energy and β-glucan content.

In 1976 collaborative physiological studies which could help the plant breeder to understand barley development were instituted. The first experiment, with Dr E. J. M. Kirby of the PBI, was an investigation of differences in development of two morphologically distinct short-strawed varieties, Maris Mink and Golden Promise, under English and Scottish growing conditions. Preliminary analysis has indicated interesting differences in the development of primordia in the two varieties under the different environments and studies are being continued for a further season. The second experiment, with Dr S. Matthews and Mr E. J. Thomson of Stirling University, was a study of day-length sensitivity and its effect on apical development. In a series of field experiments and in glasshouse studies under different photoperiods a range of responses has been detected. Further experiments, concentrating on Golden Promise and Clipper which represented the extremes of this range, are being planned for 1977.

Plant breeders at the Station now have a number of years experience in the use of composite cross populations in which natural selection alone has been allowed to operate. These populations did not contain male-sterility genes but estimates of out-crossing indicated that considerable recombination occurred in most seasons (*Annual Report 1974-75: 7-8* and *75-76: 10*). It has become apparent that, at least under Scottish conditions, further use of composite cross techniques will require the application of appropriate artificial selection pressures to correct a number of basic deficiencies in the various populations available. The most obvious deficiencies include the survival of tall genotypes and the generally unsatisfactory disease-resistance of the populations. In consequence, investigations of methods of applying mass selection have been undertaken. Selection for disease resistance is a complex problem and is still under discussion but selection against excessive height is more straightforward. In 1976 eight F_3 populations, each segregating for one of several recessive dwarfing genes, were trimmed to a desirable height at the milky ripe stage. The populations were sown at high plant density to restrict tillering which might allow tall genotypes to produce compensating tillers. In addition, sources of tolerance of acid growing conditions (*Annual Report 1975-76: 9*) which were incorporated in separate composite cross populations have been multiplied for pH screening in 1977. Attempts to screen under natural low pH conditions in 1976 at Penicuik, Midlothian, were not successful and an alternative site at West Byres Farm, East Lothian, has been chosen for use in 1977.

Work has continued on the barley collection, both in recording field observations and in coding the available information to incorporate it in the computer-based data bank EXIR, an improved and amended form of TAXIR. When the available data are encoded and filed it will be possible to investigate the potential of this system for plant breeders. The barley collection has again increased, this year by 950 entries to a total of 2,600.

A. M. Hayter, R. J. Giles, R. P. Ellis, M. S. Phillips, J. E. Bradshaw, J. S. Swanston

Barley Biochemistry (ARC 2)

Mutants of Maris Mink selected by means of a biochemical screening system were assessed in small trials. Other systems, including the use of various forms of β-amylase for the production of high diastaste barleys, are also being investigated.

SELECTION FOR HIGH DIASTASE IN ADAPTED VARIETIES

Five abscisic acid resistant mutants of Maris Mink, M20, M22, M23, M30 and M39, selected for increased diastatic power (DP), were grown with standard varieties in small replicated trials. Results from micromalting tests on the trial material show that only two lines, M22 and M23, consistently have a higher DP than does Maris Mink.

Mutant 23 has two dwarfing genes, one causing a prostrate habit during seedling growth and the other an erectoides-type growth at later stages. In addition to its diastatic activity, this mutant has milling properties (low electrical energy required for milling) typical of barleys which malt readily. Unfortunately, M23 yields poorly compared with Maris Mink, but it can still serve in the breeding programme as a source of dwarfing genes, intermediate diastatic power and an endosperm character favourable for malting.

Mutant 22 also is shorter than Maris Mink, but its yields are comparable to those of the parent. This line also produces intermediate levels of DP (210° Linter) when growing conditions favour high grain nitrogen (2 per cent or more).

The other three mutants had variable DP when examined in a number of experiments. One line was resistant to *Rhynchosporium secalis* in a lightly infected trial, and is to be tested further in the disease nurseries in Wales.

There is a possibility that high diastase barleys may have an altered amino acid balance because diastase enzymes are found in the lysine-rich protein fractions. High DP types may therefore have high grain lysine contents. It is also possible that selection for high lysine may raise the DP. Micromalting tests on five high lysine mutants from the Risø Research Establishment in Denmark have shown that one line, R56, has a high diastatic activity even at low grain nitrogen levels. Amylase activities of the other Risø mutants varied over a wide range and thus it seems that increasing grain lysine content also alters certain enzymic properties.

M. J. Allison

ENZYME ACTIVITY IN RELATION TO ELECTROPHORETIC PATTERNS

The work on isoenzymes of α- and β-amylase continued. The effect on β-amylase, associated with the appropriate locus, which was reported last year (*Annual Report 1975-76:* 8), has been confirmed in other crosses. The advantage conferred appears to be an increase in β-amylase activity over that of other lines with the same level of grain nitrogen. Thirty lines from each of two crosses have been examined both for enzyme activity and for electrophoretic pattern in respect of α-amylase. The results obtained have not indicated a relationship between the two characters. Very high levels of β-amylase, considerably in excess of that of either parent, were observed in some lines from a cross between the two varieties Akka and Feebar which are both high in diastatic power. These lines have now been incorporated into the appropriate breeding programme in an attempt to transfer these useful enzyme properties into a better adapted background.

J. S. Swanston

Barley Breeding (ARC 3)

Progress is reported on the high diastase, general purpose (feeding) and malting quality breeding programmes. The production of acid tolerant varieties is discussed. The use in the breeding programmes of generalised lattice trial designs, small-scale malting tests, disease nurseries, single seed descent, Hordeum bulbosum *(to induce haploidy) and the value of "out of season" breeding in New Zealand are discussed.*

Chronologically, the first objectives chosen for barley breeding were the production of high diastase and general purpose (feeding) varieties, using conventional pedigree breeding methods together with back-crossing of genotypes containing the high-amylose allele, first detected in the variety Glacier (Pentlandfield) (*Annual Report 1967-68:* 13), into adapted two-row backgrounds. More recently, additional objectives have been set, particularly the production of malting quality varieties. Some attention has also been given to the possibilities of producing varieties tolerant of acid soil conditions. In 1976, four general purpose F_6 selections from the cross Hassan × Universe were multiplied to produce pure stocks. At F_5, sixteen general purpose selections, from a number of crosses, were retained for further trials. A number of F_7, F_6 and F_5 lines from the high diastase programme have also been retained. In the F_4 generation classification into malting quality, high diastase or general purpose has not been completed since only preliminary tests have been made and many selections still have potential to satisfy more than one objective. More than 1,000 F_4 lines were tested in 1976 and seventy-five have been retained. In the F_2 generation more attention is being given to selection for resistance to mildew, *Rhynchosporium secalis*, yellow rust and brown rust. Mutation as a source of genetic variation has received more attention than it has in the past, and the first M_2 populations are available for sowing in 1977.

A particular problem, encountered at F_4 under our breeding system but felt at some stage by most breeders, is that of growing large numbers of selections in preliminary yield trials. The large numbers themselves pose certain problems in finding sufficiently large uniform areas of land. In addition, only small quantities of seed are available, allowing only one or two replications of selected lines to be sown. In collaboration with the ARC Unit of Statistics, investigations are continuing into the use of a class of trial designs, termed generalised lattices, which may help to overcome some of these problems. Generalised lattices permit block effects to be calculated, allowing corrections to be made for variation in one direction within a replication. They therefore belong to a larger class of designs, termed partially balanced incomplete blocks and have two important advantages to the breeder. First (and not uniquely), different levels of replication of control varieties and selections are possible, so that scarcity of seed supplies does not limit the replication of controls. Second, and more important, designs of greater or lesser efficiency are available for any number of entries. These designs therefore offer considerably greater flexibility than is available from the use of comparable designs such as balanced lattices. If adjustments were possible for block effects in two directions the designs would also have advantages over lattice squares. In 1976 four trials containing a total of approximately 1,200 entries were grown at The Murrays and initial results were sufficiently encouraging for further evaluation to be continued in 1977 at F_4 and F_5.

One F_4 trial in 1976 was derived from F_3 rows grown during the European winter at Gore, New Zealand, in co-operation with the Department of Scientific and Industrial Research. This co-operative arrangement is now in its fourth year and for the second year a visiting plant breeder, this year Dr R. P. Ellis, has been sent to record field characteristics and to harvest the selected material. This season F_3, F_4 and F_5 generations have been sent to evaluate a number of methods of using this valuable arrangement.

A number of small-scale malting tests, often using milled grain samples, have been investigated since the introduction of malting quality as a breeding objective. Of these, several were applied to selections from trials at F_4 and later generations as a routine. These included the estimation of β-glucan and β-amylase contents. Other tests, for example the sedimentation test and the milling energy test, are still being investigated. The latter test has considerable potential but the development of suitable equipment to apply it to large numbers of samples has so far prevented its application in the malting quality programme.

Among the Scottish cereal crops, barley is the least tolerant of acid growing conditions. For this reason development of composite cross populations with acid tolerance has continued both as a breeding objective and a research project. A series of crosses, commenced in 1974, has enabled populations to be constructed containing both male-sterility genes and sources of acid tolerance identified both from the barley collection and from published data. Seed collected from male-sterile plants in the field in 1976 was multiplied over winter in the glasshouse for sowing in 1977. This cycle can be repeated as many times as necessary. In each field-grown generation seed from fertile plants can be screened for acid tolerance. With artificial selection pressure for agronomic characters it should be possible to select acid tolerance in suitably adapted lines, which can be used either as parents or as varieties *per se*.

Mildew (*Erysiphe graminis*) was again widespread in 1976 and all of the breeding material was scored for resistance. Varieties in mildew resistance groups R2, R3 and R5 now appear to be susceptible to Scottish populations of *E. graminis* while varieties in groups R4, R6, R7 and R5* (=R5 plus R2) still appear to be resistant. Work on the exploitation of major-gene resistance must reflect this situation. The occurrence of scald (*Rhynchosporium secalis*) was sporadic and only at one trial site, Rossie, was a reliable estimation of susceptibility possible. It was apparent at Rossie that selections with prostrate early growth were severely attacked. However, in nursery tests at Aberystwyth it was clear that the more erect types were equally susceptible to damage if they became infected. One of the more important properties of the *erectoides* dwarfing genes may, therefore, be an escape mechanism preventing or delaying the development of the disease. Yellow rust (*Puccinia striiformis*) appeared in isolated foci of infection during late June at The Murrays but did not spread, probably due to the exceptional hot, dry weather. A low level of brown rust (*Puccinia hordei*) infection in early July did not increase during the season. The sporadic nature in Scotland of all diseases with the exception of mildew has required the development of special nurseries of breeding material at F_4 and later generations to test disease susceptibility. The whole question of strategies and methods of breeding for disease resistance is under active review.

Existing methods of cereal breeding usually require nine or more years to produce a stock ready to submit for official testing. This is costly in terms of land and labour resources. There is, therefore, considerable interest in techniques which are more efficient in saving time or space. Two such techniques are being investigated, single seed descent and the use of *Hordeum bulbosum* to induce haploidy. Each can be used at various stages in breeding programmes (*a*) to allow selection without the complications of extreme heterozygosity or (*b*) to increase the probability that lines multiplied for testing are more homozygous than would otherwise be the case. Both would allow considerable savings of time and increases in efficiency to be made when they are available as routine techniques. It is a pleasure to acknowledge the help of WPBS in providing technical training in the use of *H. bulbosum* for the induction of haploidy.

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R. P. Ellis J. S. Swanston
J. E. Bradshaw

Oat Breeding (ARC 4)

Progress is reported of oat entries already submitted, or about to be submitted, for National List Trials together with material in earlier stages of the breeding programme. Investigations of the effects of natural selection on composite cross populations are discussed.

Of the three oat selections which completed National List Trials (NLT) and Plant Variety Rights (PVR) testing in 1976, two, Leven and Etive, have continued to perform well. The third, Arkle, has been withdrawn as it was not distinct from Etive and performed marginally less well. Leven and Etive have been accepted for inclusion in Scottish Recommended List Trials in 1977 and the latter has also been included in the equivalent trials in England and Wales. Etive appears to have a low milling energy requirement as measured by the use of whole grain samples in a small-scale test and may have potential as a milling quality oat (see Chemistry Laboratory report). Two lines, Aa

758 and Aa 760, both as yet un-named, have been entered for NLT and PVR testing in 1977.

At an earlier stage in the breeding programme, 240 selections from the A69 composite cross populations were entered in yield trials in 1976, using

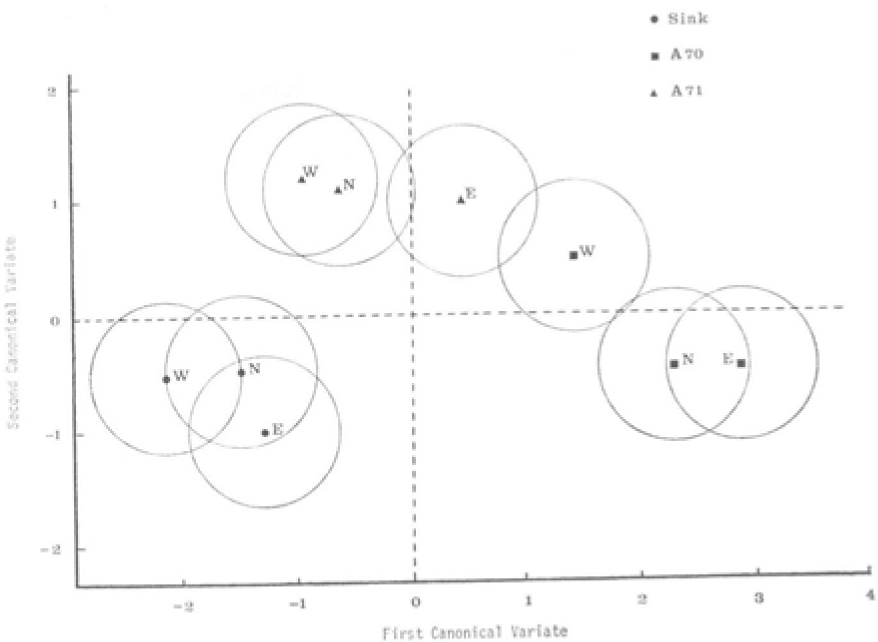

Figure 1: Canonical diagram for nine oat composite cross populations
Circles represent confidence limits P < 0·1
Key: E = East, N = North, W = West

generalised lattice designs (see Barley breeding, ARC 3). The performance of most lines was disappointing and only six have been retained for further trials. Forty-five single-plant selections with short straw and acceptable mildew resistance have been retained from the A70 composites. These will be evaluated in progeny plots in 1977. A number of lines with resistance to oat stem eelworm (*Ditylenchus dipsaci*), derived from *Avena ludoviciana* by back-crossing, have continued to show good yields combined with short straw, medium maturity and good mildew resistance.

Investigations of the effects of natural selection on composite cross populations have been extended to oat populations. In 1965 a number of F_1's between commercial cultivars were crossed with material from the museum collections to produce a composite cross population designated A65. Some of the F_1 plants of this composite were crossed again to an augmented museum collection to produce a second population, A66. This cycle was repeated annually until 1974. All populations were grown from F_3 to F_6 at three widely separated sites in the north, east and west of Scotland, and at each site a "Sink" population was derived as a mixture of A65 to A69 material after selection had been made at F_6. In 1976 nine populations, being the A70, A71 and "Sink" populations from each of the three sites, were compared at The Murrays. The A70 populations were then at F_6, A71 at F_5, while the "Sink" populations contained material from F_9 to F_{13}.

Six variates were measured; ear-emergence, mildew reaction, height, lodging, yield and thousand-corn weight. Canonical analysis of the standardised data indicated three significant canonical variates. The first two ($p<0{\cdot}01$) accounted for 90·7 per cent of the variation while the third ($p<0{\cdot}1$) accounted for a further 6·9 per cent. The spacial relationships of the nine populations are shown in Figure 1 which is a plot of the first two canonical variates. Three groups, corresponding to source populations "Sink", A70 and A71 are apparent. Differences due to sites of selection within populations were relatively smaller, the effects of natural selection thus appearing to be similar at each site suggesting that the use of three sites may be unnecessary.

A. M. Hayter, M. S. Phillips
R. P. Ellis, J. S. Swanston
J. E. Bradshaw

Studies of Swede Hybrids (ARC 5)

The purpose of this project is the identification of high-yielding F_1 hybrid swedes and the development of a method by which F_1 hybrid seed can be produced on a commercial scale.

SELF-INCOMPATIBILITY

Self-incompatibility is being introduced into swedes to promote out-crossing. Tests have shown that at least eight S-alleles are involved while another three were not completely cross-checked. All these alleles produced a high degree of self-incompatibility when homozygous and most appear to do so when heterozygous.

Thirty-four backcross lines, involving seven swede cultivars, were tested this year and twenty-eight have been carried on, mainly by further back-crossing. Three lines, previously backcrossed four times, were selfed as were nine plants of earlier generations which had large well-shaped bulbs.

F_1 HYBRIDS PRODUCED BY HAND POLLINATION

Forty-one F_1 hybrids from crosses between single plants of different cultivars were grown in transplant trials. These involved two incomplete seven × seven diallels and other material produced previously, including the four top-yielding hybrids from the 1975 trial. Three hybrids were significantly higher yielding than the best control cultivar ($p<0.05$) giving 30, 38 and 49 per cent more dry matter yield, and the best hybrid was 78 per cent superior to its highest yielding parent.

HYBRID PRODUCTION USING SELF-INCOMPATIBILITY

To examine the amount and effect of outcrossing produced by a single S-allele when homozygous or heterozygous, five swede cultivars were isolated with the self-incompatible swede APZ and with APZ × Parkside in insect cages, and trials were sown at The Murrays and Boghall (ESCA) with seed from the self-incompatible parents. The progenies involving APZ × Parkside were inferior to the higher-yielding parental cultivars but four APZ progenies were higher yielding, although not significantly so ($p>0.05$). There was a highly significant site interaction, with the best hybrid being 20 per cent higher yielding than the best control (Criffel) at The Murrays but 2 per cent lower than the best at Boghall (Bangholm Ruta Øtofte).

One of the cultivars paired with the yellow fleshed APZ was white fleshed and a scoring of the progeny indicated 97 per cent outcrossing which is similar to results previously obtained using APZ (Gowers, *Euphytica* **23**, 205–8). Calculations for the pairings of APZ × Parkside with other varieties gave estimates ranging from 16 to 61 per cent outcrossing, indicating that the S-allele concerned is not sufficiently effective when heterozygous. However, it appears that stronger alleles are available.

ESTABLISHMENT METHODS

Four methods of field-establishment were compared with machine drilling, using an inbred line derived from Champion. These were: transplanting from paper "honeycomb" pots (20 mm × 125 mm), 45 mm peat pots, or from seed-boxes, or pricking out germinated seed. They gave lower stands than the control, but yield compensation was effective except for the paper pot method (Table 1).

TABLE 1

A comparison of various methods of establishing swedes in the field

	Planting out from		*Pricking out*		*Machine*	
	Paper pots	*Peat pots*	*Seedlings*	*Germinated seed*	*drilling*	*S.E.*
Plants/plot	76·0	92·0	99·0	83·5	113·5	± 5·5
Fresh weight yield, kg/plot	54·5	64·5	64·5	69·0	67·5	± 3·5

SWEDE × TURNIP HYBRIDS

A batch of putative hybrids between an S-allele stubble turnip and an S-allele swede (APZ) had satisfactory yield and quality, but exact assessment was difficult because of the frequency of plants which had been derived by selfing. Chromosome counts showed that about 70 per cent of the plants were in fact allotriploid, and this was confirmed in the field.

S. Gowers

Swede Breeding (ARC 6)

High-yielding lines are being sought by inbreeding both within present varieties and in progenies obtained by crossing cultivars. Several promising lines have been obtained and two are being multiplied for pre-basic seed.

INBRED LINES FROM INTER-CULTIVAR CROSSES

The main objective of this programme is the production of a cultivar, suitable for mechanical harvesting, to replace Pentland Harvester. A replacement should be of higher dry matter content and without the extreme susceptibility of Pentland Harvester to boron deficiency.

Of 112 F_5 and twelve F_4 inbred lines from crosses involving Pentland Harvester, tested against six controls, four outyielded the highest-yielding control in corrected dry weight while a further nine outyielded the second control. The top-yielding twenty have been retained, plus another which showed very good field tolerance to mildew.

In trials at The Murrays and at Cockle Park, Northumberland, of fifteen multiplications from F_4 inbreds (with five controls) two showed promise. One is a green skinned type from a cross between Bangholm Wilby and Gullacker while the other is a purple-skin from the cross Bangholm Wilby × Wilhelmsburger Danila. The green-skinned line was the highest yielder at both sites while the purple-skinned one was second highest at The Murrays and third highest at Cockle Park. Both have good mildew tolerance and uniformity. Seed of each has been sent to New Zealand for multiplication.

Other inbred material from crosses of high dry matter swedes, mainly Bangholms and Wilhelmsburgers, was selfed to give the next generation—some F_5 and some F_6. The best mildew resisters from the 1975 trial were also selfed.

Isabel K. Munro

INBREEDING WITHIN CULTIVARS

High yielding lines are being sought among inbreds of commercial cultivars. Selections have been made from the four highest-yielding lines and the two with the highest dry-matter percentage derived from the cultivar Scotia. Plants have been "bag-selfed" again, and the highest yielding family was also multiplied in an insect cage for trial in 1977.

Lines obtained by selfing two other varieties showed considerable variation in yield, morphology, and mildew resistance, with dry matter yields varying by more than 20 per cent above and below the mean in both batches. To examine the effect of selection, lines with high and low yield characters have been retained for another generation of selfing.

The amount of self-pollination in the field was assessed using skin colour as a marker. Three varieties showed between 82 and 84 per cent selfing but a fourth showed only 57 per cent.

S. Gowers

Kale Improvement (ARC 8)

An outbreeding population of kale consisting of families selected on the performance of collateral relatives in yield trials, continues to show a useful response to selection. Samples extracted from this population have performed well in more extensive trials.

The trial of single-plant polycross progenies produced in 1975 (*Annual Report 1975-76:* 12) grew well despite the dry conditions and was harvested as planned in December 1976. Preliminary analyses of fresh weight and dry weight are encouraging (Table 2). However, the primary selection criterion is digestible dry matter yield and, as qualitative analyses are incomplete, the response to selection for this trait cannot yet be estimated.

TABLE 2

Yields (DM, t ha^{-1}) of a polycross breeding population of kale and of controls

		Polycross populations		
Year	*Controls*	*Generation*	*Yield*	*% of controls*
1972	5·8 ± 1·1	S_0	6·3 ± 1·5	109
1974	6·3 ± 1·0	S_1	7·8 ± 1·1	124
1976	7·0 ± 1·0	S_2	9·1 ± 1·1	130

The apparent improvement in yield of our standard controls (Maris Kestrel and Canson) over the years probably reflects an improvement in our trial expertise and the apparently dramatic (44 per cent) increase in dry matter production in our breeding population (S_2) over the base population (S_0) must therefore be interpreted with caution. An experiment to investigate this further is planned for 1977 using residual seed of S_0, S_1 and S_2. Families chosen when the qualitative data are available will be seeded in an isolation cage to produce the next generation (S_3) for trial in 1978.

Selected families bulked in 1975 (*Annual Report 1975-76: 12*) performed well in trials at two sites. Qualitative analyses are not yet available but all five equalled, or significantly out-yielded, the control cultivar Maris Kestrel in dry matter production.

Seed has been produced from selections of the reciprocal recurrent selection programme (*Annual Report 1975-76: 12*) for agronomic assessment in 1977 and to provide plants for the next round of crossing in 1978.

G. R. Mackay

Exploitation of Inter-specific Crosses as Possible Rape Substitutes or as New Forage Species (ARC 9)

Several new artificial forms of rape were produced by means of embryo culture. The development of semi-artificial rapes has resulted in some promising leafy lines. The commercial exploitation of inter-specific hybrids between turnip and rape does not seem as practicable as hitherto but the production of self-incompatible rape lines shows promise for the development of vigorous hybrid rapes.

BRASSICA OLERACEA × *B. CAMPESTRIS* HYBRIDS

Brassica napus (2n = 38, genomic formula *aacc*) is a naturally occurring (probably rare) hybrid derivative of *B. oleracea* (2n = 18, *cc*) and *B. campestris* (2n = 20, *aa*). The programme for artificially re-synthesising the species is intended to widen the range of material available for future rape and swede breeding. The main objectives are the introduction of a higher degree of *Plasmodiophora brassicae* (club-root) resistance into swedes and rape, and an increase in stem acceptability in rape.

Artificially synthesised *B. napus* plants, produced in 1975 by embryo culture, were selfed (haploids were treated with colchicine first). They were also crossed to natural *B. napus* to give semi-artificial *B. napus*. Self-fertility of the artificials was generally poor, including those derived by crossing tetraploids, but nineteen artificial and sixty-one semi-artificial *B. napus* lines were obtained.

A major effort to obtain crosses involving colchicined *B. campestris* plants resistant to *P. brassicae*, which were poor pollen donors, gave a few hybrids which are expected to show the same high degree of resistance as the turnip parent (see ARC 29).

We now have a range of artificial *B. napus* plants (F_1 and F_2) with marrow-stem kale parentage. They are expected to have better stem acceptability than existing rapes, but crosses between them and rape cultivars have not yet produced sufficient seed for the field evaluation of stem type.

A range of botanical varieties of *B. oleracea* are being crossed with several sub-species of *B. campestris* to provide material for a biosystematic study of novel *B. napus* types and a gene pool for breeding purposes.

C. L. Snell

DEVELOPMENT OF SEMI-ARTIFICIAL RAPES AND CATCH-CROPS

Seven F_4 bulks, developed from crosses between artificial rapes and the cultivar Nevin, were compared with seven leading UK and Continental rapes in a trial at The Murrays. The artificial rapes were originally obtained by embryo culture carried out by D. Harberd of Leeds University, following crossing between tetraploids of *B. oleracea* and *B. campestris* (*Annual Report 1969–70:* 19). The semi-artificial rapes were leafier but lower in dry matter (DM) yield than the giant rapes Canard, Lair and Emerald. They were superior to Nevin, Silona and Samo.

Three of the semi-artificial rapes were compared with leading commercial cultivars in trials at Ayr and at The Murrays, and two were included in a two-sowing-date experiment carried out by ESCA. Results were somewhat variable but the most promising semi-artificial produced average DM yields slightly below the highest yielding cultivar. They were somewhat susceptible to powdery mildew (*Erysiphe cruciferarum*). Sixty-seven F_4 single plant progenies were grown on for possible seed production, selection being based on results of the above trials as well as on visual differences between progenies.

F_2 seed has been obtained from crosses between the low glucosinolate cultivar Samo and higher-yielding semi-artificial rapes. The Chemistry Department is attempting to develop an assay method suitable for screening segregating material for glucosinolates at the seedling stage.

In 1975 a single allotriploid hybrid between diploid *B. campestris* (a leafy stubble-turnip) and tetraploid *B. oleracea* (marrow-stem kale) was obtained without embryo culture. It was crossed with various forms of *B. napus* (rape), giving progenies which varied in chromosome number (2n) from thirty-two to forty-six and showed wide variation in habit and leaf form. The majority of the plants were bud-selfed and seed was also obtained from uncontrolled, open pollinations. Setting appeared to be unrelated to chromosome number and was generally low. Two $2n = 37$ plants set seed, one in four of which should give rise to $2n = 38$ plants, *i.e.* semi-artificial *B. napus* (assuming all chromosomes possess homologues). Such a complex method of introducing new variation into *B. napus* is only of academic interest in view of the success in producing new forms directly by means of embryo culture.

A collection of eighty-four oriental forms of *B. campestris* (Chinese cabbage, Chinese mustards, etc.) was examined, as late sown transplants, for vigour, lack of premature flowering, etc., in a search for suitable parents for breeding of catch crops within *B. campestris* and for use in the production of artificial *B. napus*. There appeared to be some promising material in this collection, most of which was obtained from The Botanic Garden at Gatersleben in the German Democratic Republic (DDR).

Two leafy tetraploid forms of *B. campestris*, Appin and Ballater, were compared in trials with rape, stubble-turnip and fodder radish cultivars. DM yields from early August sowings were similar to those of stubble-turnips. At one site Ballater was top in yield but the advantage over the stubble-turnips (Civasto and Ponda) was not significant.

Selections have been made from late sown crosses of Appin with tetraploid stubble-turnips, Marco and Taronda, with a view to producing improved leafy stubble-turnips with better root anchorage, thus facilitating grazing and reducing bulb wastage.

I. H. McNaughton

TURNIP (*B. CAMPESTRIS*) × RAPE (*B. NAPUS*) HYBRIDS

The inbred lines of turnip which are homozygous for their S-alleles (*Annual Report 1975–76*: 13) continue to present serious problems of maintenance and multiplication. They suffer severely from inbreeding depression and their seed fertility is markedly reduced. One line produced no viable seed in 1976 and is now extinct. Four additional S-allele homozygotes were, however, isolated from F_1 hybrid cultivars. Samples of seven out of the sixteen extant S-allele stocks were sown in the autumn for the production of F_1 hybrids in 1977. Additional samples of all sixteen lines and F_1's produced from them, by hand pollination, were also sown for further studies on the dominance relationships between S-alleles.

The results of the trial of eight progenies produced from two rape cultivar pollen donors and four F_1 turnips (*Annual Report 1975–76*: 14) were disappointing. The frequency of hybrids ($2n = 29$, *aac*) was low (<60 per cent in every case), suggesting that the S-alleles in these particular turnip lines were too weak. The hybrids grew well in the trial but their vigour was insufficient to compensate for the high proportion of turnip sibs. None of the progenies was significantly higher yielding than the controls and five were lower yielding.

Additional F_1 turnips produced in quantity in 1975 (*Annual Report 1975–76*: 14) were sown in observation plots. As far as could be ascertained on morphological characteristics these F_1's contained no sibs and are therefore expected to act as better seed parents in the inter-specific cross. They were sown, with rape pollen donors, in isolation plots (80 m^2) in late August. It is hoped that they will produce hybrid ($2n = 29$, *aac*) seed, under conditions more akin to commercial practice than in insect cages, in quantities sufficient for trials at several sites in 1978.

The breeding of agronomically acceptable, self-incompatible (s.i.) rapes by backcrossing s.i. lines to good cultivars continues very successfully. Of the twenty-six lines in trial in 1976 (*Annual Report 1975-76*: 14) eight outyielded and eleven were equal in yield to their recurrent parent cultivars and further backcrossing is therefore considered unnecessary. The progenies produced by bud-selfing s.i. plants of these lines were sown in autumn to permit the isolation of S-allele homozygotes in 1977-78. In addition to facilitating the production of inter-specific hybrids with turnip, this s.i. material will be useful in its own right. It can be used to produce F_1 and/or more complex hybrid rape varieties and thus exploit the reported heterosis in this normally self-fertile crop (Johnston, *Euphytica* **20**: 81-85). The semi-artificial s.i. rapes bred by crossing and backcrossing turnips to rape (Fig. 2) (*Annual Report 1975-76*: 14) proved fully fertile on selfing and on crossing with true *B. napus*. Of twelve such plants eight proved self-incompatible and have been bud-selfed to isolate the S-allele homozygotes. Additional backcrosses between hybrids (2n = 29, *aac*) and rape were made and studies on this material continue (see report of the Cytology Laboratory).

G. R. Mackay

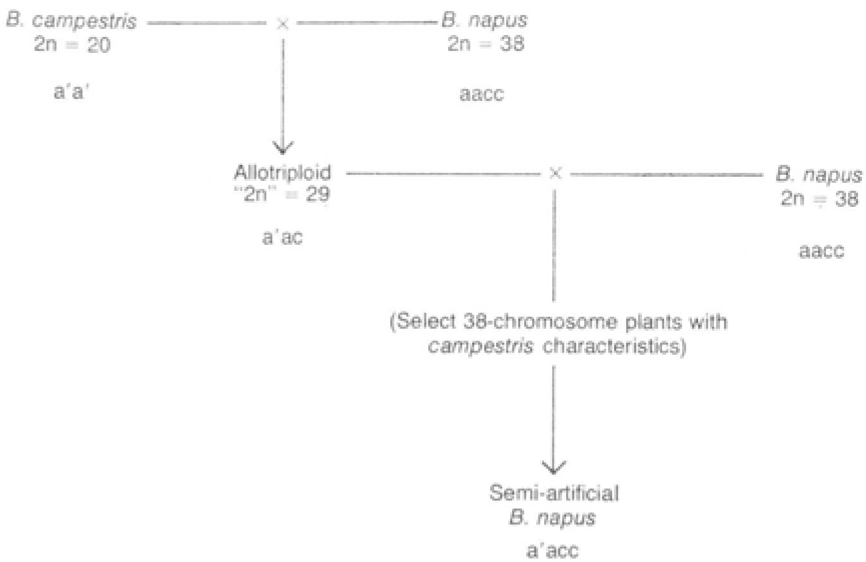

Fig. 2. Introgression from *Brassica campestris* into *B. napus* via the allotriploid hybrid.

Raphanobrassica—An Inter-generic Hybrid Species as a Club-Root Resistant Alternative to Rape (ARC 10)

Raphanobrassica *continues to show promise with regard to dry matter yield, in comparison with rape, as well as showing high resistance to* Plasmodiophora brassicae (*club-root*) and Erysiphe cruciferarum (*powdery mildew*). *Improvement in seed fertility has resulted in sufficient seed being available for comprehensive trials throughout the UK in 1977.*

Raphanobrassica is an allotetraploid (2n = 36, genomic formula *rrcc*), derived from radish (*Raphanus sativus* 2n = 18, *rr*) and from various forms of *Brassica oleracea* (2n = 18, *cc*), *e.g.* kales, cabbages, cauliflower, Brussels sprouts and kohl-rabi. It constitutes a new crop, neither kale nor rape, for which the common name "radicole" is proposed.

It is possible to create a wide range of morphologically different forms of radicole. Those now at the testing stage are based on crosses, first made at SPBS in 1968, using mainly colchicine-induced autotetraploid forms of commercial fodder radishes and of thousand-head and curly kales.

Radicoles produced more recently have marrow-stem kale in their parentage; these have been grown as transplants and appear, visually, to have greater potential than the earlier-produced material in being more vigorous and larger leaved. Lack of stem edibility, leading to wastage on grazing, has always been a problem with rape. Radicoles based on marrow-stem kale parents with highly edible stems, *e.g.* Maris Kestrel, could provide the answer to this problem.

TRIAL RESULTS

Seed of an F_6 radicole population (coded RB4/B) was distributed for trials and observations at a number of sites throughout the UK. In trials carried out by SPBS Trials Unit at The Murrays and at Yonderton Farm near Ayr, RB4/B was compared with the three highest yielding rapes on the NIAB List of Recommended Varieties, Canard, Emerald and Lair, and also with Nevin. The results (Table 3) were very promising.

TABLE 3

Dry matter yields of *Raphanobrassica* RB4/B and rape controls in two trials

	The Murrays		Ayr	
	Kg/plot	*% of Lair*	*Kg/plot*	*% of Lair*
Raphanobrassica	6·72	131·7	6·23	107·8
Rape controls:				
Lair	5·10	(100·0)	5·78	(100·0)
Emerald	5·40	106·0	6·03	104·3
Canard	5·31	104·1	6·48	112·1
Nevin	4·23	83·1	4·83	83·6
L.S.D. ($p = 0·05$)	0·75		0·89	

The plots of RB4/B at Ayr had poor stands, which may explain its less markedly superior performance.

In a trial conducted by ESCA, RB4/B outyielded Lair rape by 28 per cent from a late June sowing, but from a late July sowing Lair was superior by 14 per cent.

The above results indicate the great potential of radicole already shown in 1975 trials but also confirm its unsuitability for late sowing. The material in 1976 trials was essentially similar to that included in 1975 experiments (RB4/A), the basic difference being that the latter was from seed produced "out of season" in New Zealand, whilst the former was produced at Cambridge by NSDO.

Over 50 kg of radicole seed was produced during 1976 by NSDO and will be used entirely for agronomic experimentation. Small plot trials are being arranged at a number of sites throughout the UK, in conjunction with the Scottish Colleges of Agriculture and ADAS. It is hoped to assess live weight gain of sheep in large plot trials at two or three sites. Previous observations have not indicated any problems of acceptability. The RRI have undertaken to investigate levels of SMCO (a haemolytic anaemia factor affecting cattle) during 1977.

ADDITIONAL SELECTIONS

The yields of nineteen F_6 breeding lines, the four rape controls mentioned above, and RB4/A and RB4/B were compared. Each line was the progeny of a highly fertile F_5 plant (yielding 20 to 60 g seed). Because of acute seed fertility problems in earlier generations, this was the first occasion on which breeding material could be compared in a replicated, drilled experiment; selection had previously been based on visual assessment of transplants.

RB/4A, RB4/B and eighteen out of the nineteen lines were superior in fresh weight to the highest yielding rape (Lair), fifteen lines significantly so ($P<0{\cdot}05$), the best being 46 per cent superior. Dry matter contents were, in most instances, significantly lower than those of the rapes, mean DM percentages for radicoles ranging from 10·0 to 11·8 and for rapes from 12·7 to 14·4. Twelve radicole lines were superior to the best rape in dry matter yield, three of them significantly so.

Several F_6 lines were superior in yield and uniformity to RB4/A and RB4/B, although none was as uniform as a typical rape cultivar.

Nevin was included as a control because of its relatively high degree of resistance to *P. brassicae*, other rape cultivars being highly susceptible. All radicole lines were superior to Nevin in DM yield, the best by 68 per cent.

DISEASE RESISTANCE

Some radicole families have, in the past, shown a higher degree of resistance to *P. brassicae* than Nevin and recent experiments, conducted at NVRS, indicate even greater potential (see ARC 29).

The lines in trial in 1976 were also grown by NIAB, Cambridge, for examination of their resistance to powdery mildew. A high degree of field

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The lines in trial in 1976 were also grown by NIAB, Cambridge, for examination of their resistance to powdery mildew. A high degree of field resistance was shown in an early sown experiment; although foliage was relatively uninfected, such flowering shoots as developed showed infection. Infection was also noted by NSDO on plants grown under glass for seed production. The foliage of all radicoles sown for agronomic assessment was virtually free from powdery mildew, but some downy mildew (*Peronospora parasitica*) was noted on plants grown at The Murrays.

Turnip mosaic, cauliflower mosaic, turnip crinkle, broccoli necrotic virus and an unidentified virus infected radicole plants at Cambridge. (They were reported by NIAB to have seriously damaged a number of brassica crops in southern England.) It was considered that the increased vigour of radicoles enabled them to withstand virus attack better than the adjacent swedes and rapes.

RADISHES

Crail fodder radish, a by-product of the *Raphanobrassica* programme, performed well in trials at The Murrays and Ayr. DM yields relative to Slobolt were 102 and 119 per cent at the two sites from early harvests, and 121 and 92 per cent from late harvests. Unlike other cultivars, Crail was highly resistant to premature flowering from early July sowings. It has shown an exceptionally high degree of resistance to *P. brassicae* (see ARC 29).

Completely biennial leafy radishes are being developed as improved parents for new radicole forms; these derive from crosses between *R. sativus* and *R. maritimus* (wild sea radish). A series of new *Raphanus* × *Brassica* crosses was made in 1976, using colchicine-induced tetraploid forms of the inter-species radish hybrids and a range of tetraploid *B. oleracea* forms (thousand-head kale, marrow-stem kale and hybrids of the latter with cabbage and kohl-rabi).

I. H. McNaughton

Breeding for Resistance to *Plasmodiophora brassicae* (causing Club-root Disease) (ARC 29)

Breeding-lines of semi-artificial rape were successfully screened for resistance. Attempts are being made to introgress a very high level of resistance, from a turnip line, into swedes and rape. Some problems have been encountered with repeatability of screening tests.

Thirty-two F_4 individual plant progenies, selected from artificial rapes crossed with Nevin (see ARC 9), were examined for *P. brassicae* resistance of the "Nevin type". A number of progenies showed little or no infection while controls generally were uniformly infected. Resistant plants have been retained for selfing.

A line of stubble-turnip (*B. campestris*) known as 04, which is one of the currently-used differential host set, has proved resistant to all *P. brassicae* populations examined by SPBS and other UK workers during the past two years. Crosses have been made between this and various forage rape, oil-seed rape and swede cultivars, with a view to introgressing resistance into *B. napus* via the allotriploid hybrid. Seed setting, using *B. campestris* as female parent, was disappointingly low. This method of transferring resistance from *B. campestris* into *B. napus* will probably be discontinued in view of the successful synthesis of five hybrids (artificial *B. napus*) obtained by crossing 04 with kale (*B. oleracea*) at the tetraploid chromosome level; these crosses were facilitated by embryo culture (see ARC 9).

C_0 colchicine treated plants of 04 were used in the above crosses with kale. A small number of C_1 seeds was obtained by bud-selfing C_0 plants. A further batch of 04 seedlings has been colchicined in order to establish a tetraploid form for crossing with a wider range of tetraploid kales.

The production of *B. napus* (both rapes and swedes) with a considerably wider range of resistance to *P. brassicae* than existing commercial cultivars is almost certain in the long term.

Attempts to screen *Raphanobrassica* (radicole) families for resistance to virulent populations, infecting thirteen out of fifteen of the differential host set *i.e.* giving an ECD 21/31/31 reaction), were not successful. The control, Nevin rape, was not uniformly infected. There was strong evidence of differential loss of spore viability since all pathogenicity was not lost.

In a test carried out by NVRS, Wellesbourne, one radicole family was immune to an artificially constituted inoculum of *P. brassicae* which attacked all fifteen differential hosts (*i.e.* giving an ECD 31/31/31 reaction). Other families were highly resistant, and Crail fodder radish was immune.

In view of the appointment of a research worker at ESCA, part of whose remit is to study the nature and distribution of *P. brassicae* populations or races, no race typing work has been carried out at SPBS during the past year.

A trial for agronomic assessment by ESCA proved to be on land heavily infested with club-root. Scoring, carried out jointly by ESCA and SPBS staff, revealed less than 1 per cent infection of radicole (selection RB4/B) whilst rapes were heavily infected. Crail and Slobolt fodder radishes were immune. Appin, with only 8 per cent infection, showed a measure of resistance, whilst Ballater was more severely attacked.

I. H. McNaughton
S. Gowers

Selection for Winter Resistance in Ryegrass (ARC 12)

The mild winter of 1975-76 prevented any effective scoring for winter resistance in the progeny-testing trials of Italian ryegrass at Pentlandfield and The Murrays and these experiments, which were sown in spring 1974, were therefore grown on for a third year. All plots were cut five times during the season and received 400 kg ha^{-1} N in five approximately equal doses. Yields were not recorded at The Murrays but the Pentlandfield trial was weighed.

This trial consisted of 100 polycross progenies from ten families. Each family had been selected on the basis of winter survival in swards, and the ten full-sibs within each family for winter survival in closely planted rows. Significant differences for yield were recorded between families but not within them. Seven of the families exceeded the cultivar RvP in performance (total yield in second harvest year). A summary of the yields for 1975 and 1976 is given in Table 4.

TABLE 4

Italian ryegrass yields (DM, kg ha^{-1}) at Pentlandfield in 1975 and 1976

Family	*1975*	*1976*
Mean	14,590 ± 151	11,500 ± 127
RvP	13,850 ± 860	11,120 ± 722
Combi	15,280 ± 860	11,110 ± 722
Best family*	16,190 ± 471	12,920 ± 395
Poorest family*	13,670 ± 471	10,103 ± 395

* The same in both years.

The material was scored for winter hardiness on 14th February 1977. At that time no significant differences were detected for this character, either between or within families.

Syn II seed of an Italian ryegrass synthetic, the parents of which were selected on the basis of sward and individual winter resistance, was harvested and immediately resown in a three-hectare plot for multiplication. Seed of this material was also sown for micro-sward and spaced plant trials.

During the year the decision was taken to terminate grass breeding at the SPBS, and no new projects were started.

A theoretical investigation was made of the expected response to selection between half-sib families to allow for the effects of replication and number of plants per plot. This was extended to cover also full-sib, inbred, F_1 and "clonal" families. The results are in press.

F. J. W. England

Selection of Derivatives of Scotia Cocksfoot (ARC 13)

The object of this programme is to produce a cultivar, based on Scotia, retaining the high *D* value of that variety but with improved yield and persistence. The forty-nine selected genotypes which were included in a sixteen replication polycross (*Annual Report 1975-76*: 17) were further reduced to twenty-six by selection for uniformity of flowering time and habit of growth. A bulk sample was taken from each clone for digestibility determination fourteen days after its mean date of ear emergence. The range of *D* values recorded was from 65·6 to 70·5 with a mean of 68·2 ± 1·53. Fifteen kilogrammes of seed were harvested from this plot.

F. J. W. England

Breeding Interspecific Hybrids of *Poa* for use in Upland Pastures (ARC 14)

The five most promising third generation hybrids gave double the dry matter yield of P. pratensis *standards at a late April harvest. A method of distinguishing between apomictic and segregating families is presented and its place in the breeding programme is discussed. Results from trials examining seedling development and influence of light regimes on apomictic seed production are briefly described.*

Field performance trials of third generation hybrids following one cycle of selection will be completed in 1977. There are two lines of investigation which should lead to a more efficient use of plant material in the breeding programme: (*a*) methods of discrimination between apomictic and segregating families; (*b*) the environmental control of apomictic seed production. The problem of slow field establishment is also being investigated.

The breeding programme, which is based on the facultative apomict *Poa pratensis*, is still restricted by the need to grow unselected material to maturity in order to obtain the necessary data to distinguish predominantly apomictic from segregating progenies. Discrimination is possible from an examination of the relative magnitude of determinants from within-family variance-covariance matrices together with scatter diagrams from multivariate analyses, but these methods have so far been less successful when seedling characters are used. Separation of the two types of family makes their assessment in different field trials possible, the apomicts (as potential new cultivars) for establishment and yield, and segregating progenies (for further selection and crossing) as spaced plants for spring growth, size and habit.

Thirty-three apomictic hybrid families and nine *P. pratensis* biotypes (as standards) were planted as rows in 1974 and harvested six times in 1976 (27th April to 2nd November), samples being taken for measurement of percentage DOMD. Some of the results are summarised in Table 5. These are promising results since the main objective of the breeding programme is to produce a grass for hill sheep systems where increased pasture production is needed early and late season but where there is already surplus mid-season production.

TABLE 5

Dry matter yields (kg ha^{-1}) and per cent DOMD of apomictic hybrid *Poa* families and of *P. pratensis* controls

	Total (sum six cuts)	*First harvest*	*DOMD (first harvest)*
All hybrids	6,530	980	66·8
All *P. pratensis*	7,400	560	64·1
Five best hybrids	9,160	2,230	66·6
Best *P. pratensis*	8,550	1,020	66·8

Mrs L. Snee, while working at Pentlandfield as a sandwich student, studied seedling development in *P. pratensis* in relation to the problem of slow field establishment. The four biotypes examined showed different patterns in rate of development and in relative proportions of leaves, aerial tillers, rhizomes and roots. At the final harvest, fifteen weeks after germination, the biotypes with the greatest rhizome dry weight (rhizomes 11·8 per cent of total) had the lowest total plant dry weight and the lowest absolute growth rate. It seems likely that early production of rhizomes is one factor which may hinder rapid establishment.

The influence of different light regimes during inflorescence development on apomictic seed production was examined in one *P. ampla*, three *P. pratensis* and eleven hybrid biotypes. Both photoperiod and total daily irradiance affected seedling characters and variability in resulting progenies. The direction and magnitude of the response differed between *P. pratensis* biotypes and between hybrids.

Cynthia J. Williamson

POTATO DEPARTMENT

Breeding Commercial Potato Varieties (ARC 16)

Steady progress was maintained in 1976 in the breeding and selection of potential commercial varieties. Much of the material now under selection has been bred for resistance to a range of pathogens. Five clones were selected from the second year of regional trials (M_4) for inclusion in replicated trials at four centres in 1977. Regional trials of first-early clones support observations of previous years on the superiority of three selections over controls. The programme for breeding high specific gravity clones for processing purposes which is based at The Murrays has been seriously affected by the epidemic of leafroll virus in East Lothian. The NIAB has given the new SPBS variety Croft a provisional recommendation for general use.

THE 1976 CROSSING PROGRAMME

There were four components in the 1976 crossing programme.

(1) High specific gravity clones for specialised crisping purposes. Seventeen sister clones of tested crisping quality, with resistance to *Phoma exigua* var. *foveata* (gangrene), and with possible virus resistance were crossed with a range of named varieties selected for these three chacraters. Virus resistance has become of particular importance in this material in order that it may survive the challenge of leafroll and virus Y infection at The Murrays where both viruses are now prevalent. Good keeping quality, of which gangrene resistance is one aspect, is especially necessary in a crisping variety.

(2) First-early breeding. Some twelve early clones were inter-crossed. A number of them are resistant to potato cyst eelworm *Globodera rostochiensis*, some also to *G. pallida*. Clone 8906ab(11), itself in regional assessment trials, was used for the first time as a parent.

(3) Potato cyst eelworm resistance breeding. A group of clones with Andigena-derived resistance were intercrossed; they derive from material supplied originally by PBI, Cambridge. This material carries resistance to *G. rostochiensis* and *G. pallida* due to genes H_1 and H_3 respectively (see ARC 25).

(4) Widening the genetic base of the Tuberosum breeding programme. Previously untried clones selected from the Neo-Tuberosum programme were intercrossed with a group of well-established Tuberosum parents. These are regarded as speculative test-crosses for the assessment of the breeding value of these Neo-Tuberosum clones (see ARC 21).

The first field planting of material bred specifically for crisping quality was made in 1972 and, of this first wave, forty-eight clones remained in 1976 and were included in the first year of the regional trials. It became apparent, however, that forty-three of them were infected, to varying degrees, with leafroll. This involuntary loss of valuable advanced breeding material is unacceptable but such losses are unfortunately typical of this material which, since the principal selection criterion is high specific gravity, has been grown as field plants from the outset at The Murrays. Results from the first two years were encouraging in that virus infection was similar to that at Blythbank. However, as the figures in Table 6 indicate, infection has become progressively more serious since then. The material in this programme clearly lacks any particular resistance to leafroll and virus Y, but the principal cause of loss is undoubtedly the leafroll epidemic affecting the UK.

TABLE 6

Leafroll infection in clones of high specific gravity families of different age groups

Seedling year	*% plants infected with leafroll in*	
	1975	*1976*
1971	30	60
1972	28	53
1973	27	33
1974	—	21

Since potentially good crisping varieties are emerging from elsewhere in the Tuberosum breeding work, further breeding of high specific gravity material has been abandoned. Nevertheless, that material now in the selection sequence, including survivors of 20,000 single plants grown in 1976, will be worked through the system.

One positive consequence of the leafroll epidemic at The Murrays is that it has permitted effective selection against leafroll susceptibility.

Two of the regional trials of maincrop selections, at the Gleadthorpe and Arthur Rickwood EHF's, suffered from drought but acceptable yields were obtained at the third English site, Terrington, and also at The Murrays. A short list of five clones was selected for inclusion in a system of replicated trials to be started in 1977 at the same English centres. We are pleased to accept an offer from the NIAB to include in their Breeders' Observation Plots clones which we shall test in our replicated regional trials.

Of the nine clones included in the replicated first-early trials grown in Pembrokeshire, Glamorgan and Wigtownshire, five were equal to, or better than, the controls in yield and will be grown again. Three clones, 7762(10), 7169(10) and 8906abc(11) are particularly promising and discrimination between them is proving difficult and may only come from yield trials planted with seed tubers of the correct physiological age. Multiplication plots for this purpose will be grown by our collaborators in the first-early assessment work, Dr E. J. Allen and his colleagues of UCW, Aberystwyth.

MAINTENANCE OF STOCKS

In 1976 the area under multiplication plots of material shown to be free of PSTV exceeded that of untested material and was switched from the Drochil Castle site to Blythbank. Blythbank now multiplies stocks for all sections of the Potato Department.

Growing conditions were excellent, but aphids were numerous and early in appearing, and the consequences will doubtless be seen in an increased incidence of leafroll in 1977. The same is true for Drochil Castle where the PSTV untested material, and that undergoing test, was grown. The PSTV screening process has now reached the stage where two more growing seasons are needed for completion. Of the large bulk of material tested in 1976 by DAFS Scientific Services Branch, none showed any evidence of infection by PSTV. To facilitate bulk-testing, potato sap was "passaged" in tomato at Pentlandfield prior to the definitive test.

PENTLANDFIELD VARIETIES

The NIAB have announced the addition of Croft to the list of varieties provisionally recommended for general use. Pentland Squire continues to be in demand in both Spain and the UK. The ware and seed areas of Pentland Javelin continue to rise rapidly and the four maincrop varieties Pentland Crown, Pentland Dell, Pentland Hawk and Pentland Ivory now occupy more than 40 per cent of the maincrop acreage of Scotland, Wales and England.

COLLABORATION WITH PAKISTAN

The SPBS collaborative breeding effort with the Agricultural Research Council, Pakistan, continued, and a further consignment of surplus tubers from glasshouse grown seedlings was despatched for evaluation.

T. M. W. Davidson C. J. W. Torrance
A. W. Macarthur R. M. Ford

Potato virus resistances (ARC 24)

The breeding and testing programme for resistance to the common potato viruses X, Y, leafroll and the spraing viruses continues with some success.

LEAFROLL VIRUS

One of the features of recent years has been the high incidence of leafroll in potato stocks in Scotland. This has emphasised the need for varieties to have some resistance to this virus, a need which is indeed generally realised as evidenced by continued requests for resistant material from overseas.

The character of leafroll resistance is an arbitrary quality which can only be established upon the exposure to infection of a relatively large number of plants in trial with suitable control varieties. Breeding for this character is largely empirical in that no accurate forecast of results can be made except that the chances of success are greater if both the parents are themselves classifiable as resistant to leafroll.

The position at present of clones with better leafroll resistance than Pentland Crown is that two commence commercial acceptability trials in 1977 with seven others following a year behind; twenty-one return to the leafroll trial in 1977 to check their resistance; and there is a nucleus of fifty or so in a breeding stock.

From the 1975-76 leafroll trial, 126 out of 170 clones from the virus resistance programme showed leafroll resistance as great or better than Pentland Crown compared with three out of 126 clones in the general breeding programme.

POTATO VIRUSES X AND Y

With regard to resistance to viruses Y and X, progress is more readily attained. Some Pentland varieties have resistance to virus Y derived from the variety Katahdin which, although incomplete, in effect gives good protection from field strains of virus Y with some variation from variety to variety. The resistances used in the resistance programme are those derived from wild species which have so far proved to give a comprehensive resistance to all strains of virus Y. With virus X also, comprehensive resistance has been exploited.

The main difficulty with virus X and Y resistance breeding is bringing the material to an acceptable commercial standard and, if possible, incorporating some leafroll resistance.

Twenty-six thousand seedlings from this programme were sprayed at the cotyledon stage with sap infected with viruses X and Y; about 10,000 survived (apparent resisters) and will be planted out as single tubers next year. The equivalent 1976 planting, from 1975 seedlings, was lifted using a single-plant harvester and selected for tuber shape, etc, on the machine itself.

Over 1,000 clones were screened for resistance. They were mostly from the commercial breeding programme but some were connected with investigations of the inheritance of virus resistance and a few were from the Neo-Tuberosum programme. The common strains of viruses X and Y, and in some cases the B strain of virus X or the A, C, or VN strains of virus Y, were used.

TESTING FOR THE PRESENCE OF VIRUSES X AND Y

Inoculations onto test plants from tuber-sprouts of 274 clones destined for planting at Drochil Castle revealed eight virus X and seven virus Y infections. Only four of the others subsequently showed mosaic symptoms.

To avoid possible complications in subsequent PSTV testing about 700 field-grown diploid plants were screened for virus Y, twenty-three infections being detected.

THE "SPRAING" VIRUSES

Markings in the tuber flesh or surface known as "spraing" are caused by two different soil-borne viruses, tobacco rattle virus (TRV) and potato mop top virus (PMTV). TRV is transmitted by an eelworm vector, *Trichodorus* spp., and PMTV by a fungus vector, *Spongospora subterranea* (corky scab).

The resistance of existing and potential varieties and breeding lines is being assessed in field trials. In the 1976 TRV trial, 170 clones were grown in an infested field at Tayport, Fife, and after harvest the tubers were cut and the incidence of spraing recorded. The dry summer was unfavourable for the eelworm vector (though there was some irrigation) and infection was low and patchy; in the susceptible control cultivar Pentland Dell the incidence of spraing ranged from 0 to 18 per cent. Twenty-four clones (single plots) had more spraing than the most damaged Pentland Dell plots and are, therefore, definitely susceptible, but the remainder could not be reliably classified.

The PMTV trial involves two years. The clones are grown in an infected field at Braco and some of the tubers are cut and scored for spraing, others from each clone being planted the following year at Pentlandfield and scored for haulm symptoms. In 1976, 133 clones were grown at Braco and the tubers are currently being scored for spraing; preliminary observations are that there is some corky scab and some spraing, but some plots of the susceptible control cultivar Arran Pilot have very little spraing. From the 1975 Braco field exposure, haulm symptoms at Pentlandfield in 1976 were less marked than usual owing to the dry weather but were significantly correlated with spraing symptoms ($r = 0{\cdot}48$; $p < 0{\cdot}001$). Only one clone appeared to be as susceptible as was Arran Pilot, but some appeared more susceptible than did others.

T. M. W. Davidson
R. M. Solomon

Mechanisms of Field Resistance to Potato Blight and Variability of the Pathogen (ARC 19)

Studies of field resistance to blight in potatoes require techniques for its detection and assessment and a means of recognising its sources. For such purposes results of tests of adult plants and of seedlings were in agreement in twenty-six of the thirty-two families tested. Seedling tests are more efficient. Leaf surface features and damage were recognised as factors influencing reaction to blight. In some but not all clones, tuber susceptibility rapidly decreased after lifting.

Isolates of Phytophthora infestans *from blighted tubers from the field did not show variability of the pathogen such as could interfere with field assessment of breeding stocks. Unexplained race specificities were recognised in studies of mixtures of races of the pathogen in the laboratory.*

With a view to increasing efficiency in detecting and assessing field resistance to blight (*P. infestans*) and recognising its parental sources, families of fully developed plants were tested and the results compared with those from tests on seedlings (4") of the same families. Thirty-two families were examined, using fifty plants per family. They were of Tuberosum origin, being progenies of five parents well established in breeding for blight resistance crossed with various, recently introduced, blight resisters. The results from the adult and juvenile plants were in agreement in twenty-six families. In some an extremely high level of resistance, not attributed to R genes, was indicated. There was evidence of special combining ability for blight resistance in some parents. The six families where the results with adult plants and seedlings did not agree involved two of the established parents (three families each).

Seedling tests thus appear useful with Tuberosum derivatives in determining sources of field resistance, in assessing clones as parents for breeding for blight resistance, and in indicating possible sources of special combining ability for blight resistance in parents. Using seedlings is preferable to using fully grown plants in that they require less material, space and maintenance. Seedling tests allow early elimination of susceptibles and the resisters, grown on, are available for follow-up tests within weeks of the original tests.

Studies of leaf surfaces by impressions and scanning electron microscopy were initiated and there were indications of topographical features which could be significant in field resistance. These studies continue.

Clone 8429(4) has been consistently very resistant under severe blight conditions in the field and the glasshouse, lesions only being observed on old leaves late in the season, and usually associated with damage. In extensive tests in the glasshouse there was a marked increase in frequency of infection and in lesion size in older leaves. There was also an increase in frequency of infection, but not in lesion size, with damage. In similar tests with a reputedly field-resistant cultivar, Stormont Enterprise, considerably less difference was noted in the frequency of infection between younger and older leaves and lesion size was the same throughout.

Preliminary investigation of the effect of the interval of time between lifting and inoculation on the incidence of blight in tubers confirmed observations that some cultivars remain susceptible or increase in susceptibility for at least some weeks after lifting; others decrease in susceptibility within a few days of lifting.

Development of a simple technique for isolating *P. infestans* from blighted tissue and establishing cultures on agar facilitated work with the fungus from the field and in the laboratory.

Of c. 350 isolates of *P. infestans* from blighted tubers of Pentland Javelin (no R genes) from twelve sites over the field at Blythbank in 1975, all but three were similar in complexity to the races previously released there on infector plants. The complex races were capable of overcoming the R genes present in the breeding stocks but, as commonly occurs, there was some variability in reaction on the R_{10} and R_{11} differential clones, even with the same isolate in different tests. It would appear that under natural conditions at Blythbank there is no rapid change in host specificity of complex races and that their distribution is satisfactory for assessing the field resistance of clones in the multiplication plots (Malcolmson, *Trans. Br. Mycol. Soc.* **67**, 321-325). Crosses have been made to obtain R_{10} and R_{11} differential clones with a more consistent reaction.

Several hundred cultures have been established, on agar, from tubers and leaves inoculated with various mixtures of four races. Determination of the race content of most of the isolates has yet to be made but, as observed in previous years (*Annual Report 1975-76*, 24), isolates checked so far have sometimes contained specificities absent from the original mixture. Antagonism between isolates was again noted in certain race mixtures. In some mixtures on tubers only thread-like lesions developed, and *P. infestans* was isolated from them. Such lesions could prove to be highly significant in the field since they are likely to be overlooked in dressing seed; also, mother tubers bearing them are likely to sustain the fungus much longer than tubers with gross lesions.

J. F. Malcolmson

Potato Blight Resistance (ARC 26)

Routine laboratory tests assessing foliage and tuber resistance continued, and two scoring methods for assessing resistance in tubers were compared.

FOLIAGE BLIGHT

The foliage resistance of breeders' selections was assessed in glasshouse tests on whole plants. A satisfactory level of resistance, indicated by a score of six or more on the one to nine scale of increasing resistance, was shown by between 10 and 18 per cent of commercial breeding programme selections (Table 7).

TABLE 7

Levels of foliage blight resistance in breeders' selections

Breeders' selections	*No. clones*	*Proportion* ≥ 6 * *No.*	*%*
Commercial programme:			
5th year of selection	387	70	18
6th year of selection	120	20	17
7th year of selection	52	5	10
Potential parents for the commercial programme:			
Neo-Tuberosum clones	17	5	29
Eelworm resistant clones ex Andigena	22	0	0

* Scale 1-9 of increasing resistance

As indicated under ARC 22 the high resistance shown in detached leaflet tests in 1975 by eleven dihaploids derived from three blight-resistant tetraploids was confirmed in a test on whole plants.

In leaflet tests, a score of six or more was obtained by twenty-five of a further forty-six dihaploids, but by only seven of 103 diploid clones tested.

TUBER BLIGHT

Laboratory tests of tubers showed the proportions of breeders' selections with resistance equal to that of Pentland Crown given in Table 8. A similar level of resistance was found in three of ten Pentland Crown dihaploids, but eleven of fourteen diploid clones were very susceptible. Of nine advanced clones tested clone 7495(6) appeared highly resistant, and Croft and Strath were more resistant than Pentland Crown.

TABLE 8

Frequencies of clones with tuber-blight resistance equal to or better than Pentland Crown

Breeders' selections	*No. clones*	*Equal to P. Crown* *No.*	%
Commercial programme:			
5th year of selection	420	157	37
7th year of selection	51	4	8
Virus resistant clones	50	11	22

The new controlled environment cabinets enabled storage at 15°C and 100 per cent RH for the first five days after inoculation. The percentage of blighted tubers, which is easy to determine, was found to be correlated with the square root of a cover score of surface infection ($r = 0{\cdot}895$). It was also found that delaying inoculation until the day after lifting tended to reduce the number of blighted tubers.

It was again found that high foliage and tuber resistance were not necessarily associated. Of 119 clones with a foliage score of five or more, only 46 per cent had tubers as resistant as Pentland Crown.

Due to dry weather there was insufficient blight for resistance to be assessed in the field.

H. E. Stewart
R. L. Wastie

Potato Tuber Disease Resistance (ARC 27)

Routine disease screening was carried out against gangrene skinspot and common scab, and factors affecting the reliability of the tests and the development of the diseases were examined.

GANGRENE (*PHOMA EXIGUA* VAR *FOVEATA*)

The disease was slower to develop in the new storage cabinets in 1975-76 than in 1974-75 at The Murrays. However, results on two-thirds of 176 clones tested in both years were in satisfactory agreement and most of the discrepancies in the remaining eighty-six clones were attributable to a lower gangrene index (*i.e.*, reduced susceptibility) in 1974-75. The proportion of resistant clones (index $\leqslant$ 5) in 349 clones from the general breeding programme lay between 34 and 46 per cent in three successive years of selection; twenty-two of thirty-eight Neo-Tuberosum clones and seventy-nine of 128 clones from the high specific gravity programme were also resistant.

In an experiment investigating the effect of relative humidity on the development of gangrene, less infection developed on tubers held for four weeks at 4°C and 80 per cent RH followed by six weeks at 100 per cent RH, than on those held throughout at 100 per cent RH or incubated at 80 per cent RH after an initial four weeks at 100 per cent RH. Isolates of *P. exigua* var. *foveata* differed consistently in pathogenicity when surface-inoculated or stab-inoculated to Pentland Crown (susceptible) and Pentland Dell (resistant). The relationship between pathogenicity and growth rate *in vitro* is under investigation.

At The Murrays, strip baits exposed at weekly intervals from late July recovered very few propagules of *P. exigua* var. *foveata*, in contrast to last year. Most recoveries were in late October at the time baiting was discontinued.

SKIN SPOT (*OOSPORA PUSTULANS*)

Artificial inoculation in November (by dipping in culture macerate) of routine test material did not appreciably increase the amount of skin spot, bu experimental inoculation of named varieties in January with a cornmeal sand culture increased the intensity of spotting over dipped or uninoculated material. Assessing the extent of eye or sprout infection was not a promising scoring technique, partly because of lack of correlation between spotting intensity and eye and sprout infection.

COMMON SCAB (*STREPTOMYCES SCABIES*)

The 1975 Archerfield test area was re-designed to include two replicates of twelve named varieties in each of its six sections, thus enabling a reliable overall mean to be calculated with which the 439 test clones could be compared. Significant differences were recorded in the level of scab between sections, and wide discrepancies in the scab score were observed between many of the pairs of twin-tuber plots. Inoculating the soil under the mother tuber, or the tuber itself, with a cornmeal sand culture of *S. scabies* did not reduce the variability. A good correlation ($r = 0{\cdot}99$) was observed between two methods of expressing the scab score of the named varieties: by the standard cover score and by a simplification of this in which the percentage of tubers with one quarter or more of the surface area scabbed was calculated.

As a result of the dry summer of 1976 considerable scab infection was observed in plots being grown at The Murrays to provide tubers for gangrene and skin spot tests. Where comparisons were possible, reasonably good agreement was observed between the 1975 Archerfield score and observations made on the same clones at The Murrays in 1976 suggesting that, if soil moisture was artificially controlled, scab screening might be possible at The Murrays.

High levels of scab have been obtained in a glasshouse, in spite of high ambient temperatures, by planting tubers of six named varieties on fine terylene mesh over potting soil and covering them with inoculated Archerfield sand. Clay (not plastic) pots were used. Axillary tubers produced on cuttings of eight named varieties rooted in soil-less compost in July and transplanted into inoculated sand in August also became heavily scabbed. Both these *in vitro* methods identified the most susceptible varieties.

R. L. Wastie
H. E. Stewart

Potato Cyst Eelworm Resistance (ARC 25)

Clones of progenies segregating for H_1 resistance to pathotype A and H_3 resistance to pathotype E were classifiable as resistant or susceptible to A but showed a continuous range of resistance to E, the best having resistance to E comparable with the best with vernei*-derived resistance.*

Tests involving counts of cysts on the root ball give repeatable results and there is no evidence that total cyst counts would give greater precision, but greater accuracy could be obtained if moisture levels were more strictly controlled.

The potato cyst eelworm, initially viewed as a single species *Heterodera rostochiensis*, was subsequently found to include various pathotypes of which two, pathotypes B and E, were morphologically distinct and were separated as *H. pallida*. The generic name *Globodera* has recently been substituted for *Heterodera* (Mulvey and Stone, *Can. J. Zool.* **54**, 772–785).

The H_1 gene obtained from certain *Solanum andigena* clones is present in some recently bred cultivars including Maris Piper, Pentland Javelin, Pentland Lustre and Pentland Meteor. It confers virtual immunity to pathotype A of *G. rostochiensis*, but is ineffective against *G. pallida*.

The H_3 gene found more recently in certain other *S. andigena* clones is effective against *G. pallida*, but not against *G. rostochiensis*. No varieties with it have yet been marketed. Howard (*ADAS Quarterly Review* **7**, 132–138) has found variation in the levels of resistance of clones containing H_3, suggesting it is not a single major gene.

Resistance derived from the wild species *Solanum vernei* is believed to be polygenic. Breeding it into commercially acceptable potatoes presents special difficulties as the "wild" characters of *S. vernei* must be eliminated while sufficient resistance factors to give an effective level of resistance must be retained. The value of *S. vernei* resistance is that it is operative against all pathotypes of *G. rostochiensis* and *G. pallida*.

Over 430 clones, mostly with *vernei*-derived resistance but including 130 obtained by crossing clones bearing both H_1 and H_3 with Pentland Ivory (which contains neither), were tested for resistance to pathotypes A and E. Those with H_1 and H_3 could be classified as either resistant or susceptible to pathotype A, but they showed a continuous range of resistance to pathotype E, the best having resistance comparable to that of the best with *vernei*-derived resistance.

Resistance was estimated by counting the number of cysts on the surface of the root ball. Clones were ranked in order of increasing susceptibility to pathotype E, and significant agreement with last year's ranking was obtained providing further validation of this method of assessing resistance.

Nevertheless rankings are not identical from year to year. An important source of experimental error has been identified as variation in moisture levels due to slight sagging of the glasshouse tables under the weight of the moist sand beds constructed upon them. In six out of eleven tables for which data has so far been examined the lowest cyst counts were associated with areas of the tables which were directly supported by underlying struts and therefore tended to be drier. The converse situation occurred on one table known to have been overwatered. This lack of uniformity in moisture levels can largely explain the fluctuations in the rankings from year to year.

A comparison between free-standing plastic pots and buried clay pots on adjacent tables was made, using seventeen clones. Cyst counts were generally lower in plastic pots than in clay pots of the same volume, perhaps due to the plastic pots providing less protection from the dry conditions in 1976, even though more water was applied to them. With both plastic and clay pots there was a highly significant positive correlation between total cysts per pot and on the surface of the root ball. In this experiment a relationship was established between position on the greenhouse tables and both root ball and total cyst counts.

J. M. S. Forrest

Aspects of Potato Cyst Eelworm Biology (ARC 23)

The stimulation to hatching of G. pallida *eggs provided by some clones with eelworm resistance derived from* S. vernei *was less than that provided by commercial varieties only at certain times of the year.*

Five-minute contact with root diffusate caused significantly greater hatching of G. pallida *cysts and eggs than in untreated controls.*

Breeding to create a test series of clones representative of the sources of eelworm resistance available in Britain is in progress.

STIMULATION OF EELWORM HATCHING BY *S. VERNEI* AND *S. TUBEROSUM*

Hatching of eelworm eggs is stimulated by a substance diffused from potato roots. Deshmukh and Weischer (*Potato Res.* **13**, 129–138) observed seasonal variation in the stimulation provided by the resistant wild species *S. vernei*, the same selection giving a low stimulation in September but a very high one in the following May. Various other individually conflicting reports, when taken together, also suggest a seasonal effect. No information has been published on the stimulation provided by the progeny of crosses of *S. vernei* and *S. tuberosum*.

The stimulus to hatching provided by clones with *vernei*-derived resistance was compared with that of non-resistant commercial varieties by applying fresh diffusate from sprouts rooted for one week to batches of 100 *G. pallida* cysts *in vitro*. In December and January, diffusates from one resistant clone stimulated only half as much hatching as those from Home Guard which themselves caused relatively little, but in April, May and June both these clones induced equally heavy hatching, as also did two other resistant clones and the variety Pentland Crown. The stimulus provided by resistant clones subsequently declined more rapidly than that of Pentland Crown though the latter reached almost zero by October, by which time the tubers providing the sprouts were about a year old. The drop in activity may be connected with the fact that over this period the sprouts of potatoes in store undergo great physiological changes which are marked by a switch to the production of stolons and tubers rather than roots. Diffusates of rooted sprouts from new Home Guard tubers were then inducing heavy hatching, so diapause in *G. pallida* could be ruled out.

Tests were also conducted by burying bags of *G. pallida* cysts in pots and planting sprouts of Home Guard or a resistant clone or leaving the pots unplanted. After from six to ten weeks the bags were recovered and the viable unhatched eggs counted. In tests initiated in January and May cysts from pots planted with Home Guard showed a 70 to 80 per cent decrease in viable eggs relative to the controls, but those from pots planted with the resistant clone showed a 26 per cent reduction in the January test, 70 per cent in May.

The difference between the results obtained with Home Guard in pot tests and in sprout tests probably relates to the fact that newly-rooted sprouts are less active than those rooted for three to four weeks (Widdowson, *Nematologica* **3**, 6-14). The results suggest that there are differences in the stimulation of hatching provided by some clones with *vernei*-derived resistance and certain commercial clones, but further studies are required before generalisations can be made.

HATCHING OF *G. PALLIDA* IN RESPONSE TO BRIEF EXPOSURE TO ROOT DIFFUSATE

Cysts and eggs of *G. pallida* exposed for five minutes to root diffusates then washed for thirty minutes in running water have, in a series of weekly tests, consistently had significantly higher rates of hatch than did unstimulated controls. In some cases the hatch has been as much as thirty times that of the controls by the end of the four-week observation period. This work is being done in conjunction with Dr R. Perry of Rothamsted.

ESTABLISHMENT OF A TEST SERIES OF EELWORM RESISTANT CLONES

Breeding aimed at securing a series of clones representative of the major sources of eelworm resistance available in Britain, the H_1 and H_3 genes from *S. andigena* and also *S. vernei* resistance, is in progress.

J. M. S. Forrest

The Commonwealth Potato Collection (CPC) (ARC 20)

The function of this Collection of wild and cultivated species from Latin America is outlined. A duplicate has been sent to the German-Dutch Collection for safekeeping, without renewal or use, and we expect to receive their duplicate Collection. During the year Collection lines were used internally, at three UK stations, and in four other countries.

THE NATURE AND PURPOSE OF THE COLLECTION

This Collection of wild and cultivated species from the native home of the potato, Latin America, is maintained as a service to potato breeders and geneticists and, being one of only a few such Collections, is drawn upon by many countries. It was founded using material assembled by a Commonwealth-financed expedition in 1938-39 and has been considerably augmented since. Its main significance is as readily-available classified and quarantined material, but some of its accessions may no longer exist in Latin America where bred varieties are rapidly displacing native cultivars, and where changing land-use is threatening the habitats of many wild species. Recognition of the latter situation led recently to the establishment of an International Potato Centre in Peru whose prime function is to collect, classify and maintain potato variability. This new Collection, which already contains many more native cultivars than any other, may eventually reduce the significance of Collections such as the CPC. However, the Centre cannot yet guarantee the health of its material which thus requires time-consuming quarantine in receiving countries. In starting to collect wild species, the Centre propose to ask Collections such as the CPC to receive their accessions while they concentrate on maintaining cultivars.

The CPC is kept as botanical seed, partly to facilitate storage but largely because potato diseases generally are not transmissible in such seed. An exception is Spindle Tuber Virus (PSTV), for which it has recently been screened.

ACTIVITIES IN 1976

Tubers of lines which had not given adequate seed following clearance for PSTV were replanted for a further attempt at seeding. Some lines tested and seeded before the test-procedure was fully developed were sown to permit further testing; no suspicious cases have yet been reported.

The SPBS is co-operating with the German-Dutch Potato Collection in storing duplicates of each other's Collections, without attempting to renew or to utilise them in any way, as a precaution against loss by fire or similar catastrophe at either Station. The CPC has been received in Braunschweig, and SPBS is awaiting the arrival of the German-Dutch collection.

During the year many lines were used in the Neo-Tuberosum project (ARC 21), seven samples were passed to immediate colleagues, thirty-one were sent to three users in the UK and 112 were despatched to four other countries. The lines were required for various purposes including virus and eelworm work, studies of protein content, and a study of the aphid-trapping properties of glandular hairs.

D. R. Glendinning

South American cultivated Tetraploid Potatoes (ARC 21)

A population derived from South American potatoes of the Andigena group has been mass-selected through several generations and is now termed Neo-Tuberosum. Fifteen clones from it were used in the commercial breeding programme this year. Clones are also being intercrossed to combine their useful characters. Further variation is being incorporated from Andigena.

OUTLINE OF THE NEO-TUBEROSUM PROJECT

Commercial potatoes of temperate regions derive from South American cultivated tetraploids, introduced long ago, with subsequent incorporation of some genes from other sources. The initial introductions were probably few, mainly from Colombia, and they would involve little of the great variability of South American potatoes. To bring a further sample of that variability into use a population based on Andigena potatoes, mainly from Boliva and Peru, is being developed by methods similar to those used by farmers and selectors over the centuries. Seedlings from naturally set seed are raised and seed for re-sowing obtained from the better ones, this process being repeated continuously. In this way genes causing poor yield in our day-length conditions, unacceptable tuber shapes, long stolons, or excessive susceptibility to common diseases are being eliminated. The resemblance of the developed population to commercial potatoes, which we refer to collectively as Group Tuberosum (of *Solanum tuberosum*), is now sufficient to justify use of the term Neo-Tuberosum.

It has been found that naturally-set seed mainly derives from self-pollination. The resultant inbreeding may have facilitated rapid elimination of undesirable characters, but may also have caused some loss of scarce alleles affecting characters not subjected to selection. Tuberosum will already contain most of the common alleles of Andigena and the value of Neo-Tuberosum will lie in its content of novel alleles, which will mainly be scarcer or geographically localised Andigena alleles. In all respects yet investigated the variation in Neo-Tuberosum at least equals that in Tuberosum, and some useful new characters have already been found. But much more useful variation must still remain in Andigena.

In view of this we are seeking to establish a still richer gene-pool which can be developed by mass-selection into a "Mark II" Neo-Tuberosum population. Current Neo-Tuberosum is being crossed with further Andigena from the CPC (ARC 20) and the resultant population is being inter-mated to randomise gene-associations prior to inbreeding and selection. Scarce alleles should be less at risk of chance loss if each is distributed randomly through the population.

Meanwhile, Neo-Tuberosum parents are being used in the SPBS commercial breeding programme (ARC 16). They are chosen primarily on tuber appearance, but subsequent tests often reveal interesting disease resistances or other properties. Clones are also being intercrossed to combine their useful characters. In autotetraploids, a part of the inbred status of a parent is transmitted to its outcrossed progeny and parents obtained by intercrossing may prove superior donors of vigour relative to those used hitherto.

THE MASS-SELECTION PROGRAMME

About 4,500 seedlings were raised while about 1,000 selections from last year's seedlings were grown to provide further seed. Tubers from about 870 seedlings were retained to provide next year's seed-production plot.

CLONES FROM THE MASS-SELECTION PROGRAMME

About 130 of the retained seedlings were thought worthy of consideration as possible parents for the commercial breeding programme, or for intercrossing, and therefore were designated as clones. Of the seed-production plants, about 150 which had been similarly designated last year were grown as three-tuber plots for preliminary reassessment. Twenty-eight from 1974 seedlings which had survived reassessment in 1975 were grown in replicated six-tuber plots, intermingled with plots of commercial varieties, for more detailed assessment; the best of these may be used as parents in the commercial breeding programme in 1977. Fifteen from 1972 and 1973 seedlings, chosen primarily for maturity, tuber shape and colour, but subsequently assessed for resistance to viruses X and Y, blight and gangrene, and for cooking and crisping were used in that programme in 1976; these and others retained from earlier years were grown for maintenance.

This programme is conducted at The Murrays, and the rapid assessment and use of clones outlined above is necessitated by the high incidence of leafroll there.

ESTABLISHMENT OF NEO-TUBEROSUM AT BLYTHBANK

A more protracted and detailed assessment of clones should be possible if healthy reserve stocks can be maintained at Blythbank. With this in view, parents previously used in the commercial breeding programme are being meristem-cultured to free them of viruses and permit them to be planted there.

4,000 "singles" derived from intercrossing twenty-three Neo-Tuberosum clones were grown there and about 260 of these were retained, and 4,000 seedlings from the mass-selection programme were raised in a screened polythene tunnel for planting of "singles" to Blythbank in 1977.

ESTABLISHMENT OF A BROADER GENE-POOL

An F_1 hybrid Andigena × Neo-Tuberosum population of about 2,800 plants was raised and pollinations to secure an F_2 generation were commenced. Further F_1 seed of this cross was also obtained. The practice has been to apply bulk Neo-Tuberosum pollen (from field-plantings) to Andigena flowers so that each Andigena is crossed with many Neo-Tuberosum parents, then to apply bulk Andigena × Neo-Tuberosum pollen to produce the F_2 thus randomising the combinations of all parents with each other. About 150 Andigena lines from the Collection contributed to the initial F_1 and some additional ones to the further F_1 seed obtained this year.

THEORETICAL GENETIC STUDIES

The theoretical basis for an understanding of the dynamics of autotetraploid populations with mixed selfing and random mating is inadequately developed and work on this is in progress. Studies related to Andigena × Neo-Tuberosum crossing, and the desirability of proceeding to further generations before commencing selection, are also being made.

D. R. Glendinning

Studies of the Potential of South American Diploids and Tuberosum Dihaploids for Potato Breeding (ARC 22)

Yields which compare favourably with those of current potato cultivars are being obtained in some diploid clones derived from the mass-selection programme. Field evaluation of 250 tetraploids arising from tetraploid × diploid crosses is commencing; pollen from diploids effective in such crosses includes a proportion of large (probably diploid) grains. Among more than 330 dihaploid clones presently in the Pentlandfield collection are some having higher levels of field resistance to foliage blight, to tuber blight or to eelworm than their tetraploid parents. The resistance to foliage blight of a dihaploid clone was unaffected by colchicine-doubling of its chromosome number.

The various ways in which the native cultivated potatoes of the Andean region could contribute to the improvement of the European potato, and the concomitant use of dihaploids for genetic manipulation and analysis, have been discussed previously (Simmonds, *Annual Report 1968–69*: 18–38).

THE MASS-SELECTION PROGRAMME

The mass-selection programme is conducted jointly in Scotland and at the Rosewarne EHS in Cornwall. Rosewarne is used primarily to permit selection for, and assessment of, blight resistance, but additional interesting information on the yield potential of diploid potatoes is emerging. Table 9 shows yields and tuber sizes of five outstanding clones grown there in 1976;

TABLE 9

Yield and tuber weights of five diploid clones grown at Rosewarne, Cornwall, in 1976

Clone No.	*Origin*	*Mean yield (kg)*	*Mean weight (g) 3 largest tubers*	*Mean weight (g) All tubers*
40CP19	Mass-seln. Rosewarne	3·68	520	54
40CP20	Mass-seln. Rosewarne	1·87	593	82
DB103 (21)	Pedigree breeding, Pentlandfield	3·11	730	66
DB109 (2)	Pedigree breeding, Pentlandfield	3·04	733	101
DB109 (12)	Pedigree breeding, Pentlandfield	3·92	1,115	151

two were initially selected at Rosewarne while the others derive from "pedigree" breeding utilising parents from the mass-selection programme. The three "pedigree" clones, while good, had not seemed outstanding in yield when grown in Scotland.

In early October, haulm maturities in tuber-planted plots at The Murrays averaged 2·8 on a one (dead) to five (green, growing and flowering) scale, showing that the maturing process was under way and that diploids do not necessarily continue growth until cut down by adverse weather conditions.

As a means of avoiding the problems of leafroll infection at The Murrays farm (see ARC 16 and 21) seedlings derived from PSTV-cleared parents were raised in a screened polythene tunnel for planting at Blythbank next year.

TETRAPLOID HYBRIDS FROM TETRAPLOID/DIPLOID CROSSING

Tetraploid cultivars chosen for sexual fertility, agronomic characters and dormancy (the latter to counteract any tendency to early sprouting still present in the diploids) are being pollinated by diploids, and tetraploid offspring identified by chromosome counting. About 250 tetraploid seedlings identified in 1976 will be planted at Blythbank next season, providing the first opportunity for reasonable evaluation of such material. In 1976 the cultivars Bea, Dunbar Standard, Maris Piper, Pentland Dell, Record and Stormont Enterprise were pollinated by two diploid clones, 13T8 and 13T48, known to be superior producers of tetraploid hybrids. The yield of seed ranged from 0·1 per pollination in Dunbar Standard to 3·4 in Bea.

Tetraploids obtained in such crosses are believed to arise from twenty-four chromosome pollen grains which enjoy a selective advantage on tetraploid stigmas (Simon and Peloquin, *J. Hered.* **67**, 204-8). Measurements undertaken by the Cytology Section have shown that some of the pollen produced by the two superior diploid parents mentioned is in the size range found in anthers of tetraploid plants, while pollen of a clone which is ineffective in interploidy crosses is uniformly small.

DIHAPLOIDS

We are currently maintaining over 330 clones of various types in the Pentlandfield Dihaploid Collection, and have supplied tubers in response to requests from the USSR and West Germany. Dihaploid stocks have been protected from virus infection by growing them in a screened glasshouse. Some more sexually fertile clones are now being established at Blythbank to provide larger stocks for distribution.

Emphasis is being placed on obtaining dihaploids from tetraploids which seem favourable for disease resistance and increased vigour and fertility. Some Tuberosum × Neo-Tuberosum clones from the commercial breeding programme have been used in the hope that they would contribute male fertility (which is a feature of Neo-Tuberosum itself), but the flowering intensity and pollen fertility of these parents has not been outstanding and this is reflected in the dihaploids obtained from them. Thus of seventeen dihaploids from clone 9181(12), ten failed to flower in two successive seasons and none had more than 7 per cent stainable pollen. It is possible that problems are arising with cytoplasmic male sterility between the Andigena and Tuberosum parents since the one hybrid tetraploid clone with Andigena cytoplasm, 9198(5), had 65 per cent stainable pollen: much higher than in the others. It may prove to be preferable to use Andigena (Neo-Tuberosum) material directly for dihaploid production even though it is further from the commercial standard. The Tuberosum × Neo-Tuberosum hybrid material has also given a lower ratio of dihaploids to triploid and tetraploid hybrids in inducer pollinations than have the disease resistance selections, *e.g.*, 36 per cent in 1976 chromosome counts as against 54 per cent (late blight resistant) and 64 per cent (eelworm resistant).

The number of seeds obtained per inducer pollination was substantially higher in 1976 than in previous years (Table 10). While this was partly due to use of tetraploid clones previously shown to be favourable, especially in the eelworm resistant class, it is difficult to explain the magnitude of the improvement. The time of day at which pollinations are done may be a factor.

TABLE 10

Seed yield in the dihaploid production programme

Type of tetraploid parent	*Seeds obtained per pollination in:*		
	1974	*1975*	*1976*
Blight resistant	0·25	0·10	2·08
Eelworm resistant	0·09	0·22	0·89
Tuberosum × Neo-Tuberosum	0·32	0·11	1·43

C. P. Carroll

Of sixty-two recently obtained dihaploids from resistant tetraploid parents, twenty proved very resistant to blight (*P. infestans*) in leaflet tests. Thirteen which had previously shown high resistance in such tests were re-assessed in more rigorous replicated whole-plant tests and eleven showed high resistance. Eleven other dihaploids (ten from Pentland Crown and one from Record) were assessed for resistance to tuber blight and three (from Pentland Crown) proved highly resistant, one of them apparently immune.

Resistance to foliage blight was assessed in a dihaploid of Pentland Crown, tetraploids derived from it by colchicine doubling, and Pentland Crown itself. There was no significant difference in resistance between the dihaploid and the derived tetraploids which were slightly, though significantly ($P < 0{\cdot}05$), more resistant than Pentland Crown.

Of seven dihaploids derived from parents having both H_1 and *vernei*-derived eelworm resistance (see ARC 25) six proved to have the H_1 gene for immunity to pathotype A while a range from high susceptibility to high resistance to pathotype E was found (from 103 per cent to 7 per cent of the susceptibility of Pentland Crown). A further thirty-two dihaploids have recently been obtained from eelworm resistant parents.

It appears that dihaploids may sometimes have higher levels of expression of quantitatively inherited disease resistances than their tetraploid parents, this having been shown for field resistance to foliage blight, for tuber blight resistance, and for resistance to eelworm (pathotype E). This raises interesting questions as to the nature of genetic control of resistance. Simple additive action or simple dominance of resistance polygenes seem inadequate to explain the phenomenon.

M. J. De Maine

Biometrical Genetics of Potatoes (ARC 18)

During 1976 material for a North Carolina Experiment II was multiplied.

Thirty progenies derived by crossing fifteen parents with two others were multiplied in preparation for an experiment in 1977. About 1,500 "singles" were grown at Blythbank and individually harvested, three tubers per plant being retained. The fifteen parents were diverse, being drawn from virus resistant, Neo-Tuberosum and blight resistant groups, and the other two were 3071ab(1) which is noted for its well shaped tubers and 3683a(2) which is resistant to blight, virus Y, and leafroll. The progenies should provide estimates of general and specific combining abilities and genetic correlations which will complement those derived from the diallel cross reported last year.

Tubers from glasshouse-grown seedlings comprising a thirteen-parent incomplete diallel cross were retained for multiplication; this will give a third component of these investigations which are aimed at improving potato breeding methods.

R. J. Killick

SERVICE UNITS

Chemistry Laboratory

The work of the Chemistry Laboratory is concerned with routine analyses of quality factors important in plant breeding. This year the volume of work was increased by the addition of three comparatively new techniques. Furthermore, an infra-red reflectance instrument, the "InfraAlyser", capable of being used to predict quality factors, and a data logging system compatible with our Technicon auto-analyser outputs, were acquired. The routine work was similar to that in previous years and consisted of: digestibility determinations (826 and 507 samples of brassicas and grasses, respectively); Kjeldahl nitrogen (2,598 and 878 samples of barley and brassicas, respectively); diastatic power and alpha-amylase (3,080 barley samples); total soluble carbohydrates as a measure of frost resistance (272 samples) and fibre as an indicator of digestibility (334 samples) in brassicas.

Two of the newer methods are concerned with the estimation of toxic factors in brassicas (see *Annual Report 1975-76*: 31). A time-course study of quantities of two toxic factors, S-methyl-cysteine sulphoxide (SMCO) and thiocyanates, during growth of varieties of *B. oleracea* will show whether the amounts at early growth stages relate to the levels at maturity. Preliminary results indicate that SMCO and thiocyanates in cotyledons correlate poorly with the levels in the mature plant. Further analysis of this experiment is in progress.

The third new method to be established as routine is a milling energy measurement that relates to the malting quality of barley. The higher the energy required to mill the sample the more difficult it is to malt. This is a rapid test (approximately one minute per sample) which compares favourably with other small scale tests in predicting malting quality. Because of problems of wear in the mill leading to increases in errors, a new system which measures the energy as a braking load on a flywheel rather than the mill motor is being developed.

The possibility of using the "InfraAlyser" to estimate nitrogen in barley and quality factors in brassicas is currently being investigated.

The outputs of our Technicon auto-analysers can now be logged onto magnetic tape and this system, which is compatible with the new Wang 2200 mini-computer, promises to be a fast and efficient means of processing data.

M. J. Allison   R. B. W. Williamson
I. A. Cowe   R. Borzucki

Cytology Laboratory

All work done during the year has been for the brassica section of the Forage Department and the dihaploid and diploid projects in the Potato Department.

The routine work for the brassica section consisted of pollen fertility estimates, ploidy checks of first generation colchicined material, and mitotic counts of advanced breeding material from interspecific crosses.

Selecting the largest size range of seeds increased the proportion of triploid hybrids (2n = 29, *aac*) found in the progenies of turnip, *B. campestris* (2n = 20, *aa*) open-pollinated by rape, *B. napus* (2n = 38, *aacc*) (see ARC 9). Progenies from bud-selfing similar allotriploids varied in chromosome number from twenty to thirty-eight (Table 11). These results differ from those reported by

TABLE 11

Distribution of chromosome numbers of progeny from selfing 2n = 29 *aac* hybrids of *Brassica campestris* and *B. napus*

Chromosome number (2n)	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Number of plants	1	0	0	0	1	0	1	5	4	2	5	6	7	7	6	1	1	0	2

Jahr (*Der Züchter* **32**, 216-225) and will be investigated further. These allotriploids were also used as female parents in backcrosses to *B. napus*, and of ninety-two resultant plants examined two had thirty-eight chromosomes while six had higher and varying chromosome numbers. The latter presumably have arisen from fusion involving a gamete having more than nineteen chromosomes. This raises a question as to whether n = 19 gametes from the allotriploid are necessarily fully *ac* and thus whether the thirty-eight-chromosome plants are fully balanced *aacc*. This will be checked when the plants flower in 1977. Plants with thirty-eight chromosomes previously produced with the allotriploid as male parent have been incorporated into a rape breeding programme as semi-artificial rapes (*Annual Report 1975-76*: 14).

Routine pollen fertility estimates were made of 810 potato clones. In the dihaploid production scheme 113 dihaploids were identified, including two trisomics. In crosses onto tetraploids from diploid pollinators aimed at securing tetraploid offspring over 90 per cent of the progeny were tetraploid hybrids, formed by the participation of twenty-four-chromosome gametes from the diploid parent. The diameter of mature pollen grains can be used to estimate the proportion of unreduced pollen and the two diploid clones, 13T8 and 13T48, which were the parents of all the tetraploids obtained last year, were found this year to produce 2·8 and 6 per cent apparently diploid pollen respectively. Clone 13T48 gave approximately 16 per cent dyads at the sporad stage of meiosis.

Tubers were obtained by rooting cuttings from colchicine-treated dihaploid clones. Plants grown from the tubers were screened and, of 213, thirty were tetraploid in both the inner and outer histogenic layers. Seven of these flowered and were found to be tetraploid in the middle layer also. Only eleven plants with diploid/tetraploid chimeras within layers were found, suggesting that allowing the plants to tuber before screening reduces the frequency of such chimeras.

J. A. Fantes

Statistics and Computing Service

The section continued to advise staff on statistical and computing matters, to prepare punched cards, undertake analyses of data and interpret results in accord with its remit. During 1976 a total of 1,775 computing jobs were run at a cost of £3,105. Seventy per cent of these jobs were run on EMAS. In December a Wang 2200 was acquired. This "desk-top" computer system will greatly enhance our in-house capability for analyses of relatively small data sets. When numerous data are to be analysed we shall continue to rely on the computers of the Edinburgh Regional Computing Centre. A staff change during the year resulted in the Scientific Officer now being full-time rather than part-time; this, together with the Wang 2200, should expedite the section's work.

R. J. Killick

Photography and Illustration

Routine work included the production of slides (colour, monochrome and diazochrome), monochrome prints, graphs, charts and diagrams for publication and display purposes.

Following Mrs Sutherland's resignation the post of photographer/illustrator has remained vacant since October 1976 until the end of the period under review.

I. H. McNaughton

Forage Trials Unit

The Forage Trials Unit was created as a service organisation for the breeders of the Forage Department. It assesses advanced breeding material before submission for official and varietal rights testing, and travels extensively, covering the main crop growing areas of Scotland. Cereal and brassica trials at eight centres were serviced entirely by the Unit, whose equipment is specialised for small plot trials and is compact enough to be conveyed by Land Rover and trailer.

The year was characterised by the early spring, the prolonged summer drought and the extremely wet autumn. The winter wheat drilled on the 29th October 1975 and the spring cereals which in the main were drilled by the 6th March 1976 did not suffer unduly from this abnormal combination of weather conditions. Foliar diseases were present, but of no real significance, with cereal aphids the major pest. For the first time on record harvesting was completed by the end of August. The top-yielding barley variety produced the equivalent of 7·65, wheat 6·65 and the best oat 5·8 t ha^{-1}. Coefficients of variation for the seventeen cereal trials ranged from 3·7 to 8 per cent with a mean of 5·48 per cent.

Assessment trials were carried out on kale, rape (including *Raphanobrassica*), swedes and stubble-turnips. The swedes suffered most from the drought, the kales and rapes less, while the stubble turnips drilled early in August escaped completely. Results were very satisfactory and excellent yields were recorded considering the prolonged drought. The highest yielding swede recorded the equivalent of 8·5, kale 12·1, *Raphanobrassica* forage rape 4·4 and stubble turnip 4·5 t ha^{-1} dry matter. Coefficients of variation for dry matter production for the trials conducted at The Murrays ranged from 4·3 to 8·5 per cent with a mean of 6·4 per cent. The Unit obtained a Webb's precision space-o-matic seeder, a Claas maize harvester for kale trials, a Sisis precision fertiliser applicator, a Horsteine Microband granule applicator and a Petkus seed cleaner and grader. These machines will greatly improve precision, efficiency and productivity. Developmental work continued on other machines, further improving the field handling of experimental plots and trials.

I. M. Chapman

The Murrays

The Murrays was acquired by the DAFS in 1970 and rented to the SPBS as an experimental centre. Its 134 hectares have now been arranged into thirteen fields, ten of 11 to 13 hectares each and three smaller ones. Each year one major field is devoted to potato experiments, one to cereal experiments, and one or part of one to brassica experiments. Small experimental plots requiring isolation from the main plantings are sited, when possible, in the three smaller fields which are treated as "ex rotation". The remainder of the land has been managed on a commercial basis and also with the object of preparing it for future experimental use. The commercial crops grown are wheat, barley, and grass, the latter being sold as hay or let out for grazing, no livestock being kept on the farm. Stubble turnips have sometimes been used as a catch-crop (for grazing) after ploughing from grass in preparation for potatoes, but difficulties in getting the land ready for potato planting occur if the winter is wet and the system has been abandoned.

Since SPBS took over the farm, fencing has been renewed throughout. Problems which remain include poor drainage and infestations with couch grass and potato groundkeepers as well as considerable variation in soil type and fertility.

Work commenced early in 1977 on the installation of a new drainage system throughout the farm. About 34 ha was dealt with by the end of March.

The couch problem is being attacked with TCA after ploughing in preparation for both brassicas and potatoes and Eptam in spring before potatoes. Roundup (Glyphosate) is being used in attempts to control couch and potato groundkeepers jointly, and Aminotriazole is also being tried. The field used for brassicas this year had been treated with Roundup the previous autumn but patches of couch survived and required TCA treatment in the spring. The land which grew potatoes in 1975 was treated with Roundup in June 1976 and then left fallow all season, with periodic cultivations, to allow frost and birds to deal with the remaining tubers. The field intended for potato trials in 1977 was rotosprayed with TCA in June for couch control but potato groundkeepers, tracing to a crop pre-dating our occupancy, emerged and Roundup was applied.

Another problem has been lack of suitable accommodation for both farm and experimental machinery. Most of the existing buildings were constructed in the eighteenth century and are now in poor condition. A recent brick-built shed was converted as a store for potatoes from the experimental plots, and a building incorporating a workshop, office and cereal store for the farm together with a small common room and a work room for scientific staff was completed in 1972. A large implement shed and fertiliser store was completed in 1976 and a glasshouse early in 1977. A reconstruction and development scheme has been prepared and will be carried out as finance for capital work is made available.

In the 1976 season a mild winter was followed by a cold spring, a hot dry summer, a very wet autumn, and frost and snow in December. Total rainfall exceeded that of the previous two years (633 as against 601 and 600 mm) but 39 per cent of this fell in September and October. Cereal yields were good. Winter wheat (13·0 ha) gave 6·5 t ha^{-1} (Atou and Maris Fundin, bulked at harvest). Spring barley (21·0 ha) gave 5·0 (Midas), 4·8 (Maris Mink) and 4·0 t ha^{-1} (Golden Promise), the latter being used only to plant otherwise unusable land. Maris Mink was later ripening than was Midas and may be too late for a normal year at The Murrays. Hay was taken from 12·3 ha and 23·7 ha of grass was let for grazing. As noted above, two major fields were uncropped preceding and following potatoes. No winter wheat was sown this autumn due to a combination of weather conditions and preparations for the drainage programme.

In the experimental potato plantings, Phorate granular aphicide was applied in the drills before covering and Pyracide and Metasystox were applied alternately, at two-week intervals, from mid-June. No aphids were seen after late July and spraying was discontinued in mid-August. Maneb fungicide was incorporated in the last two insecticide sprays. Yields were good and, in spite of the very wet conditions at harvest, the tubers have kept well. Growth of the brassica crops was erratic and time of sowing in relation to the dry period in June and July had a marked effect. Swedes were, on the whole, the crop most severely affected.

G. R. White

Workshop

Meeting the requirements of the Health and Safety at Work Act has required extensive renewal and rewiring of electrical installations, especially in the older glasshouses, and work continued on improving installations which, though safe, show signs of deterioration. All but one of the dwelling-houses owned by the Station were rewired. Guards were fitted or modifications made to moving parts of workshop, agricultural and laboratory machinery. A detached brick building was converted as a store for inflammable chemicals, and a gas-fired incinerator was removed from the main building to a safer place.

Meanwhile, general maintenance of glasshouses, buildings, vehicles and machines together with many requests for repairs and fabrications has occupied a considerable amount of time.

An experimental barley-grinding machine permitting prediction of malting quality has shown some promise but requires further development. A seed-cleaning machine was made for the cereals section. An apparatus devised and built to enable the Chemistry Section to increase greatly the number of samples handled in fibre analysis was successful, and its extension is being considered. Various commercial agricultural machines were modified to meet the requirements of the scientific staff.

Two offices have been constructed in the seed store, and a secure storage area is being contructed there using steel and weldmesh partitioning. A garage has been similarly treated and is being fitted with racks to form a store for wood and metal.

A. E. Hamilton

POTATO BREEDING AT PENTLANDFIELD

J. H. W. HOLDEN

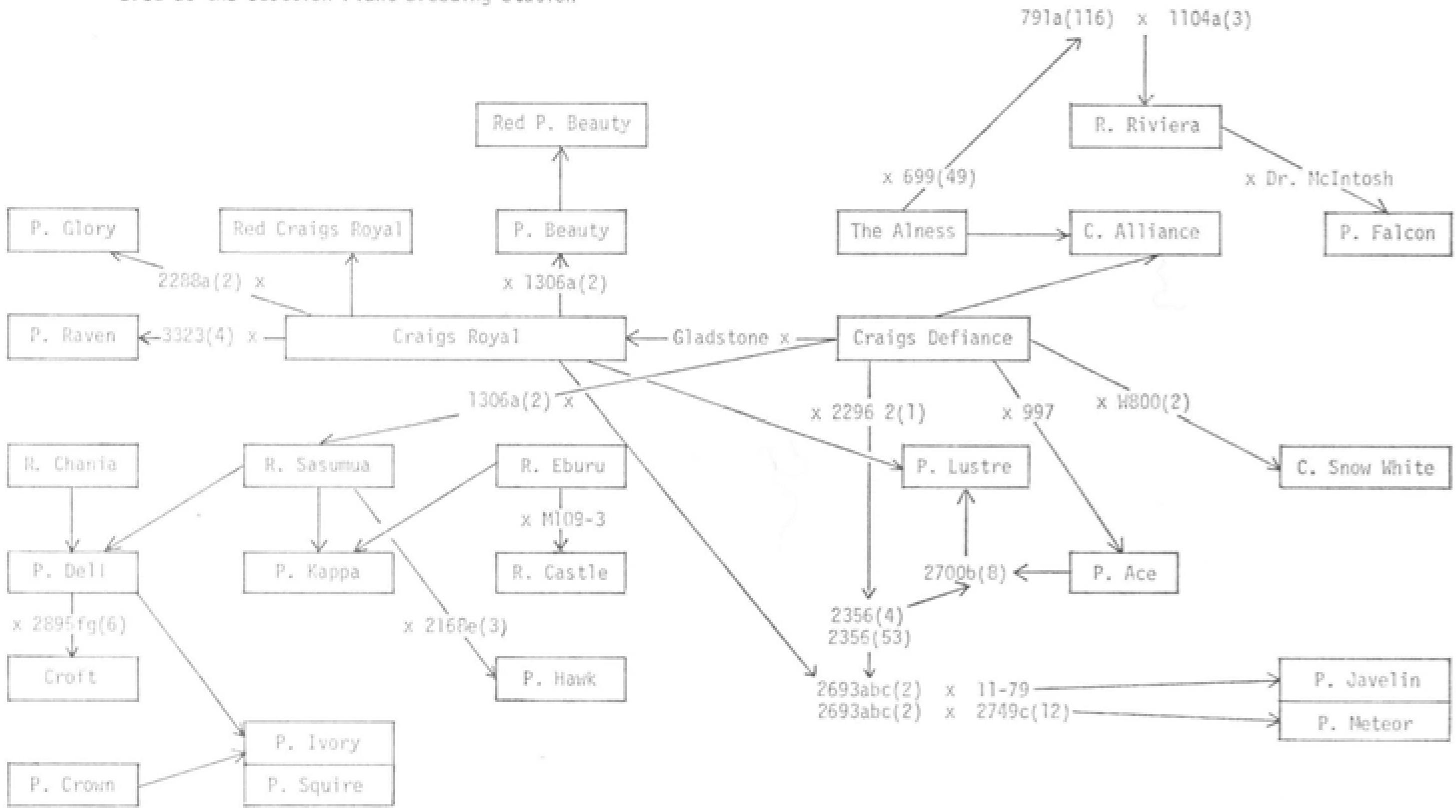
1. Historical

In the fifty-six years since the founding of the Scottish Society for Research in Plant Breeding, the Scottish Plant Breeding Station has bred twenty-four potato varieties for use in the United Kingdom. Their breeding has been described by Black (*Annual Report 1970-71: 52-60*) and their characteristics by Macarthur (1970). The full pedigrees of these varieties are given in the Appendix. Pedigrees of some of those varieties bred at Pentlandfield but selected and named overseas are included where they occur in the parentage of varieties of the Pentland series.

Whereas the early varieties were derived from the crossing of adapted cultivars, Craigs Snow White was the first of many varieties with complex pedigrees involving wild species and exotic cultivars. *Solanum rybinii* (syn. *S. phureja*) and *S. demissum* occur in the distant ancestry of thirteen of the varieties and it is a matter of speculation to what extent they may have contributed to the genotypes of the derived varieties. On the other hand *S. andigena* (CPC 1673), which appears in the ancestries of Pentland Lustre, Pentland Javelin and Pentland Meteor, has made a significant contribution to each variety in that each has inherited the H_1 gene for resistance to pathotype A of potato cyst eelworm, after several generations of back-crossing to Tuberosum forms.

It is interesting to note, however, that despite the complexity of the pedigrees and the use of exotic species and cultivars, with the exceptions of Pentland Marble and Pentland Envoy all the varieties are related to some degree. The relationships are expressed diagrammatically in Figure 3. Craigs Royal and Craigs Defiance have played a major part in the breeding of the Pentland series. Craigs Defiance was the first variety to carry "field immunity" to viruses X, A, B, C and was extensively used as a parent for this reason. It appears as a parent, grandparent or great-grandparent of twelve varieties. Craigs Royal, derived from Craigs Defiance × Gladstone, appears in the ancestries of six varieties and in addition gave rise to the red mutant Red Craigs Royal which rapidly supplanted the parti-coloured original form. Pentland Crown appears only as a parent of Pentland Ivory and Pentland Squire, and is not related by descent to the main body of Pentland varieties. Three varieties derive from crosses in which both parents were SPBS varieties, Craigs Alliance from The Alness and Craigs Defiance; Pentland Ivory and Pentland Squire both from Pentland Crown and Pentland Dell. Two others are from crosses between clones which were subsequently named in East Africa; Pentland Dell from Roslin Chania and Roslin Sasumua, and Pentland Kappa from Roslin Eburu and Roslin Sasumua. The remainder have one or two unnamed clones, or in some cases non-SPBS varieties, as parents.

Fig.3. Diagram of relationships of principal varieties bred at the Scottish Plant Breeding Station



2. Overseas Varieties

The contribution of the Scottish Plant Breeding Station to potato varieties overseas has been summarised by Macarthur (*ibid*) and discussed by Black (*ibid*). The varieties listed by them were all selected in the country of naming from material bred at Pentlandfield. Table 12 lists varieties which are known to have been derived from Pentlandfield-bred material, and includes eighteen varieties in four countries. It may be incomplete since Black (*ibid*) refers to the imminent release of other clones, but no further details have reached us.

TABLE 12

Overseas Varieties bred at Pentlandfield, with Year and Country of Release

Craigs van Riebeek	1949	South Africa
Roslin Chania	1960	East Africa
Roslin Eburu	1960	East Africa
Roslin Elementieta	1960	East Africa
Roslin Mount Kenya	1960	East Africa
Roslin Sasumua	1960	East Africa
Roslin Tsangano	1969	Malawi
Roslin Bvumbwe	1969	Malawi
Kenya Akiba	1969	Kenya
Kenya Baraka	1971	Kenya
Kufri Jyoti	—	S. India
Kufri Moti	—	S. India
Roslin Tana	1974	Kenya
Roslin Athi	1974	Kenya
Roslin Gucha	1974	Kenya
Roslin Ruaka	1974	Kenya
Roslin Karura	1974	Kenya

Apart from their general adaptation to conditions in the countries where they were selected, Roslin Eburu, Roslin Tsangano and all the more recent varieties are characterised by "horizontal" or quantitative resistance to late blight (*Phytophthora infestans*).

India and Kenya have now established their own breeding programmes and are generating their own progenies for selection, but we have more recently established a new collaborative relationship with the official potato improvement programme of Pakistan to whom we annually supply tubers from seedling progenies, for selection in the various regions of that country.

3. Changing Patterns of Varietal Use in British Agriculture

Changes in the national pattern of maincrop varieties have been quite dramatic since 1960. Of the two old dominant varieties, King Edward maintains its place with great stability but Majestic has suffered a rapid decline. In its place are four major varieties; Pentland Crown, Pentland Dell, Maris Piper and Désirée, with other newer varieties such as Pentland Hawk com-

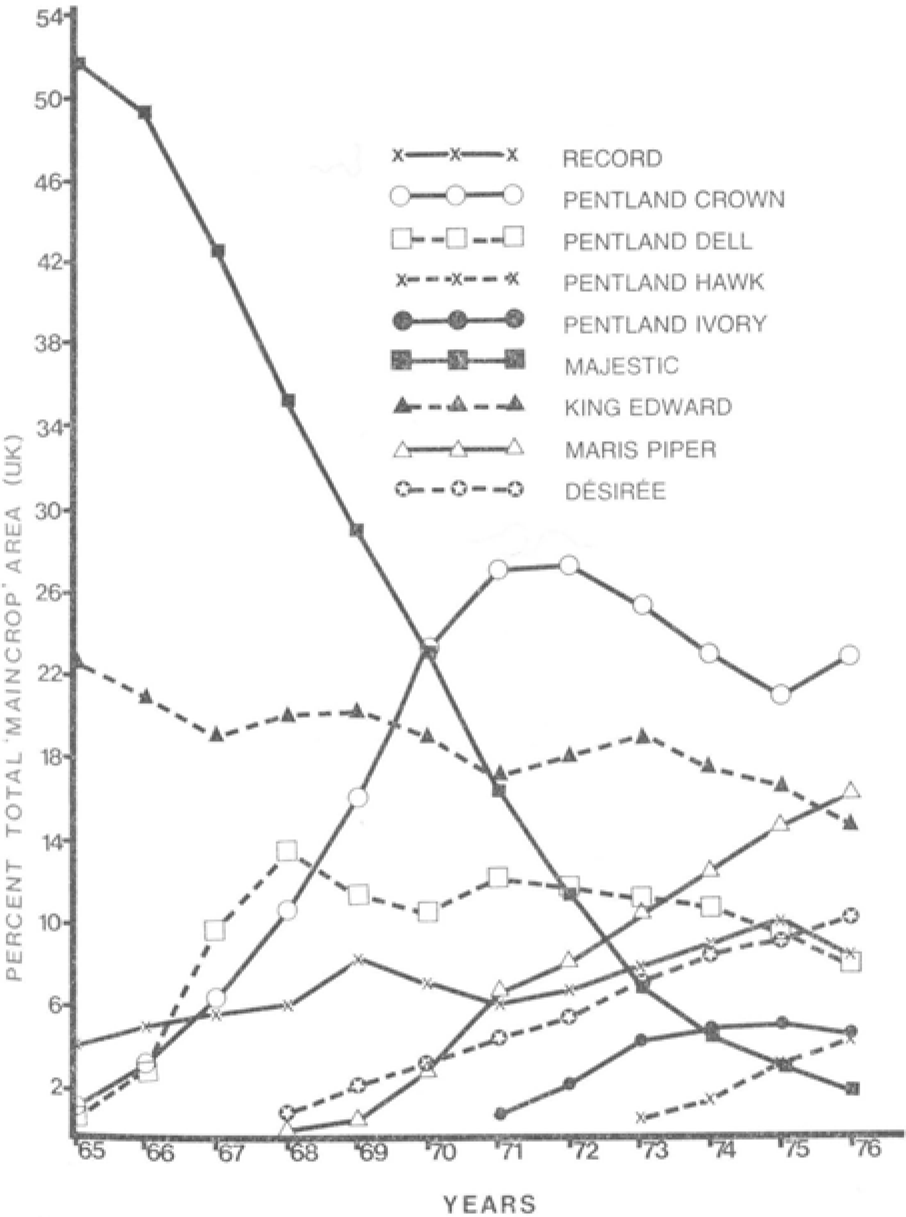


Figure 4. Percentage of the UK total "maincrop" area planted to each of certain cultivars.

peting with them. It seems highly unlikely that any one variety will ever again reach the position occupied by Majestic in the 1940s and 1950s, but rather that six to eight varieties will share the acreage according to the particular attributes which they possess. For example, Maris Piper possesses resistance to pathotype A of potato cyst eelworm. Largely in consequence of this, it has become the dominant variety on the fen peat soils of Cambridgeshire, and such resistance seems to be an essential attribute of any putative successor in this area. Elsewhere the present leading varieties are likely to come under pressure from, and may eventually be supplanted by, newer varieties such as Pentland Squire, Croft and Strath which are still wholly or largely in the seed multiplication phase. However, Pentland Crown, because of its general excellence as a grower's variety, may persist as a major variety for an extended period.

The changing area of the major varieties in the national crop is summarised in Figure 4 for maincrops and Figure 5 for earlies.

In the case of early varieties also, changes have been quite marked in the varietal pattern. In 1965 Arran Pilot, Craigs Royal (with Red Craigs Royal) and Home Guard accounted for 28, 20 and 15 per cent of the UK early acreage respectively. Whereas the area under Home Guard has been maintained, the other two varieties have shown a continuous decline, their place being taken by Maris Peer since the late 1960s, and by Ulster Sceptre since the early 1970s. Two varieties, Ulster Prince and Craigs Alliance, have made a relatively small but consistent contribution.

Craigs Alliance was released in 1948, nearly thirty years ago, and has never achieved any wide popularity. It still occupies less than 5 per cent of the early acreage, and yet its area continues imperceptibly to rise. Evidently, it is held in high esteem by a small group of growers who detect in it particular qualities to meet the demands of their environment or market.

Of the more recent early varieties released by SPBS, Pentland Javelin is now showing a rapid rate of increase and is beginning to make a significant contribution to the national crop.

4. Breeding Strategy

The clear definition of breeding objectives is a prime requirement for the successful prosecution of any breeding programme. This definition should be concerned not only with the breeding objectives to be pursued but also, since resources are inevitably limited, with the ordering of priorities between them. I take it as axiomatic that selection, when applied simultaneously and equally to a wide range of characters, is likely to be ineffective, and, in order to make progress, priorities in selection criteria need to be defined and adhered to. It is to be expected that these priorities will vary in different breeding programmes depending on the particular breeding objectives. For example, resistance to gangrene and other tuber diseases may be more important in a

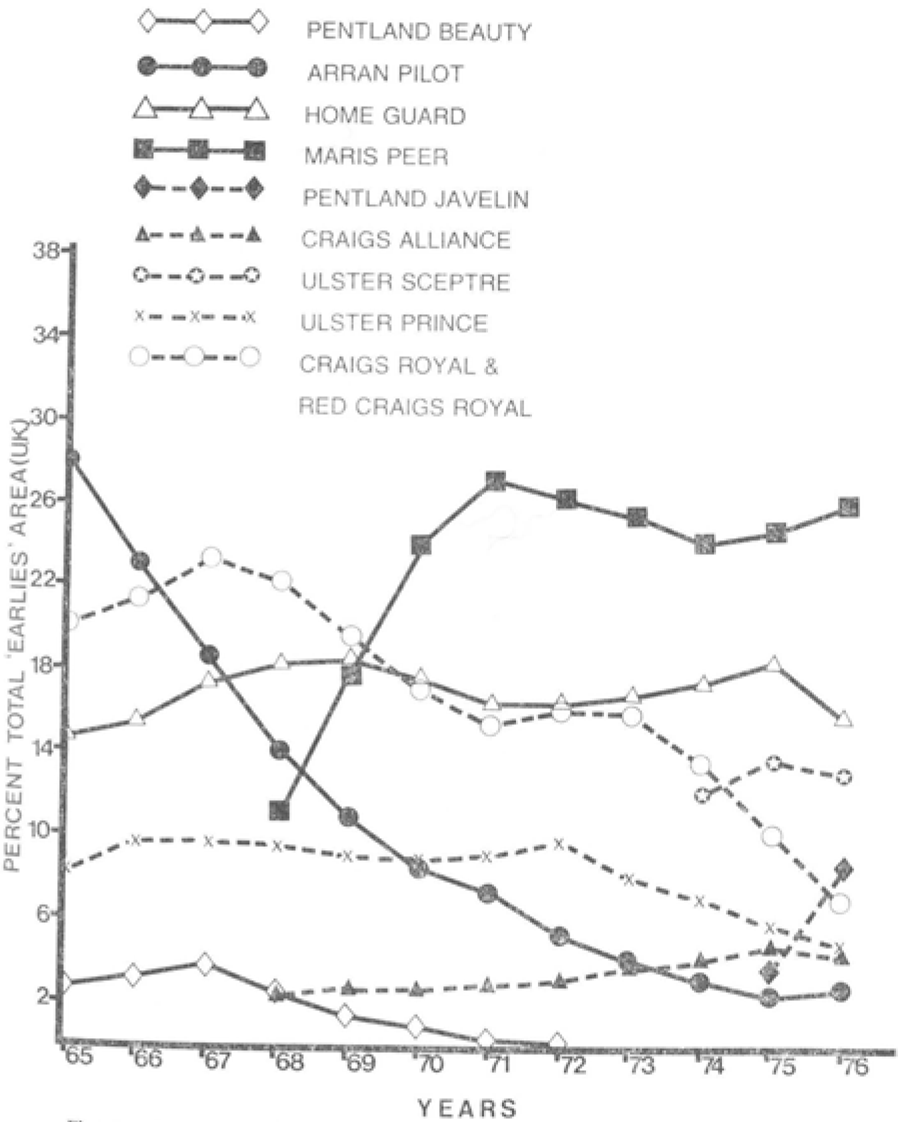


Figure 5. Percentage of the UK total "early" area planted to each of certain cultivars.

programme to breed a maincrop variety for processing purposes, with a capacity for long storage, than in the breeding of a first-early variety. In the latter case it may be sufficient to aim for a variety which has no particular susceptibility rather than one having marked resistance.

However, in the case of tuber yield at harvest, it seems possible to reach a general conclusion which could apply to all maincrop breeding work. Recent experimental studies by ADAS to determine the maximum yields which are possible have shown this to be in the region of 90 t ha^{-1} for Pentland Crown. These values were obtained after careful manipulation of all aspects of management and are close to theoretical predictions of the potential yield from *S. tuberosum*. Pentland Crown was chosen for this experimental work but it is likely that similar yields could have been obtained from other varieties. Contrasted with this experimental maximum yield are, on the one hand, credible reports of high farm yields in the region of 60 t ha^{-1}, and on the other, of a national average which for maincrop varieties had reached only 34 t ha^{-1} in 1974. It seems, therefore, a safe conclusion that production from modern varieties is not being limited by their lack of genetic potential for tuber yield, but rather by other factors which operate to reduce their capacity for expressing their potential. We shall return to consider what these limiting factors are, but first we should take one step further in the consideration of the difference between potential and realised yield. Results of ADAS Blueprint experiments for maximising yields, and indeed the not infrequent reports of exceptionally high commercial yields, are concerned with yields at harvest time. However, 60 per cent of the British ware crop is stored for more than three months and 20 per cent for six months (Church, Hampson and Fox, 1970) and a more realistic assessment of the productivity of a variety could be in terms of its saleable yield. Accurate estimates of losses in store are neither plentiful nor easy to interpret. They are subject to variation from differences in variety, farm, season, and in the grading standards applied. Recent estimates (PMB Report: "Commercial assessment of recently introduced potato varieties. Report on trials and surveys, 1976") show that, when tubers are graded to a high standard for size and freedom from disease and damage, the grading-out percentages for a range of new varieties is in the region of 50 per cent. It may be argued that the grading standards applied are unrealistically high. However, a rising proportion of the national crop is now being graded to these standards and one hopes that the trend will continue as part of a general movement for the raising of the potato in the esteem of the consumer. If, therefore, we compare saleable yields from modern varieties with the experimental and theoretical demonstrations of their potential for tuber production, we are struck even more forcibly by the great disparity between the two, and are confirmed in our conclusion that genetic potential for yield is not a significant limiting factor on potato production. This being the case, there seems to be little point in breeding for even higher yield potential which would in turn be subject to the influence of the same limiting factors on its realisation.

An alternative strategy with a considerable appeal to common sense is to breed varieties which are less subject to the operation of the limiting factors while holding yield potential at the present levels.

What are the limiting factors and which among them are amenable to amelioration through breeding? Assuming first-class husbandry, including irrigation when necessary, the principal limitations on harvested yield are pests and diseases, and a tendency for the highest yields to be derived from late-growing crops. Storage losses are principally due to the single or joint action of mechanical damage at harvest and tuber diseases developing during the storage period. Good quantitative data are scarce on the magnitude of yield reductions due to the various crop and storage diseases, to potato cyst eelworm, and to harvesting difficulties and poor storage characteristics consequent on harvests which have been delayed in an attempt to maximise yields. However the collective experience of the seed, ware, and processing components of the industry enable the breeder to identify, with some confidence, a number of appropriate and worthwhile objectives.

POTATO CYST EELWORM

The pathogen which exerts the greatest limitation on yield is probably potato cyst eelworm, because of the consistency of its effect from year to year and of its widespread dispersal in potato soils of the ware growing areas. There is at present a marked trend for potato production to be concentrated on the better potato soils and it seems inevitable that this trend should have the effect of magnifying the eelworm problem. Varieties with resistance to pathotype E of *Globodera pallida* are urgently needed to supplement those varieties which already possess qualitative resistance to pathotype A of *G. rostochiensis.* This work is well advanced at SPBS using the pathotype non-specific resistance of *S. vernei* and also, and more recently, the so called H_3 resistance to pathotype E derived from Andigena. Chemical control is both expensive and unreliable, the H_1 gene is effective against pathotype A only, and the H_3 gene is now known to show quantitative rather than qualitative segregation patterns and to be effective against pathotypes B and E of *G. pallida* and ineffective against pathotype A of *G. rostochiensis*. Varieties with resistance derived from *S. vernei*, effective against all three British pathotypes, continue to be the most promising approach to genetic control of losses due to this pest. This view is supported by the fact that many populations are of mixed pathotypes and the use of pathotype-specific resistances will inevitably lead to the selective multiplication of that pathotype to which the variety is susceptible. With an assumed multiplication rate of the nematode of about twenty times, *vernei*-derived varieties must exhibit resistances of more than 95 per cent if they are to be of use in reducing eelworm populations without use of nematicides. It seems most likely that the first varieties with *vernei*-type resistance will express it at a level below this critical point and may best be used in conjunction with nematicides in an integrated system of control.

The resistance conferred on a variety by the H_1 gene involves no reduction in the hatching inducing activity of the host nor in the ability of the larvae to invade the root, but is expressed as an interference with sexual differentiation of the larvae which prevents cyst formation. Varieties with such resistance appear to differ in their tolerance to invasion when expressed as the amount of damage caused and of the yield reduction which they suffer thereby, but their principal difference from susceptible varieties is in their effects on cyst populations in the soil; H_1 varieties act as effective population reducers.

It is necessary therefore to make a clear distinction between these two aspects of the host-parasite relationship in current (H_1) resistant varieties; namely, variations in tolerance-intolerance in the host, and the effect on cyst formation. It is not yet clear whether, or to what extent, these two factors are relevant to quantitative, pathotype non-specific resistance, derived from *S. vernei*. An understanding of the nature of *vernei* resistance is necessary in order that the breeding and exploitation of varieties with resistance from this source shall be effective. To this end a research programme is in hand at the SPBS to study the effects of *vernei* resistance on hatching, on larval invasion of roots, on larval development to sexual maturity, on cyst populations in the soil, and of the significance of root damage and of yield reductions resulting from it.

FOLIAGE AND TUBER BLIGHT

This disease is an example of a group of potato diseases including severe mosaic (virus Y), leafroll, common scab, skin spot and gangrene which exhibit irregular variations in severity, related to changes in environmental conditions affecting the dispersal of the pathogen or the establishment of infection. During recent dry years blight has receded in importance, but will no doubt return in the next wet summer to cause yield reductions in imperfectly sprayed crops and storage losses following tuber infections. There is much evidence to show that the expression of resistance in the foliage is not necessarily related to that in the tubers. Therefore, in screening for reaction to the pathogen, foliage and tuber blight must be treated as two separate diseases. Tuber resistance is perhaps the more important, any degree of such resistance being of value though, of course, the higher the resistance the better. Foliage resistance, on the other hand, must be of a high order if spraying is to be safely abandoned. In the absence of spraying, moderately resistant foliage can be expected to support sporulating lesions for lengthy periods and may thereby increase the possibility of tuber infection above that in a variety with fully susceptible foliage. The levels of resistance in both foliage and tubers of clones now emerging from the blight resistance programme are very encouraging, and varieties capable of surviving blight years without spraying seem to be a distinct prospect. These conclusions are based on screening tests conducted in glass-house and field using as inoculum a race of *Phytophthora infestans* capable of overcoming R genes numbers one to eleven. From this fact, and from the presence of occasional sporulating lesions, it seems clear that this type of resistance is not due to R genes even though one or more such genes may be present in some of this material. The field assessments of resistance made in the disease nursery at Blythbank, and even more so in the glasshouse tests, probably underestimate the effective resistance of this material. This is because the small plots in the nursery are frequently in contact with heavily infected foliage of adjoining susceptible clones and are therefore subjected to a higher spore burden than they would be if they were grown as monoclonal agricultural crops. Large-scale farm plots of about 0·5 ha are to be grown in an attempt to measure the agricultural significance of this type of blight resistance.

However, the real question which hangs over this blight resistance breeding programme concerns the permanence of "field" or race non-specific resistance. There is the possibility that, since genetic control of resistance in the host is polygenic, and since only one mating type of this heterothallic fungus occurs in the United Kingdom, the pathogen may be slow to adapt, through the production of new pathogenic forms, to the successful parasitisation of the resistant varieties. One hopes that this may be so, and that the effective life of the resistant varieties may be much longer than was the case with their R gene resistant predecessors such as Pentland Dell. However, it must be said that there is a considerable element of hope in this work. It is without doubt a necessary and worthwhile attempt to control a disease which can be a serious limiting factor on production. Present control measures, based on applying and maintaining a film of tin or copper compounds over the aerial parts of the plant, are both necessary and effective, but in the eyes of the plant breeder do not constitute an economical and desirable solution. He sees the solution in genetic control, but there are doubts about its permanence. There are few examples in other crops of extreme forms of quantitative or "field" resistance which may be used as a guide to the permanence of blight resistance in potatoes. Two factors should be borne in mind however. The first is the severe selection pressure which an extreme resister, when it comes to be grown over a large agricultural area, will exert on the *Phytophthora* gene pool. The second is the capacity which the fungus possesses for the generation of new variability by parasexual means. This capacity has already been demonstrated by the adaptation of natural populations of the fungus to the parasitisation of Pentland Dell, and has been shown experimentally by Malcolmson (1970) in the generation of new combinations of race specificities. With these examples of the versatility of this pathogen in mind one should moderate one's expectations of the outcome of this work, while remaining firmly optimistic.

VIRUS RESISTANCES

Breeding for resistance to the mosaic viruses X, A, B, C and Y presents no particular technical problems to the breeder. Major gene resistances are available; immunity to virus X and its variant B is derived from *S. andigena* and *S. acaule*, and genes conferring comprehensive resistance to all strains of virus Y (including A and C) are available from *S. demissum*, *S. microdontum*, *S. chacoense* and *S. stoloniferum*. Such genes are now widely used in our virus resistance breeding and are present in much of the material. Leafroll resistance however is a different case. Resistance has been located in several old cultivars of Tuberosum and in breeding material derived from several wild species. Its expression is quantitative and its genetic control complex. Pentland Crown possesses a significant degree of resistance to both viruses Y and leafroll, a quality much appreciated by the growers of this variety in recent years. Attempts to breed for higher expressions of leafroll resistance than that in Pentland Crown were frustrated until recently by the difficulty of combining high levels of resistance with good tuber characters and acceptable field performance. This programme seems now to have emerged from its bottleneck and recombinants possessing high levels of resistance and with good tuber characteristics are beginning to emerge. The prospect of a variety with comprehensive resistance to all strains of virus Y, immunity to X and B, and high resistance to leafroll in a background of acceptable field and quality characters, seems a distinct possibility.

COMMON SCAB (*STREPTOMYCES SCABIES*)

The effects of scab on total yield are minimal, but in dry years in crops grown on the lighter soils this disease can exert a marked influence on the appearance and marketability of tubers as high-grade ware. While it may not be realistic to select for high expressions of resistance, it is important nevertheless to select against undue susceptibility. Pentland varieties in general possess good levels of scab resistance which reaches its highest expression in Pentland Crown.

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

This disease is of particular interest to seed producers in Scotland. Effective control measures using vapourised 2-amino-butane or sprays of thiabendazole have been developed recently. However they cannot be said to have solved the problem of gangrene since their effect is to suppress the formation of lesions on the treated tubers and not to destroy the systemic infection. It is important therefore to continue to select for gangrene resistance, particularly so since some of the earlier Pentland varieties proved to be unduly susceptible to the disease. However, some of the more recent breeding material is showing high frequencies of resistant clones and the breeding aspects of this problem seem to be quite straightforward. The problems concern the fungus and our lack of understanding of certain critical aspects of its life cycle, of its epidemiology and of host-parasite relations. The method by which tubers become infected has still not been unequivocally established. The interaction of host varieties and pathogen on the development of stem lesions bearing pycnidia; the part played by the pycnospores in the infection of daughter tubers on the same and on other plants; the possible existence of fungal races differing in pathogenicity; and the significance of other hosts as carriers of *P. exigua* var. *foveata* are examples of aspects of *Phoma* biology about which more information is needed for the efficient planning and execution of a gangrene resistance breeding programme.

WART DISEASE (*SYNCHYTRIUM ENDOBIOTICUM*)

The position of wart disease resistance in the ordering of priorities of selection criteria has recently changed, immunity to wart no longer being an essential requirement for the inclusion of a variety on the national list of approved varieties. The possibility of submitting a wart-susceptible clone for statutory trials may now be considered, if it has other valuable attributes which weigh heavily in its favour. In general, however, it would seem to be prudent to breed from wart resisters and to select in favour of immunity, not as an overriding criterion but as a high priority. It should be said in the context of this discussion that legislation for the scheduling and removal of infected land from potato production has been very effective in containing this disease, and that the widespread cultivation of the non-immune King Edward has not had any detrimental effects on wart control.

SKIN SPOT (*OOSPORA PUSTULANS*)

Skin spot is a good example of a potato disease which is not of high economic importance and yet should not be ignored. The disease is capable of killing tuber eyes—of significance in seed potatoes—and otherwise of reducing grading-out percentages in ware potatoes in years when there is free development of surface pustules. Occasionally these develop to an appreciable depth and their removal causes unacceptably high peeling losses to potato processors. On balance the disease must be considered, and selection practised with a low priority against clones with particular susceptibility.

SPRAING

Susceptibility to spraing seems to be a common feature of Pentland potato material. Spraing is caused by two distinct viruses, tobacco virus rattle (TRV) and potato mop top virus (PMTV). Sources of resistance to spraing caused by TRV are available and where possible will be utilised in the breeding work, but prospects for a rapid change in the position are not good since there is no possibility of discarding advanced material highly selected for other characters in favour of TRV-resistant material which is otherwise undistinguished. However, because severe symptom expression (brown arcs in the tuber flesh) is a serious disadvantage in a variety, all clones in the later stages of the selection sequence are screened by growing them on infected ground, permitting selection against those showing marked susceptibilities.

In this case as in that of all the other diseases discussed above, complex evaluations have to be made of clones which show less than perfect expressions of resistances and of all other characters under selection. The basic assumption is, of course, that the perfect variety cannot be achieved and that progress will result from the production of a series of varieties where each succeeding one represents a degree of advantage and improvement over its predecessors. In arriving at these integrated value judgements, resistance to diseases such as gangrene, skin spot, common scab, spraing and wart would be considered along with foliage and tuber characters, cooking and processing qualities. The relative importance to be attached to each character in the long list which has to be considered will vary somewhat according to the purpose for which the variety is being bred; after-cooking blackening may be a more serious fault in a table variety than in a potential crisper; deep eyes may be a serious disadvantage to both but shape may be of economic significance to the crisper but little more than a fancy point in a table variety.

We would seek therefore to achieve at least a moderate level of resistance to all these diseases with, in certain cases such as gangrene resistance in a potential processing variety which would have to be stored for long periods, a positive selection for a high expression of resistance. Except for such special cases, resistances to these diseases may be regarded as part of the general spectrum of necessary attributes for any successful new variety.

Blight, virus and eelworm resistances fall into a special category in that each is the principal breeding objective of a distinct and long-standing part of the SPBS breeding programme. Therefore each, within its own context, should be accorded a high priority as a selection criterion. We can thus envisage the release of varieties which possess, as an outstanding feature, high expressions of resistance either to leafroll (associated with field immunity to viruses X and Y), or to blight in foliage and tubers, or to the three pathotypes of potato cyst eelworm. These major disease resistances are seen as alternatives at this stage of the breeding work, though each will be associated with moderate background resistances to secondary diseases or, at worst, absence of particular susceptibilities. The varieties must also have suitable expressions of field, quality, and processing characters and a genetic potential for tuber yield equivalent to the current leading varieties. This approach is based on the belief that such varieties can do more in the long term, to raise production and profitability, than such as would result from a concentration of effort on the probably simpler objective of breeding principally for increased tuber yield potential. A clear recognition of blight, virus and eelworm resistances as alternatives, and a strict adherence to the defined priorities, should lead not only to specialist varieties with single qualitative disease resistances, but also to the establishment of three bodies of breeding material in which each resistance is widely expressed to a high degree. In a later phase it may become possible to consider the production of varieties with multiple resistances, but such a prospect seems highly speculative at the moment.

While the principal objective of this approach to breeding is to raise the saleable yield of high quality tubers it should also, in so far as it overcomes the operation of limiting factors which vary in their effect from year to year, contribute towards greater stability of production from the national crop to the benefit of both grower and consumer.

The production of varieties for specialist uses is an appropriate topic to consider in relation to breeding strategy. A review of the requirements of the processing industry reveals little to encourage the breeder to devote more effort in this direction.

POTATOES FOR PROCESSING

A specialised canning variety, Pentland Marble, has been available for some time. Despite its excellent canning characteristics it is little used, and much of the material which is canned consists of undersized tubers from conventional varieties. It is difficult to envisage any major development in canning potatoes until the problem of taint has been overcome, and until canned potatoes really do possess what is widely recognised as "new potato" flavour. Since flavour chemistry is a notoriously difficult field, it is unlikely that a major biochemical research effort will be mounted to solve this problem while the quantity of canned potatoes remains so small. Further breeding effort is therefore unwarranted.

Varieties for the production of frozen chips already exist in Pentland Squire, which was released partly because of its very good performance in processors' assessment trials, and Pentland Hawk which has the required capacity for long storage. The other requirements of processors are related to tuber quality expressed as low enzymic browning, freedom from diseases (discussed above) and from mechanical damage, and as good shapes with shallow eyes to facilitate peeling. All are connected with the reduction of peeling losses and of the waste of raw material. The conclusion seems to be that, in general, a good variety for fresh consumption will be a good variety for frozen chip production also. The adoption of the breeding objectives discussed above, in relation to dual-purpose varieties, should lead in the long term to greater stability in production and thus permit greater precision in the placing of contracts, planning of supplies, and in the operation of production lines and as such will doubtless commend themselves to the processing industry.

The needs of the crisp producers, on the other hand, do require a variety which differs in a number of important respects from those of a conventional variety for fresh consumption. The principal needs are high dry matter content and low reducing sugars, low free amino acids and high tuber yield, but good storage characteristics including high resistance to gangrene are also important. These objectives are being pursued in a special breeding programme at the SPBS. However, the best crisping clones to date are products of the programme for breeding dual-purpose varieties. They have high dry matter contents and produce pale crisps. More extreme expressions of these characters are not needed and, for this reason, further crossing for the production of specialised high specific gravity progenies has been discontinued.

Finally, the needs of the producers of potato powder and flake for instant mash seem to be non-specialised and to centre mainly on a supply of cheap raw material. No particular breeding objective can be discerned here beyond those already discussed in relation to dual-purpose varieties, that is, disease-free tubers with shallow eyes and good storage characteristics.

It seems, therefore, that the various special needs of potato processors, in so far as they can be discerned, can be met from the programme for the production of dual-purpose varieties. Special breeding efforts appear to be unnecessary, at least at the moment, but the situation should be kept under review.

MECHANICAL DAMAGE

Breeding for resistance to mechanical damage is a much discussed subject about which very little has been done. The reasons for this inactivity are several. They include a lack of understanding of what constitutes resistance to external cuts and abrasions and internal bruises, and a perhaps unworthy suspicion in the minds of breeders that if, after much effort, a damage-resistant variety were produced, the consequence would be that engineers and growers would design and operate machines to work at a faster rate and thus nullify the breeding effort. However, the principal reason is a lack of resistant varieties which could be used as parents in a breeding scheme. Reports are appearing ("Commercial assessment of recently introduced potato varieties. Report on trials and surveys, 1972" (PMB)) of the lower frequency of damage and the superior storage characteristics of Pentland Hawk, but it has yet to be established whether this is due to damage resistance or to disease resistance and, if the former, what tuber characteristics are involved. While recognising the value of such a character in reducing losses from the harvested crop, the prospects of doing any effective breeding work are unpromising.

FIRST-EARLY VARIETIES

The area of the specialist first-early crop is small but the crop is of great importance to those growers who produce it. The characteristics of a successful first-early are well defined, relatively few in number, and quite distinct from those of maincrops. They include a relatively low tuber number such that, with fewer physiological sinks, tubers reach a saleable size earlier; early tubering; resistance to wind damage; ability to grow at low temperatures; early sprouting but not excessively so (as in the case of Home Guard); good flavour; absence of after-cooking darkening; and absence of particular disease susceptibilities. The existing SPBS early varieties have all emerged as segregates of the maincrop breeding programme, but in 1973 purposive breeding of first-earlies began. This is a small self-contained programme and it is intended that it should continue. Early potato production is, incidentally, the one aspect of UK potato production which could expand—at the expense of Mediterranean imports. There is a particular problem in the evaluation of clones in yield trials due to the marked effect of the "physiological age" of seed on the earliness of tuber production. This requires not only that selection and assessment be conducted in the areas where the crop is to be grown, but also that the seed used should have been produced for the purpose in the south. This aspect of the work is carried out in collaboration with the University College of Wales, Aberystwyth, on farms in Pembrokeshire and Glamorgan, and also in south-west Scotland.

5. Widening the Genetic Base of Tuberosum Breeding

Two strategic breeding projects have been in operation at the SPBS for some years. The first is founded on South American cultivated tetraploids—Andigena potatoes, the second on cultivated diploids.

STRATEGIC BREEDING INVOLVING ANDIGENA (NEO-TUBEROSUM)

The origins of the Andigena work, its methods and progress to the development of Neo-Tuberosum forms, is described by Simmonds (*Annual Report 1968-69:* 28-31). Since his review further progress has been made in improving yield, tuber size, shape and quality, and the best clones emerging from this work when hybridised with Tuberosum parents are yielding F_1 progeny which are at, or close to, the commercial level. Thus the first phase of this work as defined by Simmonds, namely the upgrading of the population in day-length adaptation and tuber characters, appears to be complete or nearly so. The F_1 hybrids from Tuberosum × Neo-Tuberosum have been of very encouraging yield and quality. Their production has been a tentative exploration of the potential of Neo-Tuberosum which is known to include also resistances to blight, gangrene, common scab and viruses X and Y.

The general worth of Neo-Tuberosum has thus been encouragingly demonstrated, and it seems appropriate at this point to recognise two further stages in the development and utilisation of this material. Stage two should be a thorough exploration and evaluation of the genetic resources and breeding value of Neo-Tuberosum, and should begin in the immediate future. However, the problems of how to evaluate and of what characters to look for are matters to which considerable thought should be given in the planning stage. Evaluation must of course be made in relation to the deficiencies of the genetic resources of conventional Tuberosum breeding material, but also, and perhaps more important, in relation to any long-term changes in breeding objectives, production methods or utilisation of the crop which may be foreseen. It would be too easy to partially evaluate selected clones drawn from the population, and to selectively eliminate some for which a more careful consideration would have revealed a particular function in future breeding. It is not wise to assume that such a loss could be made good by a return to the mass selection population, since we know that much selfing is taking place and that its genetic diversity is diminishing. This is not to argue that, given sufficient thought, it is possible to plan an evaluation programme which will take into account all possible demands that could be made on Neo-Tuberosum in the future, but rather that the potential value of this material and its significance to potato breeding is so great that, through prudent planning, we should make our evaluation as thorough and imaginative as our resources allow. Stage three would then be the exploitation of this material in commercial breeding based on its known potential from stage two. Two strategies seem possible, the production of Tuberosum × Neo-Tuberosum hybrids to meet conventional breeding objectives; and, alternatively or additionally, the production of Neo-Tuberosum × Neo-Tuberosum varieties where novel types of potato crops are required for new purposes. With changing patterns of agricultural production at home, and changes in the world supply of agricultural staples, the need for varieties for starch production or for stock feed, while not relevant today, may emerge in the future. Indeed, a review of the potential of the potato, based on the greater diversity of Neo-Tuberosum, may itself influence the development of new uses.

STRATEGIC BREEDING WORK AT THE DIPLOID LEVEL

This work began slightly later than the comparable programme at the tetraploid level which led to the production of Neo-Tuberosum. It follows the same general principle of upgrading the starting population, in this case of South American cultivated diploids, by a process of recurrent mass selection in order to increase the level of performance and of adaptation to British conditions. The rate of response to selection has been most encouraging and some of the best clones are giving total tuber yields close to those of Tuberosum tetraploid varieties.

Subsequent to the setting up of the diploid mass selection scheme, work began on the production of, and breeding from, dihaploids from a range of British and European cultivars. The origins of this work are described by Simmonds (*Annual Report 1968-69: 34-36*). There is now a considerable collection of dihaploids at Pentlandfield. Recently there has been a concentration of effort on the production of dihaploids from Tuberosum breeding clones with particular attributes, such as high expressions of quantitative resistance to foliage and tuber blight or to potato cyst eelworm.

There are two ways in which each of these groups of material may be utilised. The diploid mass selection population can be regarded as a source of genetic variation for the enrichment of the Tuberosum gene pool. When this material has reached an appropriate point in the upgrading process it should be subjected to a similar process of systematic evaluation to that proposed for Neo-Tuberosum, to be followed later by a stage of exploitation at the tetraploid level.

General experience of the levels of productivity of primary and secondary dihaploids indicates that they are unlikely to be utilised as crop varieties. They seem much more likely to make a contribution by providing a relatively quick and simple way of constructing particular genotypes at the tetraploid level. Dihaploids produced from resistant tetraploid clones are screened and the most resistant among them are restored to the tetraploid level by colchicine treatment. Results from the first attempts to enhance expressions of blight and eelworm resistance in this way are very promising, but it should be stressed that this work is still in an exploratory phase.

There is also the possibility that each group—diploids and dihaploids—may contribute to potato production at the twenty-four-chromosome level. It may be possible to produce varieties by hybridisation of selected diploids and dihaploids, where the vigour and sexual fertility of the former should complement the superior tuber shapes and size distributions of the latter. However, it is too early yet to make confident predictions of how this material will finally be exploited. It is still in the phase of speculative or exploratory breeding. Both it, and the rather more advanced Neo-Tuberosum programme, should be regarded as reservoirs of genetic resources whose capacity and diversity have to be understood before their utilisation can be sensibly and effectively planned.

6. Breeding Procedures

Since the Station acquired The Murrays farm in 1971, field evaluation of breeding material has been made in East Lothian while healthy stocks have been maintained and multiplied at Blythbank.

Seedlings are grown as pot plants in aphid-screened glasshouses at Pentlandfield. A tuber from each selected seedling is the foundation of each clone. All further growth is in the field; for the first two years at Blythbank only, subsequently at Blythbank for multiplication and at The Murrays for evaluation and selection. The Murrays plots are planted with seed supplied from Blythbank plots. The evaluation in The Murrays plots continues for four years and is accompanied by screening for disease-resistances, cooking and processing qualities, at appropriate times and places during this period. Up to this point the selection process will have lasted seven years and will usually have resulted in the selection of some five to ten clones from an input of more than 100,000 seedlings in year one. Henceforth, these clones will be grown for some further years in fully replicated trials grown by courtesy of the Agricultural Development and Advisory Service at the Experimental Husbandry Farms at Terrington, Mepal and Gleadthorpe on silt, fen peat and gravelly-sand soils respectively. A fourth trial will of course be grown on the medium-loam soil of The Murrays. This will permit further selection among them, and ensure that potential new varieties entered into the statutory trials procedure and the VTSC multiplication scheme will be supported by an adequate body of quantitative data on yield, on stability of performance, and on the various disease resistances. In the case of disease scores, this point will apply particularly when either blight, leafroll, or eelworm resistance has been a major breeding objective and will be based wherever possible on a thorough evaluation under field conditions as well as controlled glasshouse or laboratory tests. Published data on field trial techniques for evaluation of potato clones is very scanty, and the new trials procedure will be accompanied by experimental work on optimum plot sizes and shapes and the value of border rows. This should provide us with very necessary information on how to improve the precision of our field trials.

This critical evaluation of methods is already in hand in relation to techniques for inoculation, incubation and scoring for the various disease resistance assessments. The recently completed controlled environment cabinets are a major step forward in the struggle for precision, and should lead to a marked improvement in the quality of the data on gangrene and skin spot. However, much remains to be done in respect of other diseases; a speeding up of the pot test methods for estimating quantitative resistance to potato cyst eelworm, and the devising of an alternative to the present unreliable field test method of assessing common scab resistance in the plots at Archerfield, are two examples which spring to mind. However, greater precision is not the only objective in the attempt to improve screening methods for disease resistances. It is highly desirable that the tuber numbers required for current tests for gangrene, skin spot, and blight resistances be reduced from twenty-five to ten or less in order to increase the number of different clones which can be screened. It seems likely that there will be a need to increase the scope of the disease assessment work as part of the exploration stage of the Neo-Tuberosum and the diploid breeding programmes.

Evaluation work on elite clones from the Neo-Tuberosum and diploid mass selection schemes has been hampered until recently by severe losses due to virus infection. This material was assessed and maintained at The Murrays, where control through roguing was incapable of preserving valuable clones from the activities of viruliferous aphids. Henceforth, stocks of elite clones from the mass selection and pedigree breeding schemes, both diploid and tetraploid, together with the dihaploid collection, will be maintained in a healthy state at Blythbank and their future thereby assured until they are discarded by decision of the breeder. Stocks of clones and varieties required for research purposes will be maintained in the same way. Meristem culture provides a doorway through which valuable research material, though previously virus infected, may safely be admitted to Blythbank.

7. Breeding Plans

The discussion so far on the subject of breeding procedures has centred on aspects of selection and the methods used. However, of equal if not greater significance in any breeding programme is the basic question of how to choose parents and, having chosen them, how to use them.

Choice of parents at the present time is principally based on their appearance and performance. Favoured clones are crossed in the hope that their progeny, or some of them, may be better than the parents. The assumption is that, in respect of any one character, the parents will show a high level of general combining ability (GCA) and that genetic control of the character is due mainly to additive gene action. This may be true for certain characters and for certain parental combinations, but is not necessarily so for all characters nor for all parental combinations. For example, Killick and Malcolmson (1973) report the occurrence of special combining ability (SCA) for foliage blight resistance. In this case the breeding worth of the two parental clones could not have been predicted from their own blight resistances, which were lower than that of their progeny mean. Research work in hand at the moment is designed to provide estimates of GCA and SCA for a range of characters, and genetic correlations between them, from a sample of thirty-three clones. This sample, admittedly small in relation to the scale of the breeding work at Pentlandfield, is expected to provide some valuable guidelines to the choice of parents and the planning of the breeding work in a purposive, less subjective, and therefore more effective manner. The number of clones which can be investigated is limited by the four-year duration, and the scale, of these experiments. Earlier attempts to utilise material which was grown as part of the breeding work failed because the normal selection procedures reduced the family sizes below acceptable levels and introduced bias. The families must be specially grown, therefore, and multiplied without selection. The bulks of material which have to be handled in the fourth year are considerable, limiting the number of parents under investigation. In the evaluation of maincrop Tuberosum breeding material some forty selection criteria are considered with, of course, differing orders of priority. In breeding programmes of this complexity it is imperative to make full use of every technique which will assist the breeder to reach the most informed decisions, particularly on such a crucial matter as the making of breeding plans. In summary, therefore, the need is recognised for a greater scientific input into parental selection and into assessment of yield and disease resistances, and progress is already being made along these lines.

8. Future Developments

Yield of tubers in potatoes may be regarded at one level as a measure of the interaction of physiological, anatomical and morphological features of the plant and, at another level, of the action and interaction of different components of the genotype. Attention which is given to characters such as height, habit and amount of foliage, tuber number, tuber size distribution and dry matter content during the selection process is primarily related to their significance to the grower or consumer, and not to their significance as components of the interacting complex which finally determines tuber yield. Yield is measured directly as weight of tubers of ware size. This direct approach has the merit of concentrating on the end product and of avoiding the formidable difficulties inherent in any attempt to understand and select for favourable expressions of the components of yield. It is, however, a very blunt instrument with which to dissect the various yield components through discriminative selection. Its function is simply to discriminate between clones which may differ, for reasons which are largely unknown, in their yield of ware-sized tubers.

It is argued above that the most pressing need, at present, is to breed varieties which are less susceptible to the various limiting factors which hold down yields. The programme outlined above represents a major attempt to do this, and most aspects of the work are well advanced. If one assumes a successful outcome we shall then, of course, be growing varieties which, though greatly improved, are still imperfect, particularly in their growth pattern. This defect is evident in Pentland Crown, the highest yielding variety, which has the ability to continue dry matter accumulation until late into the autumn and which, of course, tends to produce its highest yields from the late growing crops. Attempts to maximise yields by capitalising on this character are fraught with considerable risk in a wet autumn, when difficulties with harvest and storage will ensue. The ideal variety will of course represent a remarkable assemblage of ideal character expressions and will never be achieved. However, high on the list of breeder's objectives should be the changing of growth patterns so as to produce a variety with the maturity of a second-early and the yield of Pentland Crown. Encouraging indications that this may not be too fanciful an ideal come from the work of Allen (1977) who, by appropriate management of seed tubers and planting date, recorded yields of 54 t ha^{-1} of Maris Piper by 15th August. These yields were from early March plantings in the mild climate of west Wales, but they point to the advantages to be gained by an early-developed leaf canopy able to make maximum use of the long days and high light intensities in May and June. Crops grown in the west will of course always enjoy a climatic advantage over those grown in the main ware producing areas of the east. Nevertheless, so long as we grow frost-sensitive potatoes in the east it seems both appropriate and necessary to consider what might be done, by breeding, to mould the phenotype so as to advantageously change the growth pattern within the climatic constraints.

Some physiological aspects of growth and yield which are relevant in this connection are:

(1) the definition of the ideal leaf canopy in terms of rate and time of development; the optimum leaf area index; the effective functional life of a leaf which in turn relates to frequency of renewal, and the attitude angle of leaves and leaflets in the ideal canopy;
(2) the physiology of tubering including the control of tuber number and the time and duration of tuber initiation, these factors having a major influence on the size distribution of tubers and the percentage of yield wasted as unsaleable chats;
(3) the physiology of senescence. Rapid senescence, assuming that the onset begins at an appropriate time, could well be advantageous as a means of reducing pre-harvest defoliation work and particularly of enhancing abscission layer formation between stolon and tuber.

Physiological studies of these components of yield and growth pattern should permit not only the construction of a model of an ideal potato variety for the main ware producing areas, but should also facilitate the breeding and selection of the variety by directing the attention of the breeder to those components and their levels of expression which are optimal. In this connection the broader genetic base and phenotypic spectrum of the Neo-Tuberosum and diploid mass selection populations may be of considerable value as a source of parental material.

Another important aspect of physiology in relation to yield is stability of performance. Variability of performance from year to year and site to site is a characteristic of potato varieties, not only in yield but also in other tuber characters such as dry matter percentage, texture, and discoloration after cooking. While much of this variation can be related to the influence of environmental factors, the important point is that some varieties seem to be less variable than others in the same range of environments. There is a body of practical experience which suggests that this is so, but there is little understanding of its causes. Some measure of the difference between clones in their consistency in yield may emerge from appropriate treatment of data from yield trials, and if experience is thereby substantiated, the control and physiological manifestations of the character will merit more thorough investigation.

Acknowledgement: It is a pleasure to acknowledge the help of my colleagues A. W. Macarthur and D. R. Glendinning, who provided much of the information from which the pedigrees were prepared.

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APPENDIX

The following schemes show the pedigrees of twenty-four SPBS varieties released for use in Britain and of three others, bred here but released in East Africa, which occur in the ancestries of the British varieties.

Variety	*Year*	*Scheme*
The Alness	1934	1
Craigs Defiance	1938	1
Craigs Royal*	1947	1
Craigs Snow White	1947	2
Craigs Alliance	1948	1
Pentland Ace	1951	9
Pentland Beauty*	1955	4
Pentland Crown	1958	5
Pentland Dell	1960	4
Pentland Envoy	1961	5
Pentland Falcon	1962	6
Pentland Glory	1963	7
Pentland Hawk	1966	8
Pentland Ivory	1966	5
Pentland Javelin	1967	11
Pentland Kappa	1967	4
Pentland Lustre	1968	9
Pentland Marble	1970	12
Pentland Meteor	1970	11
Pentland Squire	1970	5
Pentland Raven	1970	3
Croft	1974	10
Roslin Riviera	1961	6
Roslin Castle	1965	3
East Africa:		
Roslin Chania	1960	3
Roslin Eburu	1960	3
Roslin Sasumua	1960	4

* There also red variants of the parti-coloured varieties Craigs Royal and Pentland Beauty.

The pedigrees of these varieties trace to twenty-six initial parents used in the SPBS programme. These consist of:

(*a*) Twelve British cultivars of which nine are, so far as is known, derived entirely from earlier British cultivars, these nine being Majestic, Gladstone, Flourball, Immune Ashleaf, Witchhill, Kerr's Pink, Shamrock, Maud Meg, and Southesk. Two of the others, Abundance and Epicure, each have Magnum Bonum as one parent and the latter was derived, either by natural pollination or by crossing with Paterson's Victoria, from the American variety Early Rose (Salaman, 1926). Early Rose was a seedling of Garnet Chili (Folsom, 1945) which in turn was derived from Rough Purple Chili, introduced to the United States by Goodrich in 1851 from Panama but believed to be Chilean in origin (Goodrich, 1863). The twelfth British cultivar, Dr McIntosh, was obtained by back-crossing a hybrid between Herald and *S. rybinii* to Herald.

(*b*) Four non-British cultivars of which three, Pepo, Bismark and Aquila, were of European origin while the fourth, Katahdin, bred in the USA, had a British, a Polish, and two American grandparents (see Scheme 13).

(*c*) A breeding line, W800(2), developed by J. H. Wilson at St Andrews, Scotland, and given to the SPBS over fifty years ago. Its pedigree (Scheme 14) involves four wild species and represents one of the earliest attempts to utilise such material in potato breeding (see page 120.)

(*d*) A breeding line, 11-79, developed in Australia by Bald and Hutton utilising mainly American breeding material. Its pedigree (Scheme 13) includes a Chilean importation, Villaroella, as well as the variety Katahdin mentioned above.

(*e*) Three lines selected for field-resistance to blight in Mexico from European and North American breeding material. One, M.Ru.18, presumably derived from Russian material while the origins of the others, M.109-3 and M.136-6, are unknown. All three may have had *S. demissum* in their ancestries.

(*f*) Three accessions of South American cultivated potatoes; two of the diploid *S. rybinii* (a variant of *S. phureja*) obtained from Russia (Ru.159) and from the Commonwealth Potato Collection (CPC.979), and one of the tetraploid *S. andigena* (CPC.1673).

(*g*) Two wild species, *S. demissum* and *S. salamanii*. *S. demissum* was used twice (both Scheme 3), the particular accession not being indicated in either case, suggesting that only one was available at the time (in the 1930s). *S. salamanii* (CPC.23) is a natural hybrid between *S. demissum* and a Mexican cultivated potato.

In the schemes, a double-shafted arrow indicates a selfing. Cross-references between schemes are indicated thus: [1].

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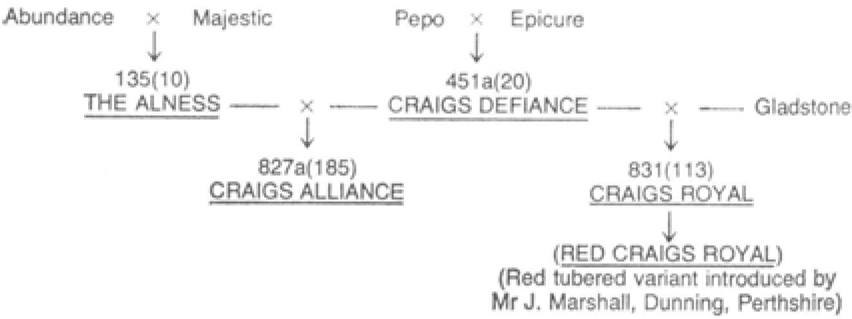
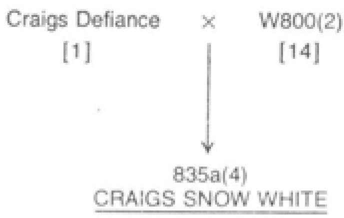
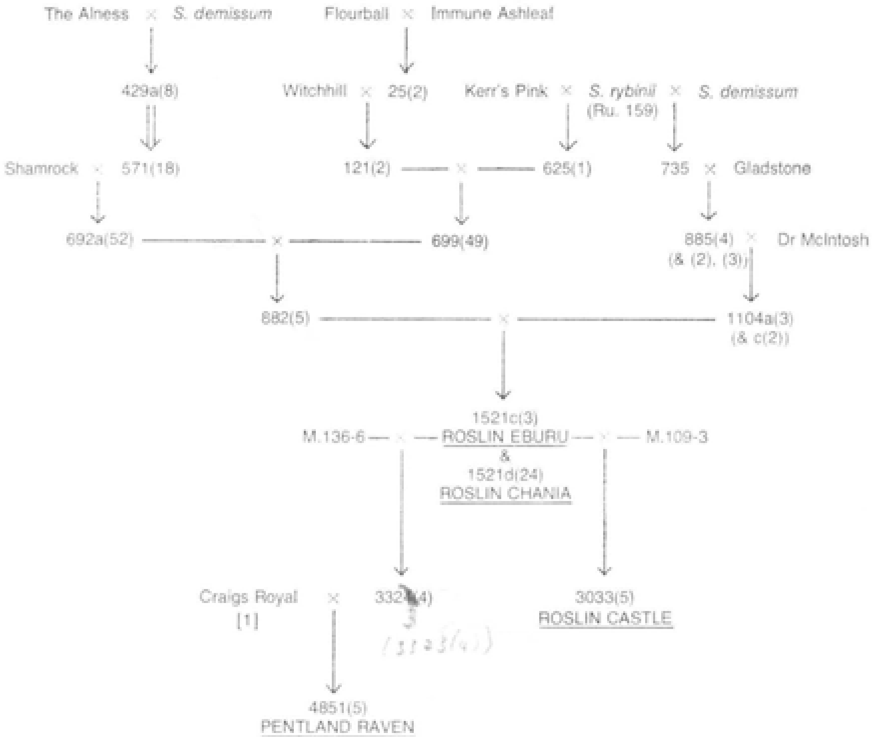
Scheme 1



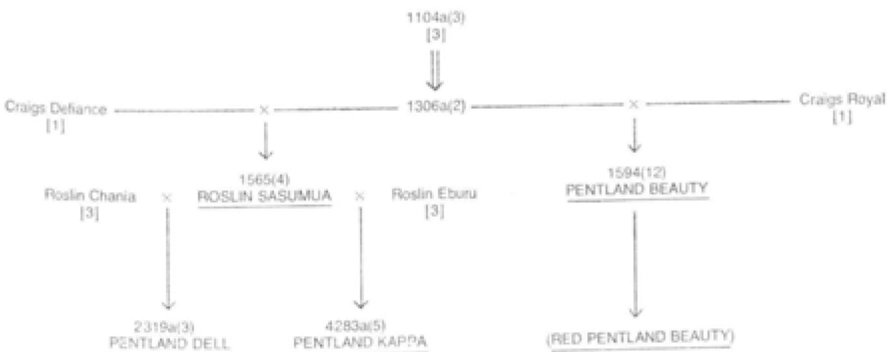
Scheme 2



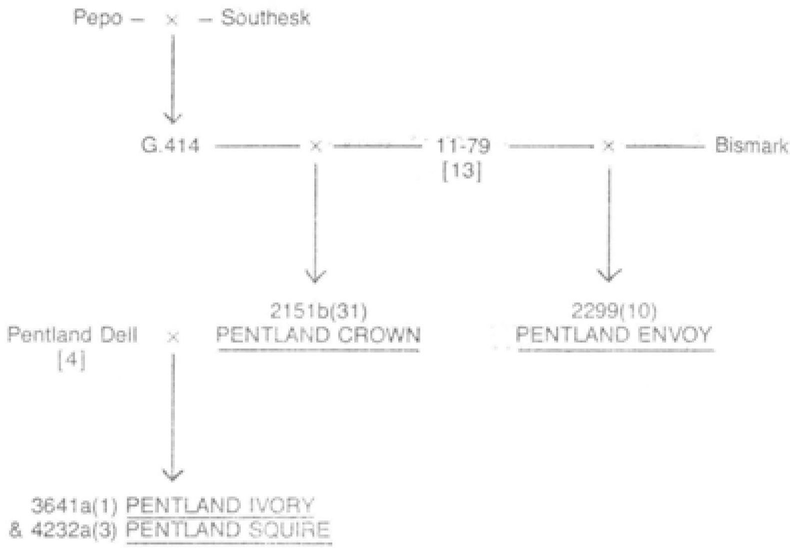
Scheme 3



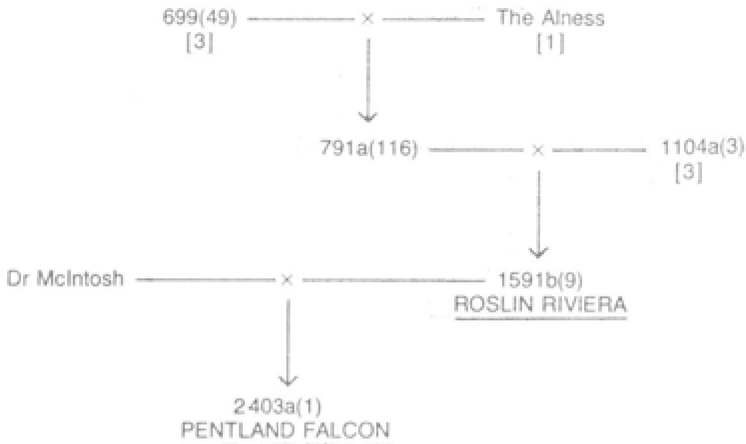
Scheme 4



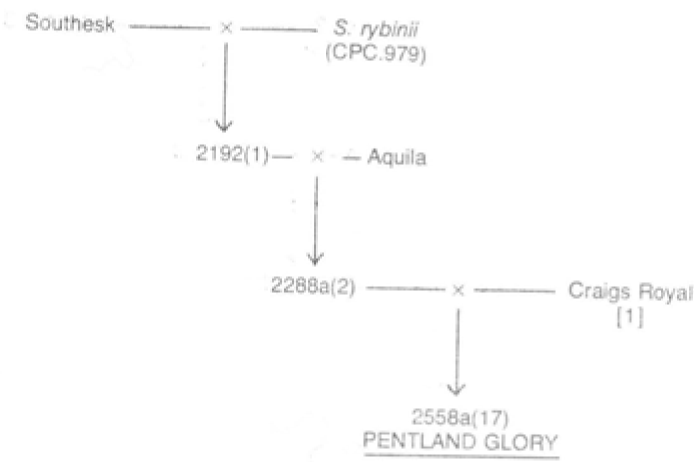
Scheme 5



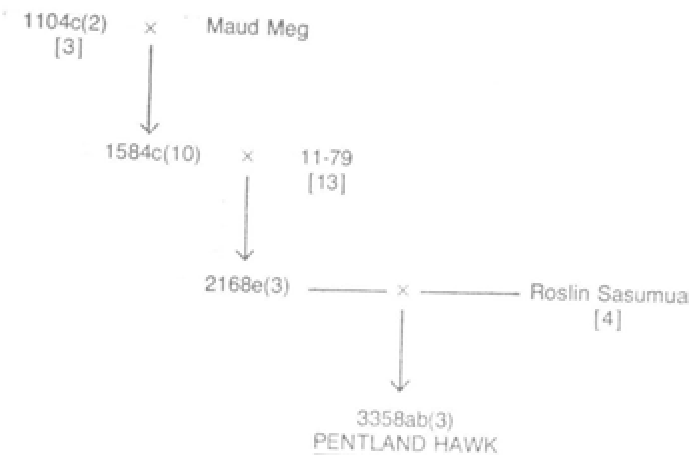
Scheme 6



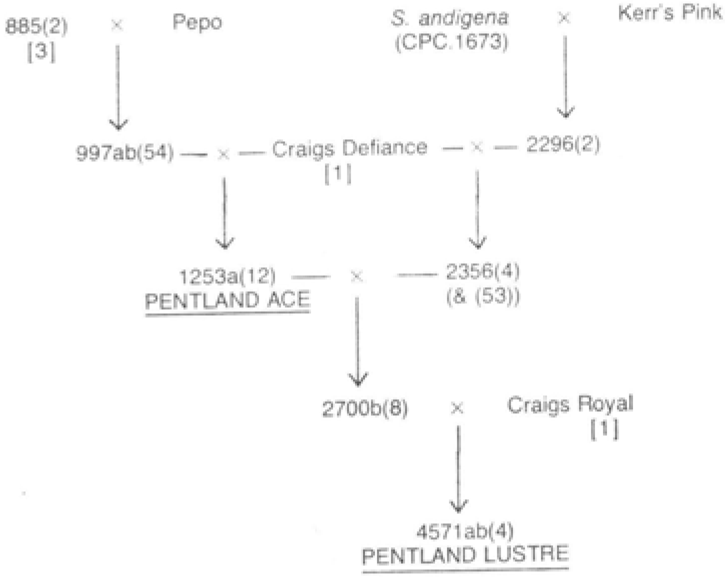
Scheme 7



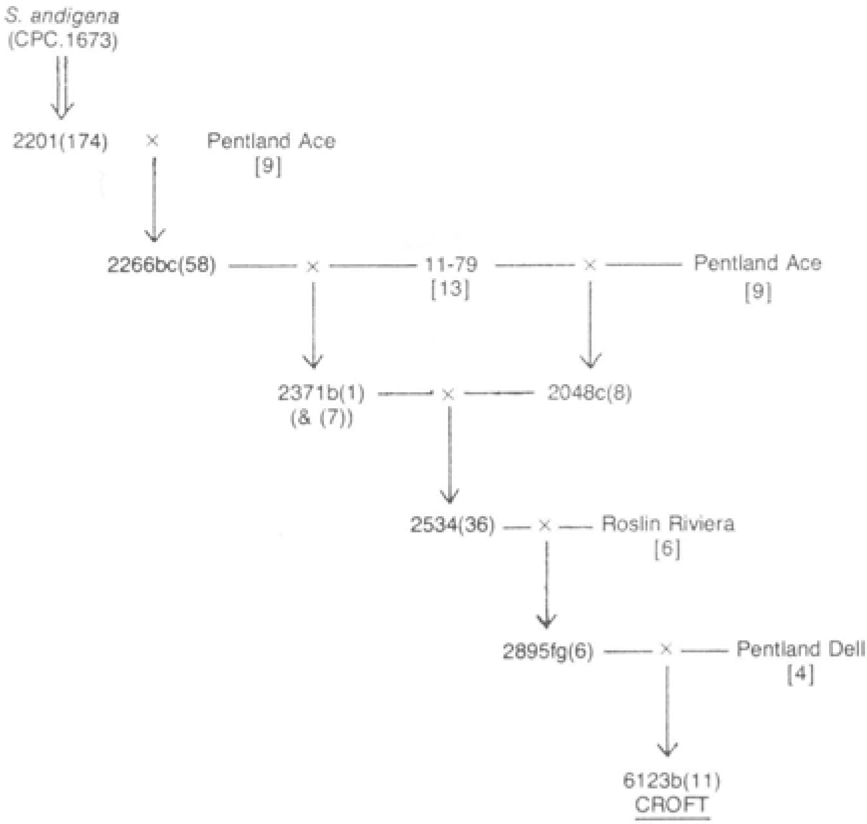
Scheme 8



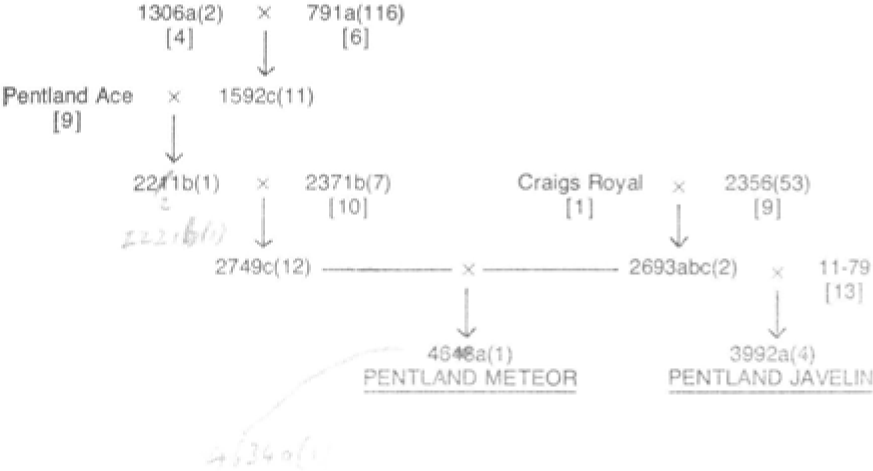
Scheme 9


885(2)
[3]
×
Pepo
S. andigena
(CPC.1673)
×
Kerr's Pink
997ab(54)
×
Craigs Defiance
[1]
×
2296(2)
1253a(12)
PENTLAND ACE
×
2356(4)
(& (53))
2700b(8)
×
Craigs Royal
[1]
4571ab(4)
PENTLAND LUSTRE

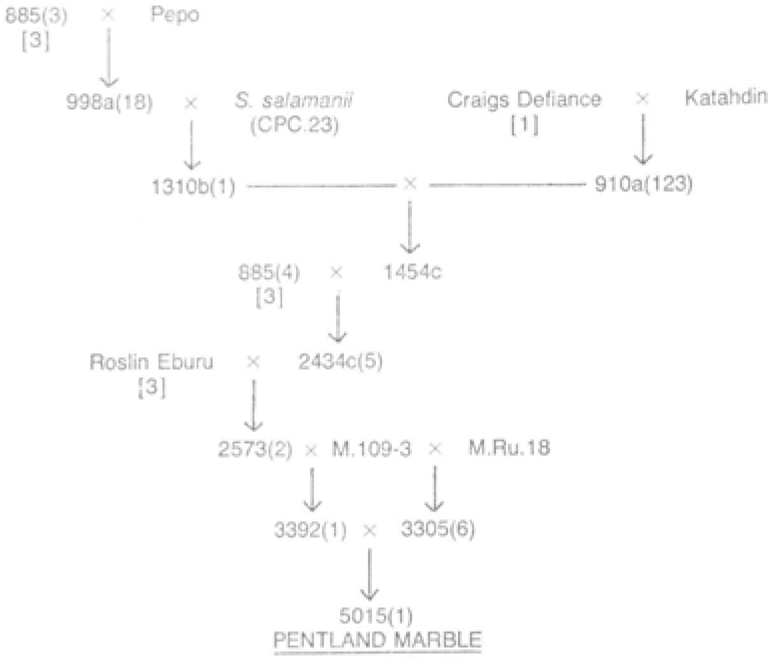
Scheme 10


S. andigena
(CPC.1673)
2201(174)
×
Pentland Ace
[9]
2266bc(58)
×
11-79
[13]
×
Pentland Ace
[9]
2371b(1)
(& (7))
×
2048c(8)
2534(36)
×
Roslin Riviera
[6]
2895fg(6)
×
Pentland Dell
[4]
6123b(11)
CROFT

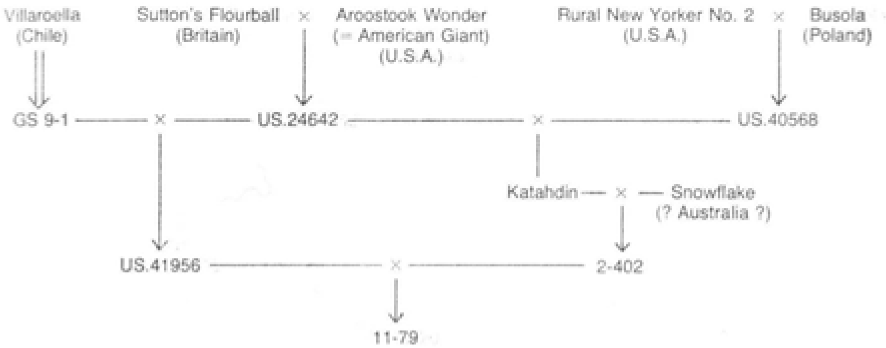
Scheme 11



Scheme 12

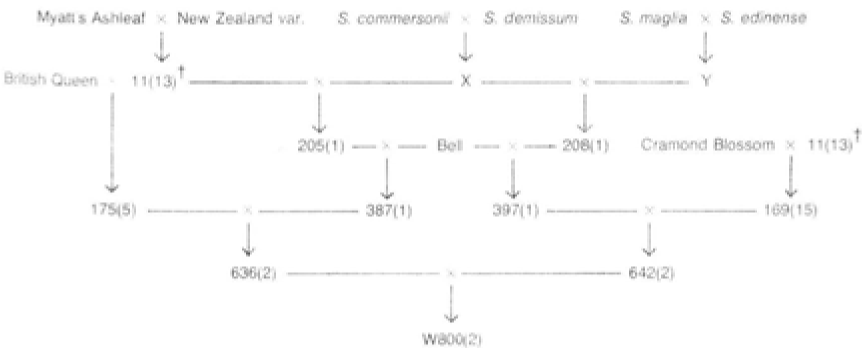


Scheme 13 *The pedigree of the breeding line 11-79*



Sources: Pedigree of Katahdin: *American Potato Journal*, **22**, 229-242
Pedigree of US.41956: *American Potato Journal*, **33**, 37-46 and **38**, 236-239
Pedigrees of 2-402 and 11-79: Information available at the SPBS

Scheme 14 *The pedigree of the breeding line W800(2)*



Source: Information available at the SPBS

CONFERENCES, MEETINGS AND SEMINARS

Brassica Fodder Crops Conference, February 1977

A two-day conference, held at the Station, on Brassica Fodder Crops was attended by about seventy-five delegates from thirty organisations. This originated from discussions of the Station's research programme and was then organised by the Scottish Agricultural Development Council as a sequel to the meeting held at the Rowett Research Institute in 1971. The scientific programme was arranged by Dr I. H. McNaughton (SPBS), Dr R. F. Thow (ESCA) and Dr J. F. D. Greenhalgh (RRI). The conference sought to examine all aspects of the breeding, growing and utilisation of the principal brassica fodder crops including kale, swede, turnip, rape, *Raphanobrassica* and catch crops, with the object of indicating areas where additional research effort may be needed.

The conference was preceded by the first meeting of UK club-root workers. Owing to the relatively low economic value of brassica forage crops, this, their major disease, is unlikely to be economically controlled except by breeding. Progress was reported in the transfer of resistance from *B. campestris* to *B. napus* and in the synthesis of *Raphanobrassica* genotypes with resistance to a wide range of *Plasmodiophora brassicae* isolates.

The first two sessions of the conference were devoted to breeding and pathology, work in progress at WPBS and SPBS being outlined and the possibilities for exploiting the available genetic variability being considered.

Two sessions considered the husbandry, agronomy and evaluation of brassica crops. These dealt with fertiliser requirements, weed control, physiology, economics, machinery and variety testing. Some disquiet was expressed because testing organisations are unable to utilise elaborate evaluation techniques involving livestock, and may therefore be encouraging the breeding of varieties which appear to be good in mechanically harvested trials while their effect on animal performance is unknown.

In two further sessions the utilisation of brassicas by various classes of livestock was discussed with particular reference to their nutritive value as cereal replacements. Forage brassicas contain S-methyl cysteine sulphoxide (SMCO) which is present in increasing proportions as the crops mature and may constitute 1 per cent of the DM of some kales. If these are fed in excess, severe symptoms of anaemia develop in ruminants. Various means of minimising the consequences of feeding SMCO-rich crops to susceptible stock were considered but, of these, only plant breeding seemed practicable in the near future. The realities of working with brassicas were explained by a farmer who grows them on 70 hectares to feed to over a thousand cattle and who was clearly not deterred by the problems raised at this conference.

The meeting was summarised, and the final discussion opened, by Professor N. W. Simmonds (ESCA).

R. N. H. Whitehouse

Agricultural Research Council Cereal Breeders Meeting

The Annual Meeting of ARC Cereal Breeders was held at Pentlandfield in July 1976. In attendance were Dr A. J. Pritchard of ARC Headquarters, Dr T. Crossett of DAFS and Professors R. Riley (PBI) and J. Cooper (WPBS) with representatives of their Cereal Department staffs.

Association of Applied Biologists Meeting

A meeting of the AAB was held in Edinburgh in July 1976. Drs R. Wastie and F. England were active as conveners of sections of this meeting, the former sharing the organisation of a conversazione to which several members of staff contributed. The Plant Breeding Group of the AAB also visited The Murrays trial plots and demonstrations of the work of SPBS at Pentlandfield.

Winter Seminar Programme

The winter seminar programme included seminars by Dr F. J. W. England (SPBS) on family planning in plant breeding; Dr R. Lyndon of the Edinburgh University Botany Department on apical growth and flowering; and Dr R. C. F. Macer (SPBS) on the foliar diseases of graminaceous plants in Israel and their relevance to cereal breeders. Mrs L. A. Turl of DAFS, East Craigs, spoke on the epidemiology of aphids on potato and cereal crops, and Dr M. Noble of Bonnyrigg (ex East Craigs) on the development of seed pathology in developing countries. Miss C. Williamson (SPBS) dealt with apomixis and its relevance to plant breeding programmes, and Dr M. S. Wolfe of the PBI, Cambridge, with barley mildew: crowd control or population control. Before his departure Dr I. Butzonitch of the Balcarce Agricultural Research Station, Argentina, also delivered a general talk on the work of his Institute and its position in Argentina.

Nutrition Society Meeting

The Scottish Group of the Nutrition Society held its 121st meeting at the SPBS on 18th March 1977. A symposium entitled "Cereals Today and Tomorrow" was chaired by the Director, Dr R. C. F. Macer, and R. N. H. Whitehouse delivered a paper on Cereal breeding and its future trends. The meeting was attended by forty-seven researchers representing eight other institutes, seven universities or colleges and two commercial firms.

VARIETIES BRED BY THE STATION

The following are commercially available in Britain:

Oats
- Albyn Empress
- Shearer
- Pentland Provender*

Swede
- Pentland Harvester

Stubble turnip
- Appin

Horticultural kale
- Pentland Brig

Grass
- Scotia Perennial Ryegrass

Potatoes
- Craigs Alliance
- 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. The commercial development of Scotia Perennial Ryegrass is also in the hands of NSDO, as is that of Pentland Brig, a garden variety producing succulent leafy young shoots in early spring (a by-product of the Station's work). The oats Albyn Empress and Shearer are maintained by Mr R. Miller, Tullochgorum.

The following, recently named, are undergoing final trials or multiplications:

Oats	Etive*	Leven*
Stubble turnip	Ballater	
Fodder radish	Crail	

Those marked * have been granted Plant Breeder's Rights. All five will be marketed through the NSDO.

PUBLICATIONS

ALLISON, M. J., COWE, I., and MCHALE, R. (1976). A rapid test for the prediction of malting quality of barley. *Journal of the Institute of Brewing*, **82**, 166-167.

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Macarthur, A, W., and Killick, R. J. (1976). Environmental and genetic variation in some economically important traits in potatoes. *Journal of Agricultural Science, Cambridge*, **87**, 39-43.

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.
* 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
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
* Plant Breeding Institute	Maris Lane, Trumpington, Cambridge CB2 2LQ
* Rothamsted Experimental Station	Harpenden, Herts. AL5 2JQ
* Welsh Plant Breeding Station	Plas Gogerddan, Aberystwyth, Cardiganshire SY23 3EB
Wye College, Department of Hop Research	Ashford, Kent TN25 5AH

State-aided Institutes in Scotland:

Animal Diseases Research Association . .	Moredun Institute, 408 Gilmerton Road, Edinburgh EH17 7JH
Hannah 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
* National Institute of Agricultural Engineering (Scottish Station)	Bush Estate, Penicuik, Midlothian EH26 0PH
* Rowett Research Institute	Bucksburn, Aberdeen AB2 9SB
* Scottish Horticultural Research Institute .	Invergowrie, Dundee DD2 5DA
Scottish Plant Breeding Station . . .	Pentlandfield, Roslin, Midlothian EH25 9RF

* There has been collaboration during the year between these Institutes and the S.P.B.S.

REPORT

to the

ANNUAL GENERAL MEETING

of

THE SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING

21st July 1977

by the

BOARD OF DIRECTORS

BOARD OF DIRECTORS, 1976-77

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ROBERT L. SCARLETT, C.B.E., C.D.A., S.H.M., V.M.H., Sweethope, Musselburgh.

Chairman of Directors

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

Vice-Chairman

JAMES GRAY, O.B.E., T.D., (James Gray & Co. (Stirling) Ltd.), Stirling FK8 2DQ.

Ordinary Directors

1974

J. LESLIE DAWSON, B.Sc., (S.A.I. Ltd.), West Mains of Ingliston, Newbridge, Midlothian EH28 8NZ.
O. T. GRIFFIN, B.Sc., Balnafoich, Dores, Inverness-shire.
JAMES R. MARSHALL, Duncrub Park, Dunning, Perthshire.
DOUGLAS V. RENNIE, South Belton, Dunbar, East Lothian.
G. A. STORRAR, M.C., B.Sc., J.P., Rossie, Auchtermuchty, Fife.
H. A. WATERSON, M.Sc., West of Scotland Agricultural College, Advisory and Development Department, Auchencruive, Ayr KA6 5HW.

1975

JAMES D. G. DAVIDSON, M.V.O., M.I.Ex., Royal Highland and Agricultural Society, Ingliston, Newbridge, Midlothian.
G. B. R. GRAY, Smeaton, East Linton, East Lothian.
Mrs B. A. GORDON, B.Sc. (Agric.), Rosefarm, Cromarty.
JAMES McFARLANE, Kames, East Mains, Leitholm, Coldstream, Berwickshire TD12 4JW.
WILLIAM H. PORTER, West Scryne, Carnoustie, Angus.
DEREK A. J. RANDALL, The Miln Marsters Group, King's Lynn, Norfolk.

1976

JOHN M. FELL, 78 High Street, Boston Lincolnshire.
W. H. M. GILL, Rosskeen, Invergordon, Ross-shire.
J. B. D. HERRIOTT, B.Sc., Ph.D., Edinburgh School of Agriculture, West Mains Road, Edinburgh EH9 3JG.
Sir DAVID LOWE, C.B.E., D.Sc., F.R.S.E., F.R.Ag.S., Elvingston, Gladsmuir, East Lothian.
C. D. SCOTT, Waterside, Newburgh, Aberdeen.
C. G. SPENCE, Biel, Dunbar, East Lothian.

Directors Co-opted

G. CLAPPERTON, Sherriffhall Mains, Dalkeith, EH22 1RX.
A. PATTULLO, M.C., J.P., Littleton of Airlie, Kirriemuir, Angus.
JAMES M. ROY, (Gordon Innes Ltd.), 69 Bogie Street, Huntly, Aberdeenshire.

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

Professor ROBERT BROWN, D.Sc., F.R.S., Edinburgh University, Botany Department, King's Buildings, Mayfield Road, Edinburgh EH9 3JA.

Professor G. R. DICKSON, B.Sc.Agr., Ph.D., F.I.Biol., School of Agriculture, University of Newcastle-upon-Tyne, Newcastle-upon-Tyne NE1 7RU.

H. P. DONALD, C.B.E., Ph.D., D.Sc., F.R.S.E., 5 Glenorchy Road, North Berwick, East Lothian.

W. O. KINGHORN, B.Sc., 25 Cumlodden Avenue, Edinburgh EH12 6DR.

J. M. TODD, B.Sc., A.I.C.T.A., Department of Agriculture and Fisheries for Scotland, Agricultural Scientific Services, East Craigs, Edinburgh EH12 8NJ.

Sir MAURICE YONGE, C.B.E., D.Sc., F.R.S., F.R.S.E., 13 Cumin Place, Edinburgh EH9 21X.

STANDING COMMITTEE—FINANCE

JOHN ARBUCKLE, *Convener.*
W. A. BIGGAR.
R. BROWN.
G. CLAPPERTON.
J. D. G. DAVIDSON.
W. H. M. GILL.
G. B. R. GRAY.
O. T. GRIFFIN.
J. B. D HERRIOTT.
Sir DAVID LOWE.
R. L. SCARLETT.
Sir MAURICE YONGE.
VICE-CHAIRMAN (*ex officio*).

RESEARCH COMMITTEES

Brassicas

J. B. D. HERRIOTT, *Convener.*
G. CLAPPERTON.
G. B. R. GRAY.
W. H. PORTER.
D. V. RENNIE.
H. A. WATERSON.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

Cereals

O. T. GRIFFIN, *Convener.*
Mrs B. A. GORDON.
Sir DAVID LOWE.
A. PATTULLO.
D. A. J. RANDALL.
C. G. SPENCE.
H. A. WATERSON.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

Grasses

G. CLAPPERTON, *Convener.*
J. LESLIE DAWSON.
G. B. R. GRAY.
J. B. D. HERRIOTT.
A. PATTULLO.
C. D. SCOTT.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

Potatoes

W. H. M. GILL, *Convener.*
H. P. DONALD.
J. M. FELL.
Mrs B. A. GORDON.
W. O. KINGHORN.
Sir DAVID LOWE.
J. R. MARSHALL.
J. McFARLANE.
W. H. PORTER.
J. M. ROY.
C. D. SCOTT.
G. A. STORRAR.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

Farm Advisory

G. CLAPPERTON, *Convener.*
J. D. G. DAVIDSON.
G. B. R. GRAY.
J. McFARLANE.
A. PATTULLO.
D. V. RENNIE.
C. G. SPENCE.
G. A. STORRAR.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

ADMINISTRATION

Membership

At 31st March 1977 the total membership was 317, comprising 206 Life Members and 111 Annual Members. Twenty-four new members were elected during the year and twelve died or resigned.

Meetings

The Board met four times during the year, on 8th April 1976, 10th June 1976, 22nd July 1976 and 18th November 1976.

The Finance Committee met on 10th June 1976.

The Brassica Research Committee met on 28th October 1976.

The Cereals Research Committee met on 8th December 1976.

The Farm Advisory Committee met on 6th May 1976 and 9th December 1976.

The Potato Research Committee met on 5th November 1976.

Board of Directors

The Board welcomed on election for the first time, Mr J. M. Fell, Mr C. D. Scott, Mr C. G. Spence.

Finance

The Abstract of Audited Accounts on pages 121–131 reveals the Society's financial position at 31st March 1977. The cost of the research programme at the Scottish Plant Breeding Station was met by a maintenance grant of £709,000 from the Department of Agriculture and Fisheries for Scotland. Sundry items of income at Pentlandfield amounted to £2,323. The unspent balance of the grant was £15,794 which has been added to unspent balances from previous years, increasing them to £31,543.

DAFS Grants were received to cover Capital Expenditure at Pentlandfield; these totalled £165,643, with £61,678 being spent on equipment and £103,965 on buildings and works, the main items being temporary accommodation to alleviate overcrowding, improving coal-fired heating system, the new East Wing and a replacement glasshouse.

The Department also approved the expenditure of £52,499 at The Murrays to provide storage facilities, new glasshouse and improve the field drainage. However, Capital Expenditure at The Murrays is not included in The Fixed Assets of the Society because the farm is let to the Society by the Secretary of State for Scotland.

Election of Trustee

To fill the vacancy created by the resignation of Mr R. L. Scarlett the Board recommends the election of: George B. R. Gray, Smeaton, East Linton, East Lothian.

Election of Directors

In accordance with the rules of the Society, the following Directors retire from the board at this time:—

J. Leslie Dawson, B.Sc., (S.A.I. Ltd.), West Mains of Ingliston, Newbridge, Midlothian EH28 8NZ.

O. T. Griffin, B.Sc., Balnafoich, Dores, Inverness-shire.

James R. Marshall, Duncrub Park, Dunning, Perthshire.

Douglas V. Rennie, South Belton, Dunbar, East Lothian.

G. A. Storrar, M.C., B.Sc., J.P., Rossie, Auchtermuchty, Fife.

H. A. Waterson, M.Sc., West of Scotland Agricultural College, Advisory and Development Department, Auchencruive, Ayr KA6 5HW.

To fill the existing vacancies the Board recommends election of the following:—

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.

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

FIFTY-FIFTH ANNUAL GENERAL MEETING

MINUTE OF PROCEEDINGS AT THE FIFTY-FIFTH ANNUAL GENERAL MEETING OF MEMBERS OF THE SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING, held at Pentlandfield, Roslin, Midlothian, on Thursday, 22nd July 1976.

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

Minute. The Minute of the 54th Annual General Meeting, held at the Scottish Plant Breeding Station on Thurdsay, 24th July 1975, 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.

Director of Scottish Plant Breeding Station. Mr Arbuckle informed the meeting that Dr N. W. Simmonds, Sc.D., A.I.C.T.A., F.R.S.E., F.I.Biol., had resigned from his post as Director of the Scottish Plant Breeding Station with effect from 31st March 1976 and that he would be succeeded by Professor R. C. F. Macer, M.A., Ph.D., F.I.Biol., who would take up his duties on 1st September 1976.

Annual Report and Accounts. The 55th Annual Report of the Directors embodying the audited accounts for the year ended 31st March 1976, which had been distributed to members before the meeting, was submitted by the Chairman.

After a brief speech the Chairman moved and Mr J. D. G. Davidson, M.V.O., M.I.Ex., Royal Highland and Agricultural Society, Ingliston, Newbridge, Midlothian, seconded the adoption of the Report and Accounts and the motion was carried unanimously.

Election to the Board of Directors. A motion by Mr James Gray, O.B.E., T.D. (James Gray & Co. (Stirling) Ltd.), Stirling, seconded by Mr D. V. Rennie, South Belton, Dunbar, East Lothian, was unanimously adopted to elect to the Board of Directors the following members:—

John M. Fell, 78 High Street, Boston, Lincolnshire.
W. H. M. Gill, Rosskeen, Invergordon, Ross-shire.

J. B. D. Herriott, B.Sc., Ph.D., Edinburgh School of Agriculture, West Mains Road, Edinburgh EH9 3JG.

Sir David Lowe, C.B.E., D.Sc., F.R.S.E., F.R.Ag.S., Elvingston, Gladsmuir, East Lothian.

C. D. Scott, Waterside, Newburgh, Aberdeen.

C. G. Spence, Biel, Dunbar, East Lothian.

Appointment of Auditors.

On the motion of the Chairman, seconded by Mr G. A. Storrar, M.C., B.Sc., J.P., Rossie, Auchtermuchty, Fife, Messrs Brown, McDonald & Fleming, Chartered Accountants, were re-appointed Auditors of the Society.

This concluded the business of the meeting.

In the informal business of the meeting, the Chairman in the course of his address to members said that under the direction of Dr Simmonds there had been a steady expansion of the Station's research programme. Improved facilities along with more staff had led to significant scientific achievement and much was still to emerge. The past successes of the potato breeding programme were well known and from the complex brassica breeding programme, two new varieties, Appin and Ballater, would soon be available. These new brassicas, he was sure, would be a major success for the Station. The cereal breeding programme was also coming to fruition with some very good oat material undergoing National List trials and the barley programme making steady progress.

He went on to say that Pentlandfield was now firmly established both nationally and internationally and that he expected that the future work of the Station would evolve around the main crops (potatoes, brassicas, and cereals) where reputation had been established, but as Professor Macer, who unfortunately was unable to be present today owing to a long-standing prior engagement, has a special interest in plant pathology, he was sure that his influence would be felt in some of the programmes. Plant breeding, however, is a long-term business and it would probably be the 1980s or 1990s before policies initiated now will come forward.

Mr Arbuckle thanked the Department of Agriculture and Fisheries for its continued support and said that the Board would endeavour to ensure that Scottish agricultural requirements were given top priority within the present and continuing economic climate of financial constraint.

The Chairman thanked his fellow Directors for their continued support and spoke highly of the work being done by the Research Committees.

Mr Arbuckle, in thanking the staff for their excellent effort over the past year also expressed his gratitude to the following long-serving members of staff who had recently retired: Mr J. L. Fyfe, Mr D. Cameron, Mr A. A. MacFarlane and Mr V. Schacht.

Mr D. A. Leitch, Assistant Secretary of the Department of Agriculture and Fisheries for Scotland, in his address to the meeting, tendered apologies on behalf of Mr J. I. Smith and Mr W. W. Gauld, who due to a late change of plans were not able to be present. He went on to say that the Station had made remarkable progress under the guidance of Dr Simmonds, with potato varieties bred at the Station claiming one-third of the United Kingdom commercial potato crop and the outstanding scientific success of the *Raphanobrassica* programme. This success was due to the quality of the scientific staff of the Station and the way they had responded to good leadership. Mr Leitch said that this kind of success was the best way of ensuring continued support from public funds. He then went on to praise the staff and the consultants who had been responsible for the design of the new East Wing which he thought was extremely good value for the money that had been spent. However, he did warn that because of the present financial climate funds for future capital projects would be very limited.

Mr Leitch, in thanking Mr Arbuckle and the Board for their continuing interest and support, said that the Society was extremely lucky to have had the services of Dr Simmonds in the past decade and doubly fortunate to have Professor Macer for the future.

The informal business was brought to a close with a vote of thanks to the Chairman proposed by Mr J. McFarlane.

The Seventh S.S.R.P.B. Lecture:

POTATO HEALTH IN RETROSPECT AND PROSPECT

Delivered on the 7th April 1977, by

J. M. HIRST

Director of the Long Ashton Research Station.

Never was the potato more aptly and succinctly described than in the title of the Potato Marketing Board's film "A crop of problems". The wealth of diseases to which potatoes are subject is to some degree attributable to its vegetative propagation, almost unique among our major arable crops. Not only does this greatly affect the transport, cultivation and economics of the crop but the lack of any true seed generation in commerce ensures its continual susceptibility to infection. Another consequence may be the particular attraction that the crop has had for the plant pathologists who have studied it. The three who were my early mentors, P. H. Gregory, F. C. Bawden and E. C. Large, were all of the kind who value healthy crops more than their individual diseases, an attitude that is common among those interested in epidemiology and the more likely to benefit agriculture quickly. I therefore greatly welcome the opportunity to give personal opinions about these problems about two years after they ceased to be part of my direct responsibilities.

The ways of decreasing the diseases of the potato may be grouped into three broad divisions; first, the integration of cultural practices with the limitation of pathogens and their opportunities to infect; second, chemical protection; and third, your speciality of plant breeding.

EPIDEMIOLOGICAL FACTORS

There can seldom have been a better opportunity to illustrate how climate and its many indirect consequences can affect diseases than by looking at the recent history of the aphid-transmitted potato viruses. The troubles began with a long sequence of mild winters, often interspersed with warm, dry summers. Thus, having truthfully written in 1973 that "scourges such as sugar beet yellows and aphid-transmitted potato viruses were no longer causes of serious loss" by 1974 I had to admit that once again both were (reports of Rothamsted Experimental Station for 1973 and 1974). In later years the situation got worse in England and caused damage in Scotland that will take years to repair. What lessons must we learn from this experience? Surely, first, that we failed to use the warnings that existing technology offered us; second, that Scotland would be unwise to rely on its enviable record of scarcity of aphids;

and third, there was an extra risk that is difficult to assess, contributed by the increasing prevalence of aphids resistant to organo-phosphorus insecticides.

Unlike the potato viruses, which redeveloped to major threats from very small sources, many other potato pathogens have never been so controlled but are also much affected by both weather and climate. For example, powdery scab (*Spongospora subterranea*) is most prevalent on seed from the wetter areas and common scab (*Streptomyces scabies*) from the drier areas, but infection by either is much affected by soil moisture content at crucial periods. The studies of common scab infection by Lapwood and Adams illustrated most dramatically that the distribution of infection on tubers is determined so precisely by soil moisture that it is possible to control the disease merely by timing irrigation. Both these pathogens are examples of those where there is doubt about the relative importance of seed tubers or soil as the site of perennating inoculum. Resolving such doubts is very important to determining the strategy of attempts to control the soft rot and blackleg bacteria, skin spot and *Rhizoctonia*, because there are at present better prospects of decreasing tuber-borne than soil-borne inoculum. Often it is the relative prevalence of inoculum that matters more than the absolute amounts. Thus so long as seed stocks are commonly infected with the skin spot fungus, *Oospora pustulans*, even large amounts in the soil make no appreciable difference to disease severity, but even amounts too small for test procedures to detect may be sufficient to re-establish the disease on the most carefully produced healthy stocks. This is, of course, a major difficulty in maintaining pathogen-free stocks such as have been introduced to the VTSC scheme. Observing the first steps in re-introduction has helped teach us much about what transmits the blackleg bacterium and about the survival in soil or debris of *O. pustulans*. The recent dry summers have also stressed the caution necessary concerning negative results, because the absence of the pathogen can only be presumed when it can be demonstrated that the test condition effectively challenged the pathogen's ability to multiply, to infect and to express symptoms. There is great need for fundamental studies of latency in pathogens such as *Erwinia carotovora* and *Phoma exigua* to show how latent inoculum may be detected or readily expressed.

These difficulties must be understood before we can analyse the currently disappointing performance of the VTSC Scheme in decreasing the prevalence of fungal tuber pathogens or before we can decide how we could do better in future. First, I think it is fair to recall that Dr G. A. Hide and I proposed and tested the use of rooted stem cuttings as, and only as, an effective way of ridding nuclear stocks from *O. pustulans*. In my view it was right and proper for the Department of Agriculture to enquire whether it could also be used to free stocks from blackleg, silver scurf and *Rhizotonia* as well as the major goal of freedom from gangrene. I regret that the need to establish the method in Scotland at little cost was not matched by much more intensive research on the particularly difficult problems of blackleg and gangrene. We did, of course, predict that the dispersal or survival of pathogens might re-infect healthy stocks despite care over hygiene and isolation and we also feared that not all growers would manage as well as the best. Unfortunately these fears have been substantiated and although Scottish seed growers tell me they still gain in faster multiplication and smaller discard ratios it is disappointing to find the FS stocks now reaching England are little or no healthier than they were before the scheme was introduced, although there is strong evidence that the best improve yields by rather less than 10 per cent. How could we have done better?

CHEMICAL PROTECTION

Because few expected that hygiene would be adequate alone, efforts were increased to find chemicals that could eradicate vestigial infections or protect plants against the challenges of infection from the residual inoculum surviving in soil, the debris of previous crops or in groundkeepers. Tuber surface sterilants could never be effective against infections during growth and the best, the organo-mercurials, were properly questioned because of real hazards to operators and the environment. There were, and still are, no systemic bactericides effective during growth. However, the advent of the benzimidazole fungicides promised the activity needed against fungal pathogens. The first experiments at Rothamsted in 1968 gave much more promising results than some of those that followed. When we were able to add chemical investigation to the empirical field experiments it was soon found that when applied to seed tubers these materials were retained within the outside few millimetres of flesh and skin. Although penetration can be improved by more acid formulations, unless systemic distribution can be achieved these materials seem limited to the present valuable superficial action or protection against subsequent wound infection. In Scotland, the Department of Agriculture developed an alternative treatment involving seed tuber fumigation with 2 amino butane. Like the other possibilities this treatment was only partially successful because it did not deal with all pathogens and also fails to eradicate all latent infections. Thus it, too, does more for the current image of seed tuber stocks than it does for their perennial health, which matters most.

It is asking much, perhaps too much, of any treatment that it should eradicate most pathogens but I think there is need for much more intensive research on crop protective chemicals which may be active against potato pathogens and the most effective ways of applying them. Especially there is need for an effective bactericide, for downward translocated systemic fungicides (of which a few are in prospect) and systemics active against phycomycetes (including *Phytophthora infestans*). Almost equally important is the need to find better methods of application and how to supplement the pathogen spectrum of one material with that of others without the costs of multiple treatment.

POTATO BREEDING

The major alternative to limiting epidemics or chemical protection is to breed resistant plants—your speciality. The record of your achievement is commendable but nevertheless touched with some sadness because Dr W. Black was not infrequently the pioneer who had to show the rest of science where the pitfalls lay. He could scarcely be blamed for the susceptibility of some of his progenies to soil-borne viruses that were not then recognised as causes of spraing symptoms. Similarly, someone had to show that epidemic pathogens like the blight fungus can often outpace the breeder's attempts to base continuing hypersensitive resistance on single genes. Had other breeders been quicker to appreciate the lesson we might have had fewer recent failures in cereals and other crops besides potatoes.

Nevertheless, Dr Black's work was among the first to utilise the special epidemiological circumstances of the Toluca Valley in Mexico for selecting "field-resistant" clones in a population of the pathogen that contained most of the "major genes" in complex specialised races. I recently had an opportunity to visit this work, begun under the Rockefeller Potato Improvement Programme, which is now the responsibility of the International Potato Centre based in Peru. The achievement over a quarter century is impressive, with the most resistant selections still being little infected when the variety (Alpha), selected in the earliest years as the most resistant, is completely defoliated. Furthermore, having survived so long, the selections show real evidence of having the necessary durability.

The progress at Toluca and all the breeding that I inspected in US Universities now seems to have "diversity" as its keynote rather than the former manipulation of identifiable genes. The diversity is often introduced from repeated wide out-crossing to wild or other cultivated species. Experts on the genetics of *Solanum* estimate that the initial potato introductions to North Temperate latitudes comprised no more than about 2 per cent of the available germ plasm. Subsequent expeditions and introductions have, it is guessed, raised this to no more than 10 per cent. The International Potato Centre (CIP) being located within the centre of diversity of the potato has unique access to its germ plasm; the advantage is not unmixed because the area seems also to be the home of many of its pathogens. The unusual advantage of being able to select genotypes resistant to the widest possible range of viruses, fungal and bacterial pathogens and pathotypes of cyst nematodes, is therefore associated with serious risks that to distribute these hosts would court the folly of also spreading parasites that at present have very limited distribution. The future of the work of CIP must therefore depend on developing technologies that effectively separate host from pathogen with a reliability that gains international acceptance.

Much effort has been devoted to improving procedures at CIP for virus testing but there is still room for improving techniques and facilities. One technique essential to freeing clones from viruses is apical meristem culture. In collaboration with work at Birmingham University the staff at CIP have developed the production of meristem cultures into a routine system for microvegetative propagation by multi-meristem cultures. When testing for bacteria and systemic or latent fungi is added these techniques should produce potato propagating material in the form most suitable for transport, testing by quarantine authorities and subsequent multiplication. Assuming that present promise is fulfilled and desirable genotypes can be distributed free from pathogens, then the collections of CIP seem to me to have great international importance. Like the other International Agricultural Research Institutes, the International Potato Centre aims to benefit agriculture in developing countries rather than to devote effort to countries already advanced in science and agriculture. Nevertheless, the wiser among the latter recognise the enormity of CIP's task and its need for experienced collaborators.

UK science has contributed already but must contribute much more if we are to expect adequate rewards in knowledge of unfamiliar pests and pathogens or of the wider range of genotypes on which the next generation of new varieties will be based. In my view such extended collaboration is not only our international duty but also a form of self-help that we would ignore at the peril of your ability to be among the breeders of the best potatoes in the future.

A BRIEF HISTORY OF THE DONORS AND OTHERS COMMEMORATED BY THE PRIVATE FUNDS OF THE SOCIETY

James Munro

Mr Munro was born in 1859 at the family farm of Achinarras, Halkirk. He was one of a large family and along with his brother William, farmed for many years at the farm of Old Crook, Bilbster.

He died in December 1933 at the age of seventy-four.

William J. Reid, J.P.

Born in 1874, Mr Reid trained in his early days for the banking profession. However, he retained an interest in agriculture which he had inherited from his father, who was both banker and farmer and, in 1905, he left the bank to take over the Fordhouse of Dun farm near Montrose.

He became interested in the potato seed trade and, in addition to his extensive local trade, he also developed a considerable export trade in seed. Mr Reid had wide connections among growers in Scotland and England and was a pioneer of the Potato Marketing Board.

At Fordhouse of Dun, Mr Reid had a well-established flock of Border Leicester sheep to which he added a herd of Aberdeen Angus. He became a noted cattle breeder and enjoyed the reputation of being a first-class judge, both at home and abroad.

A member of many agricultural societies, William Reid became a Director of the Royal Highland and Agricultural Society in 1947. During his short term on the Board his initiative was primarily responsible for the institution of the Overseas Pavilion at the Society's Show. He was engaged in preparing for the 1950 Show when he collapsed and died in Glasgow at the age of seventy-six.

James C. Thyne

Mr Thyne was born in 1872 and was educated at Dundee High School. He left school in 1886 to join the nursery and seed firm of Thyne & Paton which had been founded by his father, Mr Thomas Thyne, and Mr George Paton. His father dissolved the partnership and they formed together the business of Thyne & Son with nurseries at Downfield. Mr James C. Thyne became managing director on the death of his father.

In 1920 Mr Thyne gave up the nursery side of his business to concentrate on the seed potato trade. The firm flourished under his able management and soon earned the reputation of being the largest supplier of seed potatoes to seedsmen in England.

A keen golfer and in his younger days an enthusiastic walker, Mr Thyne also travelled extensively both at home and abroad.

Mr Thyne, although in his seventy-fifth year, was still actively engaged in his business when he died in September 1946.

Dr John H. Wilson

John Hardie Wilson was born in 1858, the second son of James Wilson, a nurseryman of St Andrews. He received his early education at Madras College and on leaving school joined his father's business. He then spent several years at the Royal Botanic Garden, Edinburgh, before entering Edinburgh University as a student of botany and geology where he carried off the highest honours in the advanced botany class. He then followed a degree course at St Andrews University, graduating B.Sc. in 1887. Before his final examination, at the instance of the Board of Fishery for Scotland, Dr Wilson published an elaborately illustrated memoir on the common mussel as well as several botanical papers.

Soon after graduating, Dr Wilson gave a pioneer course in botany at the University which led to his appointment as University lecturer on the subject in 1888. After studying in Germany and Belgium he became the first person (1889) to obtain a D.Sc. at St Andrews and this led to his appointment as Lecturer in Agriculture and Rural Economy. Immediately after this appointment, he toured Canada and the United States, visiting all the main agricultural centres.

Most of Dr Wilson's experiments were devoted to improving garden and farm plants; latterly, he concentrated his efforts on potatoes, oats and turnips with considerable success. His potato varieties, "Templar", "Bishop" and "Rector" which were bred for disease resistance and quality were particularly successful.

A fellow of the Royal Society of Edinburgh, Dr Wilson was a gifted intellectual with a wide range of interests and, although botanical and agricultural studies claimed most of his attention, he attained considerable success in the fine arts. He was a talented musician, writer, poet and photographer.

Dr Wilson died after a brief illness in January 1920 at the age of sixty-one.

ABSTRACT OF ACCOUNTS

ABSTRACT OF ACCOUNTS

For Year ended 31st March 1977

INCOME

1976			
£ 213	Sales of Produce, etc..		£ 1,649
119	Annual Subscriptions		118
693	Rents received		556
£ 1,025	*Total Ordinary Income*		£ 2,323
597,000	Maintenance grant from Department of Agriculture and Fisheries for Scotland—		709,000
£598,025	*Total Income*		£711,323
	Department of Agriculture and Fisheries for Scotland—		
15,645	Unexpended maintenance grants brought forward at 1st April 1976	£15,749	
33,413	Capital Grants—The Murrays Farm	52,499	
			68,248
£647,083			£779,571

EXPENDITURE

1976				
	Salaries:—			
£276,123	Scientific and Technical Staff		£270,443	
25,158	Administrative and Clerical Staff		27,516	
8,833	Pensions and Supplementation		10,896	
£310,114				£308,855
88,821	Wages			109,182
25,972	National Insurance			31,822
11,330	Apparatus and Equipment (Including Safety Equipment £885; 1976 £916)			31,865
25,217	Chemicals and Materials			33,512
11,091	Travel and Subsistence (Including Visits Abroad £2,299; 1976 £23)			16,963
10,942	Rates and Rents			12,714
24,209	Power, Light and Heat			43,058
8,095	Stationery, Postages and Telephones, etc.			8,092
1,500	Library Books and Periodicals			1,591
1,397	Printing			1,905
7,446	Motor Vehicles—Purchases	£1,813		
9,024	Maintenance	10,203		
				12,016
1,603	Property Alterations			1,401
2,620	Property Repairs			5,320
3,282	Trial Centres			4,746
5,309	Edinburgh Centre of Rural Economy			6,453
6,714	Repairs and Servicing			9,269
863	Seed Testing			1,101
650	Transport			1,517
2,874	Staff Recruitment			3,543
1,013	Staff Training			1,926
465	Furniture and Fittings			2,244
2,516	Hire Charges and Rentals			2,820
—	Land improvement			1,315
29,077	The Murrays Farm—net operating costs			39,393
5,777	Miscellaneous			2,906
£597,921				£695,529
33,413	The Murrays Farm—improvements			52,499
15,749	Department of Agriculture and Fisheries for Scotland—unexpended maintenance grants carried forward at 31st March 1977			31,543
£647,083				£779,571

BALANCE SHEET

as at 31st March 1977

1976				
	I Funds:—			
£525,127	Balance brought forward as at 1st April 1976	£698,430		
	Add: Grants received from Dept. of Agriculture and Fisheries for Scotland during year to date:—			
155,810	Capital Works	103,965		
17,493	Capital Equipment	61,678		
£698,430		£864,073		
—	*Less:* Fixed assets written off	2,279		
£698,430			£861,794	
	II Current Liabilities:—			
331	Sundry Creditors	£ 4,332		
	Department of Agriculture and Fisheries for Scotland:—			
15,749	Unexpended Maintenance Grants . .	31,543		
			35,875	
£714,510			£897,669	

NOTE: The following items were written off Fixed Assets during the year—
Heritable property—Venlo glasshouse (cost £2,000) which collapsed due to weight of snow.
Capital equipment—Cost of Boby seed cleaner equipment purchased in 1953 for £279.

1976		Cost	Less Charged to Revenue	Nett
	I Fixed Assets:—			
£607,895	1. Heritable Property . . .	£ 709,860	—	£709,860
90,043	2. Capital Equipment . . .	151,442	—	151,442
£697,938		£ 861,302	—	£861,302
36,040	3. Implements and Tools. . .	50,779	£ 50,779	
18,477	4. Vehicles	18,791	18,791	
66,318	5. Laboratory Apparatus. . .	83,054	83,054	
15,143	6. Furniture and Fittings. . .	17,385	17,385	
11,509	7. Library Books	13,100	13,100	
£845,425		£1,044,411	£183,109	£861,302
147,487	*Less:* Charged to Revenue to 31st March 1976			
£697,938				
	II Current Assets:—			
403	Sundry Debtors (including deposits £235; 1976 Nil)		£ 2,338	
16,169	Cash and Bank Balances		34,029	
				36,367
£714,510				£897,669

Edinburgh, *27th May 1977*—The undersigned, having had access to all the Books and Accounts of the Society and having examined the foregoing Statement of Accounts and verified the same with the Accounts and Vouchers relating thereto, now sign the same as found to be correct, duly vouched, and in accordance with the law.

16 Alva Street, Edinburgh.

Messrs BROWN, MACDONALD & FLEMING, *Auditors.*

JOHN ARBUCKLE, *Convener, Finance Committee.*

LIFE MEMBERSHIP SUBSCRIPTIONS AND DONATIONS FUND

for the year ended 31st March 1977

1976	Income		
	Balances brought forward at 1st April 1976:—		
	Investments at cost—		
£ 6,355	Narrower range	£ 6,800	
7,210	Wider range	7,762	
£13,565		£14,562	
323	Recoverable Income Tax	390	
1,106	Bank of Scotland—Current and Savings Accounts	235	
£14,994		£15,187	
8	*Less:* Sundry Creditors	99	
£14,986			£15,088
	Gross Interest/Dividends on Investments:—		
551	Narrower range	£ 597	
571	Wider range	672	
			1,269
35	Interest on Savings Bank Account		16
40	Life Subscriptions		235
50	Donations		50
£16,233			£16,658

1976	Expenditure		
£ 3	Registrar of Friendly Societies		£ 4
103	SSRPB Lecture		50
350	Retirement/resignation presentations (Dr N. W. Simmonds and Mr A. Macfarlane)		450
294	Hospitality		10
210	Travel Grant to Dr Holden (1976: Dr J. Bradshaw)		386
—	Travelling expenses		23
	Donations—		
150	SPBS Common Room	£ 150	
—	Frank Horne Memorial Fund	50	
			200
35	Bank Charges		51
	Balances carried forward at 31st March 1977:—		
	Investments at cost (see Appendix)—		
6,800	Narrower range	£ 6,800	
7,762	Wider range	7,904	
		£14,704	
390	Recoverable Income Tax	444	
235	Bank of Scotland—Current and Savings Accounts	336	
		£15,484	
(99)	*Less:* Sundry Creditors	—	
			15,484
£16,233			£16,658

W. J. REID AND JAMES MUNRO BEQUESTS

1976	Income		
	Balances brought forward at 1st April 1976:—		
	Investments at cost—		
£ 1,792	Narrower range	£ 1,942	
424	Wider range	574	
£ 2,216		£ 2,516	
48	Recoverable Income Tax	54	
270	Bank of Scotland—Current and Savings Accounts	124	
£ 2,534		£ 2,694	
1	*Less:* Sundry Creditors	—	
£ 2,533			£ 2,694
	Gross Interest/Dividends on Investments—		
124	Narrower range	£ 139	
34	Wider range	52	
			191
9	Interest on Savings Bank Account		8
£ 2,700			£ 2,893

1976	Expenditure		
£ 6	Bank Charges		£ 3
	Balances carried forward at 31st March 1977:—		
	Investments at cost (see Appendix)—		
1,942	Narrower range	£ 1,942	
574	Wider range	607	
		£ 2,549	
54	Recoverable Income Tax	67	
124	Bank of Scotland—Current and Savings Accounts	274	
			2,890
£ 2,700			£ 2,893

DR. WILSON MEMORIAL FUND

1976	*Income*		
	Balances brought forward at 1st April 1976:—		
	Investments at cost—		
£ 317	Narrower range	£ 317	
249	Wider range	283	
£ 566		£ 600	
11	Recoverable Income Tax	13	
—	Sundry Debtors	1	
105	Bank of Scotland—Current and Savings Accounts .	109	
£ 682			£ 723
	Gross Interest/Dividends on Investments:—		
21	Narrower range	£ 20	
17	Wider range	20	
			40
5	Interest on Savings Bank Account		7
£ 725			£ 770

J. C. THYNE BEQUEST

1976	*Income*		
	Balances brought forward at 1st April 1976:—		
	Investments at cost—		
£1,050	Narrower range	£1,049	
1,050	Wider range	1,048	
£2,100		£2,097	
24	Recoverable Income Tax	91	
103	Bank of Scotland—Current and Savings Accounts .	99	
			£2,287
£2,227			
	Gross Interest on Investments:—		
134	Narrower range	£ 138	
134	Wider range	138	
			276
5	Interest on Savings Bank Account		11
£2,500			£2,574

DR. WILSON MEMORIAL FUND (continued)

1976	*Expenditure*		
£ 2	Bank Charges		£ 3
	Balances carried forward at 31st March 1977:—		
	Investments at cost (see Appendix)—		
317	Narrower range	£ 317	
283	Wider range	283	
		£ 600	
13	Recoverable Income Tax	14	
1	Sundry Debtors	—	
109	Bank of Scotland—Current and Savings Accounts .	153	
			767
£ 725			£ 770

J. C. THYNE BEQUEST (continued)

1976	*Expenditure*		
£ 197	Travel Grant to Dr R. Wastie		£ —
16	Bank Charges		2
	Balances carried forward at 31st March 1977:—		
	Investments at cost (see Appendix)—		
1,049	Narrower range	£1,049	
1,048	Wider range	1,048	
		£2,097	
91	Recoverable Income Tax	97	
99	Bank of Scotland—Current and Savings Accounts .	378	
			2,572
£2,500			£2,574

APPENDIX

INVESTMENTS AS AT 31st MARCH 1977

Life Membership Subscriptions and Donations Fund ("B" Account)

Book Value		Gross Interest/ Dividends for Year to Date	Middle Price as at Date	Market Value as at Date
	(Narrower Range)			
£ 1,508·39	£1,581·40 6½% Funding Stock 1985/87	£ 102·80	£80%	£ 1,265
2,253·58	£2,359·35 8¾% Treasury Loan 1997	206·44	£76%	1,793
1,493·09	£1,648·20 8½% Treasury Loan 1980/82	140·10	£99%	1,632
1,099·96	£1,153·00 Stirling County Council 7¾% Loan 1977/79	89·36	£93%	1,072
445·26	£450·00 City of Westminster 13% Red. Stock 1981	58·50	£103%	464
£ 6,800·28		£ 597·20		£ 6,226
	(Wider Range)			
£ 864·09	1,980 Ordinary 25p shares National Commercial Banking Group	£ 71·80	68p	£ 1,346
714·05	413 Ordinary 25p shares Guardian Royal Exchange Assurance Co.	54·80	195p	805
1,498·89	830 Ordinary 5p shares London & Manchester Assurance Co. Ltd.	61·89	107·5p	892
750·72	388 Ordinary £1 Stock Units Imperial Chemical Industries Ltd.	73·63	365p	1,416
1,372·87	345 Ordinary 25p shares Shell Transport & Trading Co. Ltd.	74·62	486p	1,677
794·57	1,420 Ordinary 50p shares Claverhouse Investment Trust Ltd.	69·91	65p	923
290·99	1,161 Ordinary 25p shares Imperial Group	82·31	72p	836
1,172·28	£1,468·20 8½% Treasury Loan 1980/82	124·80	£99%	1,454
445·26	£450·00 City of Westminster 13% Red. Stock 1981	58·50	£103%	464
£ 7,903·72		£ 672·26		£ 9,813
£14,704·00	"B" ACCOUNT TOTAL	£1,269·46		£16,039

W. J. Reid and James Munro Bequests ("C" Account)

Book Value		Gross Interest/ Dividends for Year to Date	Middle Price as at Date	Market Value as at Date
	(Narrower Range)			
£ 1,333·85	£1,359·29 6½% Funding Loan 1985/87	£ 88·36	£80%	£ 1,087
199·70	£208·00 Stirling County Council 7¾% Loan 1977/79	16·12	£93%	193
258·73	£215·00 English & International Trust Ltd., 7% Convertible Stock 1986	15·05	£93%	200
149·58	£150·00 City of Westminster 13% Red. Stock 1981	19·50	£103%	155
£ 1,941·86		£ 139·03		£ 1,635
	(Wider Range)			
£ 198·59	90 Ordinary £1 Stock Units Imperial Chemical Industries Ltd.	£ 17·08	365p	£ 328
258·72	£215·00 English & International Trust Ltd. 7% Convertible Stock 1986	15·05	£93%	200
149·59	£150·00 City of Westminster 13% Red. Stock 1981	19·50	£103%	155
£ 606·90		£ 51·63		£ 683
£ 2,548·76	"C" ACCOUNT TOTAL	£ 190·66		£ 2,318

Dr Wilson Memorial Fund ("D" Account)

Book Value		Gross Interest/ Dividends for Year to Date	Middle Price as at Date	Market Value as at Date
	(Narrower Range)			
£ 265·77	£276·60 6½% Funding Stock 1985/87	£ 17·98	£80%	£ 221
51·20	£35·00 English & International Trust Ltd. 7% Convertible Stock 1986	2·46	£93%	33
£ 316·97		£ 20·44		£ 254
	(Wider Range)			
£ 232·04	133 Ordinary 25p shares Guardian Royal Exchange Ltd.	£ 17·65	195p	£ 259
51·20	£35·00 English & International Trust Ltd. 7% Convertible Stock 1986	2·46	£93%	33
£ 283·24		£ 20·11		£ 292
£ 600·21	"D" ACCOUNT TOTAL	£ 40·55		£ 546

J. C. Thyne Trust ("E" Account)

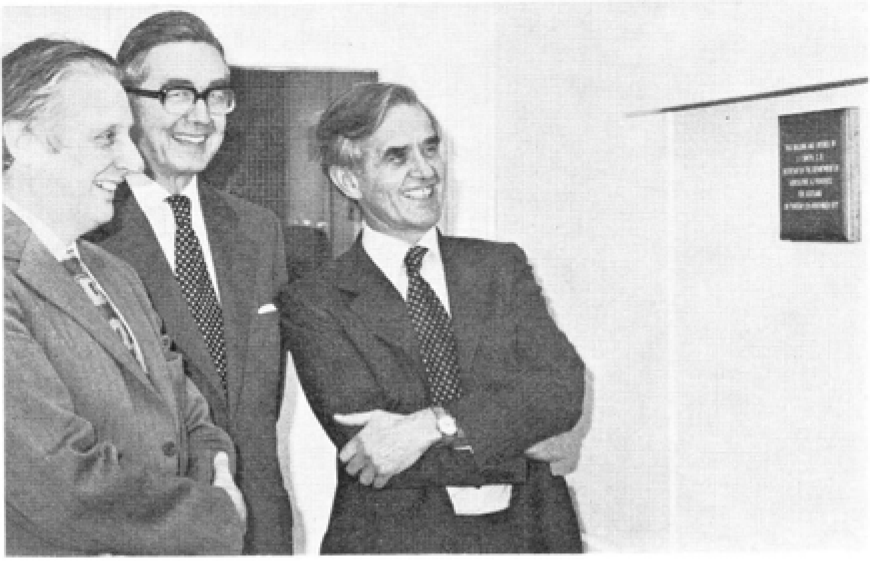
Book Value		Gross Interest/ Dividends for Year to Date	Middle Price as at Date	Market Value as at Date
	(Narrower Range)			
£ 1,048·55	£1,060·00 City of Westminster 13% Red. Stock 1981	£ 137·80	£103%	£ 1,092
	(Wider Range)			
£ 1,048·55	£1,060·00 City of Westminster 13% Red. Stock 1981	£ 137·80	£103%	£ 1,092
£ 2,097·10	"E" ACCOUNT TOTAL	£ 275·60		£ 2,184
£19,950·07	TOTALS	£1,776·27 (8·9% on invested capital)		£ 21,087

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

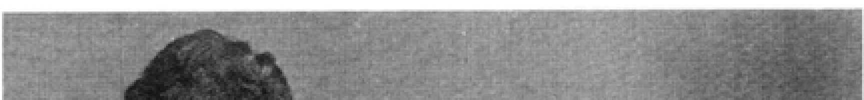
The Scottish Society for Research in Plant Breeding was founded in 1920 with the dual aims of conducting scientific investigations into plant breeding and of breeding crops for Scottish agriculture. Membership of the Society is open to any interested person whether farmer, merchant, scientist or other, in or out of Scotland (see p. 133 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.



Dr R. C. F. Macer, Mr John Arbuckle and Mr J. I. Smith after the unveiling of the plaque at the opening of the new SPBS building on 17th November 1977.



Milling energy apparatus and chart recorder being used to estimate grain hardness in barley as a measure of malting quality.