SCOTTISH PLANT BREEDING STATION

REPORT

April 1977 to March 1978

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

SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING

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STAFF LIST

(In post 31st March 1978)

Director: R. C. F. Macer, M.A., Ph.D., F.I.Biol.
Deputy Director: R. N. H. Whitehouse, M.A.
Secretary: H. C. M. McLeod

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Caretaker/ Handyman: T. K. Purves

Handyman: J. G. Butt

Groundsman/ Driver: A. E. Cochrane

Storekeeper: R. G. Gray

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Strategic Pathology Unit

PSO: Miss J. F. Malcolmson, B.Sc., Ph.D., M.I.Biol.

ASO: Miss D. J. Fullerton

Agronomy Department

PSO: F. J. W. England, B.Sc., Ph.D. (Head)

ASO: T. G. Archibald

Trials Unit

HSO: I. M. Chapman, B.Sc.

SO: A. Young

ASO: Miss C. M. MacParland, Miss D. Watt, G. R. Young

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ASO: Miss S. C. Murray

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Glasshouse Staff

Agricultural Worker: G. Wilson

Experimental Workers: J. S. Orkisz, Mrs J. Turner

Agricultural Workers: Miss V. Purves, R. Simpson

The Murrays

SSO: G. R. White, B.Sc. (Superintendent)

Tractormen: T. Gifford, D. Ritchie, R. G. Tait

Vermin Control: J. Ramsay*

* Part-time

FORAGE DIVISION

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

Cereals Department

PSO: A. M. Hayter, B.Sc., Ph.D. (Head)

SSO: M. J. C. Asher, B.Sc., Ph.D., R. P. Ellis, B.Sc., Ph.D.

HSO: R. J. Giles, B.Sc., W. T. B. Thomas, B.Sc., Ph.D.

SO: J. C. Penman, H.N.D., J. S. Swanston, B.Sc., L.I.Biol.

ASO: Miss C. E. Anderson, D. A. B. Brown, J. Brown, O.N.C., D. M. Farrer, O.N.C., R. S. Hird, J. A. Scott

Experimental Workers: Miss S. A. Byiers, Mrs I. Davidson, G. R. Drabble, Mrs M. H. McGuigan, Mrs J. Speirs, Mrs M. H. Tulloch

Chemistry Department

PSO: M. J. Allison, B.Sc., Ph.D. (Head)

HSO: I. A. Cowe, H.N.C.

SO: R. Borzucki, H.N.C., P. N. Easson, B.Sc.

ASO: Miss F. M. Bruce, H.N.C., J. G. McClusky, R. McHale, O.N.C.

Experimental Workers: Mrs E. B. Hoy, Miss L. A. MacPherson

Brassica Department

PSO: I. H. McNaughton, M.A., D.Phil. (Head)

SSO: J. E. Bradshaw, M.A., M.Sc., Ph.D., S. Gowers, B.Sc., Ph.D., W. H. MacFarlane-Smith, B.Sc., Ph.D.

HSO: Miss I. K. Munro, B.Sc., Mrs C. L. Ross (née Snell), M.Sc., Miss C. J. Williamson, B.Sc., Ph.D.

ASO: Mrs D. J. Barclay, H.N.C., Miss J. A. Galbraith, Miss J. E. Middlefell, O.N.C., Miss D. A. Page, O.N.C., Miss E. A. Young, O.N.C.

Experimental Worker: A. R. Whitelaw

Photography:

Assistant Photographer: Miss G. Cruickshank

POTATO DIVISION

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

Commercial Breeding Department

PSO: T. M. W. Davidson, B.Sc., Ph.D., N.D.A. (Head)
G. R. Mackay, M.Sc.

SSO: R. J. Killick, B.Sc., Ph.D., M.I.Biol.

HSO: C. J. W. Torrance, H.N.C.

SO: Mrs R. M. Hine (née Ford), B.Sc.

ASO: Miss M. E. Pearce, Mrs J. S. Spence, G. E. L. Swan

Experimental Workers: M. P. L. Campbell, Mrs M. M. S. Dugan, L. G. Robertson

Pathology Department

PSO: R. L. Wastie, M.A., Ph.D., F.I.S.P. (Head)

SSO: J. M. S. Forrest, B.Sc., Ph.D.

HSO: M. S. Phillips, B.Sc., Miss H. E. Stewart, H.N.C., M.I.Biol.

SO: Mrs L. E. Gray, B.Sc., A.I.M.L.S., Miss R. M. Solomon, B.A., M.Sc.

ASO: Miss F. Mathison, Miss J. G. Queen, Miss L. A. Wilson, H.N.D., L.I.Biol.

Experimental Worker: Mrs E. M. Wann

Strategic Breeding Department

PSO: D. R. Glendinning, B.Sc. (Head)

SSO: C. P. Carroll, M.Sc.

SO: M. J. De, Maine, B.Sc.

ASO: P. W. Gettings, Miss D. L. Harris, Miss S. Milligan

Cytology Unit

HSO: Mrs J. A. Fantes, M.A.

ASO: A. C. Wilkinson

DIRECTOR'S REPORT

R. C. F. MACER

The year 1977-78 has been one of consolidation in the Station's activities. In many areas, ranging from the content of the scientific programme and putting into effect the new management structure, to the occupation of additional buildings and the drainage of experimental land, changes have been taking place. Inevitably this has led to some disruption of the work programme and has placed additional burdens on staff at all levels. It is to be hoped that the benefits from this reorganisation will appear in 1978-79 and in future years.

The whole scientific programme has been reviewed and a new series of projects has been established which has been fully commissioned by the Department of Agriculture and Fisheries for Scotland.

The new programme which will commence on 1st April 1978, is fully in accord with various recommendations made by the JCO Arable Crops and Forage Board and now incorporates all the recommendations made by the ARC Visiting Group which was received at the Station in 1975. During the discussions on the new research programme it was encouraging to note how closely the Station's existing priorities met those of the JCO Arable Crops and Forage Board. It has been possible to increase substantially the Station's capacity for work on aspects of durable disease resistance on our three major crops—Brassicas, Cereals and Potatoes—a major recommendation of the Board. The Crop Committees of the Board of Directors of the Scottish Society for Research in Plant Breeding have played a major role in guiding the Station's research programme during the past year.

Rationalisation decisions made in 1976-77 were put into effect during the year. Grass and white clover material was transferred to the Welsh Plant Breeding Station in the autumn of 1977 and most of the work on these crops at the Station has ceased. The staff formerly working on these crops have been redeployed within the Station to areas of priority work, notably to Brassica pathology and to Agronomy.

The management structure introduced early in 1977 has functioned satisfactorily during the year.

At Pentlandfield new temporary accommodation has come into use during the year. A large additional building has been provided, largely for the use of the Brassica Department, and three smaller buildings to serve the needs of the Potato Pathology Department. The new buildings were opened by Mr J. I. Smith, Secretary of the Department of Agriculture and Fisheries for Scotland, on 17th November 1977. These new buildings have further eased the pressure on the older accommodation and have made possible the redesign and extension of the Chemistry Laboratories. A specialised glasshouse for Cereal Pathology is nearing completion.

The Experimental Station at the Murrays, near Pathhead, has been developed during the year. The drainage operations commenced in 1976, during which 34 hectares were re-drained, have been continued by draining a further 68 hectares. A section of the main drain has been rebuilt and the peripheral waterways cleaned out. These improvements will enable the Murrays to be used more effectively, but even after these improvements it does not fully meet the requirements of a plant breeding station.

A notable achievement this year has been the provisional recommendation by the NIAB of the potato variety "Croft". This variety will add to the range of potato varieties developed by the Station and which dominate potato growing in Great Britain. Other Station varieties such as Pentland Crown, Pentland Hawk, Pentland Squire and Pentland Javelin have performed well in the difficult seasons of 1976 and 1977 and have increased their U.K. market share. Pentland Squire is also showing considerable promise in Spain.

1976 and 1977 have both been difficult years agriculturally and the Station has faced the climatic and biological hazards affecting the farming community in the east of Scotland. Of these hazards potato virus diseases have been the most damaging. To counter these, an additional temporary isolation site was obtained at Fullarton in Midlothian at an altitude of about 300 metres, and this together with the enforcement of rigorous hygiene measures, should have safeguarded the health of the Station's potato breeding material.

The Brassica species provide most interesting possibilities for future development. They contain a wide range of genetic diversity and potentially useful characteristics. Dr I. H. McNaughton has been working with these crops for many years and material from his programme is now flowing into agricultural use. Dr McNaughton and Mrs C. L. Ross have written this year's review article (page 75) outlining some of the developments in the Brassica Department.

This year we have said farewell to two long-serving members of staff. Mr A. W. Macarthur resigned in February 1978 after twenty-eight years service to the Society. During this period he has been responsible for the health and purity of multiplication stocks of potato breeding material. Miss E. Vallery, an Experimental Worker in the Cereals Department, and who joined the staff of the Station in 1955, retired in September 1977.

We learned with regret of the death of Mr J. Leslie Dawson shortly after his retirement from the Board of Directors in 1977. Mr Dawson served on the Board, and on its various committees, with distinction and his counsel will be sadly missed.

I should like to thank Dr F. J. W. England and his colleagues on the Editorial Committee who have edited this Report and who have seen it through the press.

OPENING OF NEW SPBS BUILDING ON 17th NOVEMBER 1977

By Mr J. I. SMITH, C.B.

Secretary, Department of Agriculture and Fisheries for Scotland

Mr Chairman, ladies and gentlemen. As Mr Arbuckle has explained the new building has already been formally opened albeit in comparative privacy. It now falls to me to declare in this wider forum and at greater length that I have done the deed.

As you know I was unable to attend your Annual General Meeting this year because of other and, I fear, particularly pressing commitments. I am grateful therefore to have this opportunity to make good that deficiency and to renew my acquaintance with old friends on the Board of Directors and colleagues at the Institute. Indeed, I am doubly grateful in that today's is a less crowded gathering; and that gives me what is now too rare an opportunity to see research at first hand and to hear in some detail of the progress that is being made at the Station.

The new building is, I know, not all that you might have wished but together with the two smaller temporary buildings and the modifications to the chemistry laboratory it represents a considerable investment and one I am sure that will allow the work of the Station to go ahead in a less congested and more positive way. Indeed I was encouraged to see how well the building is already being used and found most interesting the demonstration of some of the work being done there.

I know, of course, that Dr Macer has rather more ambitious plans for the future development of Pentlandfield. As I need hardly tell you, however, these are difficult days for securing increased investment in the public sector; and that applies to Agriculture in the same way as it applies to hospitals and to other essential services.

Nevertheless, I am sure you will take this new project for what it is—an earnest of our faith in the importance of crop research and plant breeding to the future well being of our farming industry.

As to the level of investment in the years ahead I will give you and Dr Macer two undertakings:

> The first—my Department will continue to do all that it can through research and development to foster Scottish arable farming, and in this context I am well aware of both the long-term nature and the importance of plant breeding.
>
> The second—and this perhaps less to Dr Macer's liking, that it is extremely unlikely that we will ever be in a position to meet all his requests

for additional investment, but neither you nor he should however be over-discouraged at that. As you know I have been associated with agricultural research for many years and I have never known a time—even in the most affluent days of Government backing for agricultural research and development—when we could meet in full the demands of our Directors. So much so that if that day were to arrive I would think that something had gone sadly wrong with their motivation.

The only counsel that I can offer the Director comes not from an erudite source but from a motto-a-day calendar that I saw recently in the office. The caption read: "you can't have everything you want so you must decide what you want most", but even that you can't take as a promise: it would depend on how much it would cost to provide that which you would want the most. Being canny men we would still want to do our sums and might still say no.

Finally, Chairman, I should like to thank you again for your invitation to be with you today and to extend my good wishes to the staff who are working in the new—and I hope comfortable even if utilitarian—building; and also to the remainder of the staff whose work can go on in less crowded conditions. I trust that in the not too distant future they will have some new success to crown their efforts.

INFORMATION CONCERNING STAFF AND VISITORS

Director

Dr R. C. F. Macer continued to serve as a member of the Arable Crops and Forage Board of the JCO and to act as Chairman of its Cereal Committee. He also continued to be a member of the board of ECRE and several of its committees.

He acted as External Examiner in the Departments of Agricultural Genetics and Agricultural Botany of Queen's University, Belfast, Northern Ireland.

He attended the Seventh International Plant Protection Congress at Brighton where he chaired the session entitled "Plant Disease Control".

He was invited to serve on the Silver Medal Panel of the Royal Agricultural Society of England.

Staff

Miss E. Vallery retired after twenty-two years service with the SSRPB, having originally joined as a member of the field staff before becoming a Laboratory Attendant and finally an Experimental Worker in the Cereals Department.

New appointments made during the year included: Drs M. J. C. Asher and W. H. Macfarlane-Smith (Senior Scientific Officers); P. N. Easson (Scientific Officer); Miss C. E. Anderson, D. A. B. Brown, Miss J. A. S. Galbraith, Miss D. L. Harris, J. G. McCluskey, Miss S. C. Murray, Miss M. E. Pearce and Miss J. G. Queen (Assistant Scientific Officers); Miss G. Cruikshank (Assistant Photographer); Miss D. Trench (Clerical Officer); L. G. Robertson, A. R. Whitelaw and J. S. Orkisz (Experimental Workers); M. C. Osinski (Agricultural Worker).

Resignations included: A. W. Macarthur (Principal Scientific Officer); P. G. N. Digby and R. B. W. Williamson (Scientific Officers); G. J. Bleazard, K. Ireson, J. B. McGregor, Miss P. M. MacVeigh, Miss S. Mann, D. D. Mathieson and J. J. Rolls (Assistant Scientific Officers); Mrs M. M. Inglis (Clerical Officer); Mrs C. M. Leith (Shorthand Typist); Mrs S. Bell and W. G. Robertson (Experimental Workers).

Dr J. E. Bradshaw (formerly a Higher Scientific Officer in the Cereal Breeding Department) was appointed to the post of Senior Scientific Officer in the Brassica Department; M. S. Phillips (formerly a scientific officer in the Cereal Breeding Department) was appointed to the post of Higher Scientific Officer in the Potato Pathology Department. J. C. Penman was promoted to Scientific Officer on his transfer to the Cereals Department of the Forage Division. Mrs Isa Davidson, Mrs May Dugan and M. P. L. Campbell were promoted to EW1 during 1977.

Visitors

In April 1977 the Earl of Selborne, M.A., J.P., member of the Agricultural Research Council, visited Pentlandfield for a general tour of the institute to survey the work of SPBS. In February 1978 Dr G. W. Cooke, C.B.E., F.R.S., Chief Scientific Officer, ARC headquarters, visited SPBS and took the opportunity to talk to staff on various aspects of the Agricultural Research Service, including the roles of the various committees concerned with the JCO.

Among other visitors from ARC headquarters were Mr D. C. M. Corbett, ARC adviser in plant pathology; Dr Daphne Vince-Prue, ARC adviser in plant sciences; Dr J. D. Hayes, ARC adviser in plant breeding and Dr H. Fore, ARC adviser in animals and food, who discussed the work of the SPBS with various members of staff.

Numerous other visitors during the year included Professor J. Hirst, Director of Long Ashton Research Station, who delivered the Seventh SSRPB Lecture (*Ann. Rep. 1976-77*, 114-18); Dr B. Miflin, head of the Biochemistry Department of Rothamsted Experimental Station, who discussed various aspects of cereal biochemistry; Professor R. Riley, F.R.S., Mr H. H. Rogers and colleagues from the PBI Cambridge to discuss co-operative work with potatoes; Professor A. Bunting of Reading to discuss aspects of cereal physiology; Dr D. Charlton of DSIR, New Zealand, to study the work of SPBS in general; Dr D. S. C. Wright also of DSIR, New Zealand, to discuss a joint project in cereal breeding; Dr Horst Gaul, President of the General Organising Committee of the International Barley Genetics Symposium, to discuss arrangements for the 1981 Symposium; Professor A. T. Preston of Alberta University, Canada, on a general tour of Agricultural Research Stations; Drs L. Breese and W. Ellis-Davies to discuss aspects of grass breeding arising from the cessation of this work at SPBS; Messrs Wardle and Wilson-Jones of the Ministry of Overseas Development to consider the role of SPBS in overseas programmes; Dr V. M. Shorroks of Borax Consolidated Limited, to discuss the role of boron in relation to various crop disorders; Mr J. G. Stevens, editor of *Span*; Dr W. Hornwick of Imperial College, London; Dr R. Perry, Dr A. R. Stone and Miss S. Turner of Rothamsted Experimental Station; Professor A. Dixon of the School of Biological Sciences, University of East Anglia; Dr B. Loschenkohle of the Agricultural University of Copenhagen; Dr N. Gustafsson of IVK Potatis AB, Sweden, together with Dr H. Carlsson of the Swedish University of Agricultural Sciences, Uppsala, Sweden, who discussed the performance of SPBS varieties and selected clones in Swedish trials; Mr R. Dean and Dr Alex. Howard of Ross Produce Limited, to discuss problems and collaborative work in the processing of potatoes; Dr R. Trobridge and Messrs J. G. Evans, J. Allison, D. Garvet, A. Boswell, representatives of Cadbury Typhoo, Dornay Foods and Swell Foods, who outlined their problems as potato processors and discussed potato processing quality in the context of a breeding strategy; Messrs P. Beswick, D. Jesson and C. McCarthy of McCain International (UK) Limited, who discussed potato processing problems with particular reference to the production of frozen French fries and the SPBS variety Pentland Dell; Dr Marco, a virologist concerned with quarantine problems, from the Volcani Institute, Israel, with a particular interest in the management of the PSTV problem; Dr R. W. Gibson of Rothamsted Experimental Station, who described his work on insect resistance in wild potatoes; Mr Mulholland, Chairman of the Farmers' Federation, New Zealand, to discuss malting quality in barley; Dr T. Wainwright of the Brewing Research Foundation, also interested in barley malting quality; Drs A. Gosden and R. W. Welch of WPBS, to discuss chemistry service work in general and the analysis of SMCO in kale in particular; Dr E. P. Maher, Department of Genetics, Aberdeen University, who discussed abscisic acid resistance in barley mutants; Mr F. Fearn, Technical Manager of Technicon Company Limited, to discuss "InfraAlyser" work at SPBS.

Parties of visitors included the ASCAR delegation of the USSR; students from the universities of Aberdeen, Edinburgh, Glasgow and London, of the East and West of Scotland Colleges of Agriculture and Napier College, Edinburgh; a party of trainee plant breeders from the Swedish Seed Association, Svalöf, specialising in the improvement of the nutritional quality of barley and wheat also toured SPBS.

Visits abroad

Dr Jean Malcolmson attended the Fifth Anniversary celebrations and the inauguration of new research and teaching facilities at the Centro Internationale de la Papa, Peru, where she conferred with workers at the centre on matters of mutual interest.

Dr M. J. Allison visited research centres in Utrecht and Wageningen to discuss work on barley hormones, cereal and potato quality testing.

Dr I. H. McNaughton attended the Woronin + 100 Conference, as an invited speaker, at Madison, Wisconsin, USA, where he presented a paper entitled "Possibilities for improved *Plasmodiophora* resistance through inter-specific and inter-generic hybridisation". He also presented two papers on behalf of other British research workers who were unable to attend. Following the conference Dr McNaughton toured numerous North American institutes of agricultural research, including the Universities of Wisconsin, Minnesota and Michigan, where he delivered seminars on "Inter-specific and inter-generic transfer of disease resistance in *Brassica* and *Raphanus*".

Dr Cynthia Williamson, Mrs Carol Ross and C. P. Carroll attended the Eighth Congress of Eucarpia in Madrid, where each delivered a paper on an aspect of their work at SPBS; these were respectively: the utilisation of inter-specific hybrids of *Poa* in a plant breeding programme; the synthesis of *B. napus* by inter-specific hybridisation of *B. oleracea* and *B. campestris*; and the use of hybridisation between diploid S. American and tetraploid European potatoes in a breeding programme.

Dr J. M. S. Forrest visited centres of potato breeding and nematological research in Denmark, Sweden, Germany and The Netherlands to discuss matters of mutual interest with European scientists.

Dr R. L. Wastie attended the European Association of Potato Research, Pathology section, meeting at Braunschweig.

Dr T. M. W. Davidson attended the Fourteenth planning conference at the International Potato Centre, Lima, Peru, where he was invited to present a paper on SPBS work on the breeding for virus resistance. He also took the opportunity to visit the Estacion Experimental Regional Agropeonaria, Balcarce, Argentine, to discuss problems of mutual interest with breeders and virologists.

Dr R. P. Ellis returned from DSIR, Gore, New Zealand, in April 1977 after spending three months selecting and harvesting SPBS barley lines; R. N. H. Whitehouse left for New Zealand in January 1978 to carry out this year's selection.

Dr R. P. Ellis also visited the Carlsberg Institute, The Danish Atomic Energy Commission at Risø, the Weibullsholm Plant Breeding Institute at Landskrona and the Danish Seed Association at Svalöf to discuss barley biochemistry and physiology, and mutagenesis in oat and barley breeding.

Visits, Conferences and Lectures within UK

There were several visits by members of staff to sister institutes within the ARS and to commercial firms with whom there is collaboration. These included attendance by several members of the SPBS Forage Division at the ARC Cereal Breeders meeting at WPBS and a meeting with Rothwell Plant Breeders at Middleton House, Teesdale, to discuss cereal breeding problems. Members of the Potato Division visited potato processing factories of Cadbury Schweppes and McCain International. The annual NIAB Potato Breeders meeting at Cambridge was attended by staff of the Potato Division. Several members of staff visited the PBI, including Dr F. J. W. England and G. R. White to observe and discuss farm organisation; Dr J. M. S. Forrest to visit colleagues and to attend the Potato Cyst Nematode working party meeting of ADAS; Dr J. E. Bradshaw for two weeks, during which he studied cereal pathology techniques and Messrs M. S. Phillips and A. Young, who attended the PBI Open Day.

There were discussions, with ADAS at MAFF headquarters, London, on the place in agriculture of the new brassica crops bred by SPBS, where SPBS was represented by Drs I. H. McNaughton and M. J. Allison.

Dr M. J. Allison also visited Rothamsted Experimental Station to discuss biochemical aspects of his work with Dr B. Miflin and colleagues, and the Botany department of Birmingham University, where he discussed solanine in potatoes with P. Schmeideke and Dr D. Coxon of FRI.

M. S. Phillips spent two weeks in the Arable Crops department at WPBS studying cereal pathology techniques.

Several members of staff gave lectures or seminars to external bodies; these included lectures by I. A. Cowe on the use of infra-red analysis using the Technicon "InfraAlyser" to predict nitrogen levels in barley, to members of local institutes and University departments in Cambridge and Edinburgh; a series of twelve lectures on Genetics and Plant Breeding to fourth-year students of the Department of Botany, Edinburgh University, and a seminar on "Potato Breeding Problems and Prospects" to the University College of Wales Agricultural Society at Aberystwyth, by Dr J. H. W. Holden; a lecture on Maintenance of Potato Breeders' Stocks to the students of the Seed Technology course at Edinburgh School of Agriculture by Mrs Rosalind Hine, and a talk by G. R. Mackay to the Newcastle-upon-Tyne University Genetical Society on the work of the SPBS.

Among conferences attended by SPBS staff were: the Genetical Society meeting in Cambridge, Drs W. T. B. Thomas and R. J. Killick; a conference on field beans at SHRI, R. N. H. Whitehouse; an EAPR Agronomy section meeting in Powys, the VTSC growers annual general meeting at Aviemore, Dr J. H. W. Holden; the AAB/FBPP virus group workshop at East Malling, and a meeting on plant disease epidemiology and dispersal of plant parasites at the London School of Economics, Miss Ruth Solomon; Dr M. J. C. Asher and Dr F. J. W. England; the NIAB fellows' conference on Potato Production, G. R. Mackay and Dr R. L. Wastie.

Meetings, Conferences and Seminars

WINTER SEMINAR PROGRAMME

The winter Seminar programme included seminars by Dr A. M. Hayter (SPBS) on "The inheritance of starch hydrolysing activity in barley"; Mrs Maureen Weatherhead, University of Birmingham, on "The induction of haploids by tissue culture techniques"; Dr I. H. McNaughton (SPBS) on "Plant Breeding and Pathology in the North-Eastern United States"; Dr J. M. S. Forrest (SPBS) on "Nematology and the plant-breeder"; Dr M. Asher (SPBS) on "Pathogen variation in the take-all disease of cereals"; Dr W. Spoor of ESCA on "Incompatability in the Graminae".

EDINBURGH PLANT PATHOLOGY AND MYCOLOGY GROUP

This group held a one-day meeting at SPBS in November on the subject of Breeding for disease resistance. The meeting was organised by Dr R. L. Wastie and chaired by Dr R. C. F. Macer; papers were contributed *inter alia* by Dr J. C. Bradshaw and Messrs D. R. Glendinning, M. J. De Maine, Miss Ruth Solomon and Drs I. H. McNaughton and J. M. S. Forrest of SPBS.

The meeting concluded with demonstrations of the work of the pathological sections of SPBS.

Memberships of Committees

Dr Jean Malcolmson served on the Scottish Joint Committee for National Certificates and Diplomas in Agriculture and sub-committee E (Infraspecific) of the International Mycological Association.

Dr J. H. W. Holden served as a member of the National Proficiency Tests Council.

Dr R. J. Killick remained on the Research Council Users' Committee of ERCC until January 1978.

Dr F. J. W. England continued to be the convener of the plant breeding group of AAB.

R. N. H. Whitehouse continued to act as joint-editor of the *Cruciferae Newsletter*. He and other members of the SPBS staff also constitute the local organising committee for the Fourth International Barley Genetics Symposium, which is planned to be held in Edinburgh during 22nd-29th July 1981. (Enquiries relating to this symposium should however be directed to Dr J. W. Midgley, Centre for Industrial Consultancy and Liaison, 16 George Square, Edinburgh, EH8 9LD.)

Courses Attended

Several members of staff attended RoSPA courses: which included a safety officer's course (D. W. Speed); health and safety at work and in the laboratory; Safety Committees (H. C. M. McLeod); fork-lift truck driver's safety courses and use of fire extinguishers.

R. J. Giles, S. Gowers, Ruth Solomon and Dr J. M. S. Forrest attended an ARC course for occasional speakers.

H. C. M. McLeod, Drs R. L. Wastie, I. H. McNaughton, J. H. W. Holden and R. C. F. Macer each attended an SRC/ARC course on interviewing and selection.

G. R. Mackay passed the Potato Roguers course at East Craigs and attended part I of the SRC/ARC III Management course.

A. Young attended the SRC/ARC I Management course.

A number of staff attended routine courses on ARC JAR interviewing.

T. Gifford attended a course on management. D. Ritchie and R. G. Tait continue to attend the Oatridge Agricultural College. J. Mellon and G. Stevens attended a tractor service course at British Leyland. Miss Barbara Hay attended a one-day Dialog training course (computer information retrieval). J. A. Scott passed the Crop Inspector course at East Craigs and his licence was renewed. J. Penman completed the first stage of the M100 Foundation Mathematics course of the Open University.

New Qualifications

Miss Cynthia Williamson was awarded the degree of Ph.D. by the University of Edinburgh for her thesis: *Problems in the identification and utilisation of interspecific hybrids of* Poa *in a plant breeding programme.*

Miss Frances Bruce and Mrs Dorothy Barclay gained their HNC in biology.

D. M. Farrer and Misses Jill Middlefell, Deborah Page and Elizabeth Young successfully completed the ONC course in biology.

Subsequent Promotions

Mrs R. Hine (née Ford) and Miss R. Solomon were promoted to Higher Scientific Officer and Miss L. Wilson to Scientific Officer, with effect from 1st April 1978.

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. 113.

(b) Other official bodies

Agricultural Development and Advisory Service at Gleadthorpe, Terrington and Arthur Rickwood Experimental Husbandry Farms; Rosewarne Experimental Horticulture Station; Swansea and Shardlow Hall.
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, Research Branch, Edinburgh.
National Institute of Agricultural Botany, Cambridge, Cockle Park and Headley Hall.
National Seed Development Organisation, Cambridge.
Potato Marketing Board, London.
Royal Botanic Garden, Edinburgh.
Swedish Seed Association, Svalöf.

(c) Universities and Colleges

Agricultural Research Council Unit of Statistics, Edinburgh University.
Birmingham University, Department of Genetics.
East of Scotland College of Agriculture, Edinburgh.
Edinburgh Regional Computing Centre.
Edinburgh University, School of Agriculture and Department of Botany.
Hebrew University of Jerusalem, Levi Eshkol School of Agriculture.
Heriot-Watt University, Department of Brewing and Chemistry.

Imperial College of Science and Technology, Department of Zoology and Applied Entomology, London.
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.
British Association of Plant Breeders, Ely, Cambridge.
Calan Electronics Ltd., near Ormiston, Midlothian.
Dalgety Agricultural Research, Timaru, New Zealand.
Glynderwen Estates Ltd., Llandre-Egremont, Dyfed.
Golden Wonder Ltd., Broxburn, W. Lothian.
Miln Marsters Group, Chester.
Moray Firth Maltings, Inverness.
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.
Technicon Instruments Ltd., Houndmills, Basingstoke.
Twyford Seeds Ltd., Adderbury, Oxfordshire.

(e) Individuals

J. Black, Drochil Castle, Peeblesshire.
G. H. Coudwell, The Firs, Friskney, Lincs.
V. Evans, Bubbleton, Penally, Dyfed.
G. Finlay, Shanwell Farm, Tayport, Fife.
R. Gladstone, Fullerton Farm, Penicuik.
E. Jones, Lunnon Farm, Lunnon, Swansea.
A. Lewis, Cefn Ceido, Rhayader, Radnor.
J. F. MacBrayne, West Byres, Ormiston, E. Lothian.
W. McCrone, Cairnside, Kirkcolm, Stranraer, Wigtown.
R. Miller, Tullochgorum, Inverness-shire.
J. Riddell, West Peaston Farm, Ormiston, E. Lothian.
R. G. Robinson, Christchurch, New Zealand.
T. 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.

LIST OF ABBREVIATIONS

Organisations:

AAB	Association of Applied Biologists.
ADAS	Agricultural Development and Advisory Service.
ARC	Agricultural Research Council.
ASCAR	Anglo Soviet Co-operation for Agricultural Research.
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.
EHF	Experimental Husbandry Farm.
FBPP	Federation of British Plant Pathologists.
FRI	Food Research Institute.
GRI	Grassland Research Institute.
HFRO	Hill Farming Research Organisation.
JCO	Joint Consultative Organisation.
MAFF	Ministry of Agriculture, Fisheries and Food.
NIAB	National Institute of Agricultural Botany.
NSDO	National Seed Development Organisation.
NVRS	National Vegetable Research Station.
PBI	Plant Breeding Institute (Cambridge).
RoSPA	Royal Society for the Prevention of Accidents.
SARI	Scottish Agricultural Research Institute.
SHRI	Scottish Horticultural Research Institutes.
SPBS	Scottish Plant Breeding Station.
SSRPB	Scottish Society for Research in Plant Breeding.
UCW	University College of Wales.
WPBS	Welsh Plant Breeding Station.

Others:

APZ	Code-name of an SPBS swede breeding line.
CPC	Commonwealth Potato Collection.
DOMD	Digestible Organic Matter in the Dry Weight.
DUS	Distinctness Uniformity Stability.
ECD	European Club-root Differential.
EMAS	Edinburgh Multiple Access (Computer) System.
JAR	Job Appraisal Review.
NLT	National List Trials.
PSTV	Potato Spindle Tuber Virus.
PVR	Plant Variety Rights.
RLT	Recommended List Trials.
SMCO	S-Methyl Cysteine Sulphoxide.
TCA	Trichloroacetate.
VTSC	Virus Tested Stem Cutting.

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FORAGE DIVISION

Barley genetics

Trials to investigate methods of measuring and predicting malting quality have continued. Collaborative physiological studies have been extended to include a third barley variety and a second season. Mass selection for acid tolerant barley varieties was successful, but for reducing plant height, was not. Work continued on the barley collection. Crosses for two new genetic experiments have been completed.

The third and final trial in a series investigating methods of measuring and predicting malting quality in barley was grown in 1977 (*Ann. Rep. 1975–76*, 7 and *1976–77*, 19) and contained sixty varieties. Investigations into the factors determining malting quality have continued, with increased emphasis on small-scale tests which could be used in the F_3 and F_4 generations, before conventional micro-malting is feasible. In addition, the data from three trials of F_5 and F_6 selections grown at each of three sites were used to examine the genetics of the malting characteristics. The broad-sense heritabilities of raw grain nitrogen and β-glucan content were intermediate (h^2 approximately 0·6) and of thousand corn weights and sedimentation values were high (approximately 0·9). These experiments have shown that no single small-scale test can predict malting quality in all crosses under all circumstances. If more than one test can be applied, prediction of good malting quality is more reliable and it is possible to visualise an efficient grouping of the milling energy, infra-red reflectance and sedimentation tests which would be useful for early generation selection in a breeding programme.

The collaborative physiological studies with Dr E. J. M. Kirby of the PBI were continued for a second season (*Ann. Rep. 1976–77*, 19) and extended to include Clipper in addition to Golden Promise and Maris Mink. The yield of barley depends very largely on events which occur during primordial development (growth stages 1·0–4·0 Feekes) and determine final grain number per ear and grain weight. In Scotland in 1976 temperatures were high and rainfall was low during the grain filling period. In 1977 temperatures were lower and rainfall higher and both Golden Promise and Maris Mink responded by producing higher yields, due mainly to increased grain weights. Grain numbers were slightly reduced in 1977 but stem dry weights were substantially lower. Clipper, which is daylength insensitive, flowered earlier than did Golden Promise, which resembles most adapted barley varieties in requiring a certain minimum daylength to induce flowering. The consequence was that Clipper produced fewer primordia and yield of grain was considerably lower. Grain number per ear was approximately 66 per cent of Golden Promise. The physiological studies with Dr S. Matthews and Mr E. J. Thomson of the University of Stirling were also continued for a further season.

The effects of low soil pH on barley varieties were examined in a trial at West Byres Farm, East Lothian, in 1977. Three strips of soil with pH levels 4·4, 4·6 and 4·8 were used. Lowering pH significantly reduced plant heights, numbers of grains per ear, thousand corn weights, yields and harvest indices. Significant varietal differences were detected for plant height, number of grains per ear and yield, and there were no variety by environment interactions. Grain yield at pH 4·4 was only 20 per cent of the pH 4·8 mean. Taking mean yield over all three pH levels as an index of tolerance, Scots Bere was the most tolerant of acid conditions and Gerkra, Aapo and Effendi exhibited useful levels of tolerance. Golden Promise was least tolerant of low pH conditions. The composite cross population multiplied in 1976 from seed set on male-sterile plants was screened under the same conditions and effective selection was possible for acid tolerant types. Surviving plants will be sown with the base composite population in 1978 and recurrent selection will continue from male-sterile plants for a number of generations.

In contrast to the success in screening for acid tolerance, mass selection for plant height in composite cross populations (*Ann. Rep. 1976–77*, 20) was not successful. A small number of very tall plants was eliminated from some clipped populations but the overall response was disappointing and the experiment has been discontinued.

Field observations were made in 1977 on 2,530 entries in the barley collection, which increased by approximately 200 to a total of 2,815 entries. Work has continued on the coding and filing of observations in the EXIR databank; some information is now recorded on 1,200 entries in the collection. R. J. Giles spent three days at PBI in January 1978 gaining practical experience in manipulating the EXIR system. A total of 115 accessions of *Hordeum spontaneum* was multiplied in the glasshouse. This material has a brittle rachis and shatters when mature so special precautions are necessary for successful multiplication. A further 3,500 single seeds of *H. spontaneum* are also being multiplied as part of a collaborative project with PBI and WPBS to conserve germ-plasm collected in Israel in 1977. A total of 54,000 single seeds is to be multiplied over a five year period by the three stations.

In a collaborative experiment with Professor J. L. Jinks of Birmingham University, five pair-crosses were selected in 1977 for the production of triple test cross progenies to investigate cross prediction. These will also provide genetic analysis of some important agronomic characters. The progenies will be sown in the field in 1978 together with parental, F_1, F_2 and back-cross generations. In addition, a number of crosses has been made to locate several commercially important major genes determining short-straw in different barley varieties. These will also be sown in the field in 1978 as part of a longer term genetic study.

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

Barley Biochemistry

Several mutants of Maris Mink, resistant to abscisic acid, were shown to have relatively "soft" endosperms (requiring a low milling energy). A wide variation for milling energy was also observed for high lysine mutants from the Danish Atomic Energy Commission at Risø. Five of the Risø mutants had milling energies typical of barleys that malt readily. Work continued on the production of well-adapted, high diastase barleys from crosses between varieties with different forms of β-amylase.

Abscisic acid-resistant mutants of Maris Mink (*Ann. Rep. 1976–77*, 20) having greater diastatic power than the parent were grown for further assessment as part of the barley breeding programme. Since resistance to abscisic acid (ABA) is scored as germinative growth, despite the presence of the inhibitor ABA, it is possible that some mutants may germinate well because of changes in endosperm structure. From studies on the electrical energy required to mill barley, it is known that barleys which malt readily, usually have "soft" endosperms (low milling energies). When the milling energies of ABA-resistant mutants were measured, a small proportion (three out of fifty tested) had significantly lower milling energies than either Maris Mink or the other mutant selections. Thus, selection for ABA resistance may also select for an endosperm attribute favourable for malting quality.

During an investigation of some properties of high lysine mutants from the Danish Atomic Energy Commission at Risø, the observation was made that milling energy varied markedly among the high lysine mutants. Five out of seventeen mutants tested had very low milling energies comparable with that of Ark Royal, a British barley with good malting quality. In addition to a possible increase in enzyme activity (*e.g.* the high β-amylase activity of Risø 56) selection for high lysine, may also select for an endosperm attribute favourable for malting.

Five lines high in β-amylase, which were derived from a cross between the two varieties Akka and Feebar (*Ann. Rep. 1976–77*, 21) have been crossed with well-adapted varieties which are good sources of short straw and disease resistance. The progeny will be grown as a part of the F_2 barley breeding material in 1978. Single plants, selected in the 1977 F_2 population, from four crosses in the high diastase programme are being classified on the basis of their electrophoretic pattern of β-amylases in a study on the prediction of diastatic power.

M. J. Allison
J. S. Swanston

Barley Breeding

Progress with high diastase, general purpose and malting quality barley breeding is reported. Investigations of generalised lattice trial designs continued. Small-scale tests for malting quality were used routinely for F_3 selection for the first time. Progress with nurseries for the selection of disease resistant plants is discussed.

In 1977, four selections from the cross Hassan × Universe again performed well and have been retained, some represented by more than one family. Three EMS (ethyl methane sulphonate)-induced high diastase mutants of Maris Mink have also been advanced for further evaluation. At F_6 one high diastase selection of Maris Mink × Akka, one general purpose selection of Maris Mink × Mazurka from Scottish based trials plus two Akka × (Maris Mink)^2 selections advanced at F_5 in New Zealand, have been retained for further trials. A number of F_5 crosses are still being evaluated, including eight high diastase selections from Akka × (Maris Mink)^2, a general purpose selection from a Zephyr high-amylose line × Universe, and two selections from Maris Mink × Wing which have some potential for malting quality. Two selections from Armelle × Maris Mink and two from Armelle × Mimi were advanced from F_4 to F_5 in New Zealand and are now at F_6 and have been placed in trials in 1978.

Investigations continued of generalised lattice designs for F_4 and F_5 trials (*Ann. Rep. 1976-77*, 22). A total of five trials at F_4 and four at F_5 were sown to these designs in 1977. Results were encouraging and indicate that if block sizes are reduced, and the proportion of controls increased to a minimum of one per block these trials can be used routinely in the breeding programme in future. Work also continued with the use of computer programmes for all data handling in the breeding programme.

The Technicon "InfraAlyser" measures infra-red reflectance at six wavelengths and by multiple regression can be programmed to predict a number of grain quality characters in cereals. In the breeding programme the "InfraAlyser" has been used to estimate raw grain nitrogen and β-glucan contents in F_3 lines. The method is extremely quick, involving only the milling of samples through an Udy cyclone mill and presentation of the milled samples in glass fronted cups for estimation. One hundred to 150 samples can be processed daily. Milled samples have also been shown to be suitable for direct sedimentation testing, without seiving, making this test considerably faster. Investigations are continuing of the potential for these and other small-scale malting tests, together with the development of more robust apparatus for the direct measurement of milling energy.

The late arrival of a natural epidemic of mildew (*Erysiphe graminis*) in Scotland prevented effective selection for resistance in F_2 and F_3 nurseries. It was not possible to score mildew levels on any of our yield trials in Scotland. Samples from F_4 and later generations were, however, sown as hill plants in special disease nurseries. A satisfactory epidemic of leaf blotch (*Rhynchosporium* *secalis*) was induced by late autumn sowing, with susceptible spreader varieties as surround crops, and straw infected with race UK1 as a source of inoculum spread over the entire nursery area. The nursery was top-dressed with nitrogen in the spring and rolled to damage plants. Stem elongation occurred during hot, dry weather in May and the spread of the disease was halted. However, sufficient rain followed for the disease to continue developing up to the flag-leaf in susceptible varieties. In future years irrigation equipment will be available if required. In late spring a similar nursery was sown and inoculations were made of yellow rust (*Puccinia striiformis*). These established well but were not made sufficiently early and the foci of infection did not spread sufficiently far to coalesce and provide a uniform attack. However, by the end of July it was possible to obtain useful measurements of mildew resistance on this nursery. A third nursery at Trefloyne (Gwent) sown by WPBS provided satisfactory scores of brown rust (*Puccinia hordei*) resistance.

The disease resistance composite cross (*Ann. Rep. 1974-75*, 11) was grown for the first time in 1977. Male-sterile plants selected from F_2 rows grown in the field in 1976 were multiplied over winter. Approximately 16,000 F_4 seeds were sown at a low seed rate at the Murrays and *Rhynchosporium* infected straw was spread over the area. During the season susceptible plants were removed, as were those with dark grains or six-row heads. In future generations selection will be for mildew and rust resistance. Eventually this population will be used for conventional pedigree selection and continuous selection pressure will be applied for short straw and suitable maturity.

The Murrays was also used to provide one site of an extensive series of experiments being conducted by Dr M. S. Wolfe (PBI) to examine the use of varietal mixtures as a strategy for mildew control. The twelve treatments included Hassan, Midas, Wing and a 1 : 1 : 1 mixture of these varieties at three seed rates (low, normal, high). Milstem seed-dressing was either absent or present at one-third of the normal rate of application. The late arrival of mildew in this trial meant that only very low levels of mildew attack developed, but the analysis of data from sites with a range of mildew attacks should prove interesting. These experiments are being continued for a second season at the Murrays in 1978.

A. M. Hayter — W. T. B. Thomas
M. J. C. Asher — M. S. Phillips
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Oat Breeding

The progress of oat breeding material through official and station trials continues steadily. Work commenced on the measurement of agronomic characters on the oat collection. Collaborative physiological studies have been extended to include oats.

Leven (Aa 749) and Etive (Aa 752) completed one year of Recommended List Trials (RLT) by the Scottish Colleges in 1977 and both varieties performed sufficiently well to be retained for further evaluation in 1978. Etive also completed RLT by the NIAB in England and Wales, where it failed to realise the earlier promise shown by two years of National List Trials (NLT) and did not receive a recommendation. The names Earn and Fyne have been accepted for lines Aa 758 and Aa 760 and both have performed particularly well in their first year of NLT in 1977. These lines are, however, similar and it is probable that one may have to be withdrawn in 1978. Aa 773, an unnamed selection from the A66 (*Ann. Rep. 1976-77*, 26) composite population, has been entered for first year NLT and Plant Variety Rights testing in 1978.

The six lines from the A69 composite and the eelworm resistant lines (*Ann. Rep. 1976-77*, 25) did not perform well in yield trials. All have been discarded except as parents in a new pedigree crossing programme. A total of thirteen progeny rows have been retained for first yield trials. Work on the selection of material from composite cross populations has now decreased and a new programme of pedigree plant breeding and genetic investigation has been started. Crosses were made to investigate the genetics of height and some quality characteristics.

The oat collection has now been assigned to R. J. Giles and the Pure Stocks Unit. All *Avena* collections have been aggregated in a single collection of 747 entries, although special precautions are necessary to deal with some species and cultivars which shatter when mature. The collection was sown at Trefloyne (Gwent) by WPBS to obtain information on mildew and crown rust resistance. Scores were obtained from a late epidemic of mildew but crown rust did not develop. The same collection was sown at the Murrays but no useful disease resistance information was obtained.

An oat variety, Maris Tabard, was included in the collaborative physiological experiments with Dr E. J. M. Kirby (PBI) for the first time in 1977. Maris Tabard was slower to germinate and begin development but panicle development was extremely rapid compared with the three barley varieties (Golden Promise, Maris Mink and Clipper). Approximately 300 primordia were formed although only seventy mature grains were produced by the oat panicle. This represented a considerable loss of resources compared with averages of forty-six primordia developed and thirty-five mature grains produced by the barley spikes. Panicle development was complex and more difficult to follow than spike development in barley. In 1978 more attention will be paid to the first sixty days of development when the events are most complex.

A. M. Hayter   W. T. B. Thomas
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Studies of Swede Hybrids

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

Backcrossing of existing S-gene lines to their recurrent swede parent continued, with selfing of the advanced lines to obtain homozygous S-allele lines for F_1 hybrid production. The programme to introduce stronger S-alleles (*i.e.*, those which will be effective even when heterozygous, *Ann. Rep. 1976–77*, 27) was continued and crosses were made to a further eight cultivars.

The work of checking S-genes was mainly concerned with three lines derived from H52 (*Ann. Rep, 1973–74*, 12). These lines were self-incompatible but were found to be cross-compatible. Unless there is something unusual in the dominance relationships, such as reversal of dominance between stigma and pollen reaction, this means that three S-genes must be present. H52 was an allodiploid obtained by crossing *Brassica oleracea* with *B. campestris* at the diploid level, and seed was only obtained on open-pollination. If these seeds were produced by selfing or parthenogenesis only two S-genes should be present. It is assumed, therefore, that out-crossing has occurred to another *B. napus* carrying a different S-allele, even though only commercial cultivars could be involved and these are usually self-compatible.

F_1 HYBRIDS PRODUCED BY HAND POLLINATION

Due to problems of establishment with transplant trials, it was decided not to prick out seed from the 1976 crosses but to repeat those with low seed set, to try to produce enough seed to sow out with a hand drill. Sufficient seed to drill a ten × ten half-diallel was obtained with the exception of one cross. Several other crosses of interest were also made, mainly to check results obtained in previous trials.

S. Gowers

Swede Breeding

High-yielding lines are being sought by inbreeding both within present cultivars and in progenies obtained by crossing cultivars. Several promising lines have been obtained and these are being examined as possible new varieties.

INBRED LINES FROM INTER-CULTIVAR CROSSES

The programme, to produce a suitable replacement for Pentland Harvester, continued in 1977.

Two trials were conducted at the Murrays, with seed produced by selfing in 1976, one with F_5, and the other with F_6, progenies. Each trial consisted of two randomised blocks with the controls in the form of an embedded Latin Square to give some indication of intra-block variability. Germination and establishment were good in parts of the field, but poor in others and subsequent growth followed much the same pattern.

The first trial consisted of ninety-six F_5 inbred lines, with four control cultivars. The lines were developed from crosses between the green-skinned cultivar, Teviotdale, and a deep purple-skinned line, developed at SPBS from the old cultivar Champion. The second trial involved 225 F_6 lines derived from crosses mainly between Bangholms and Wilhelmsburgers plus six controls.

Harvesting of both the above trials was delayed due to adverse weather and detailed analysis of data has not yet been completed.

The Field Trials Unit laid out trials at two sites, the Murrays and at the NIAB Trials Centre at Cockle Park, Northumberland, to further evaluate the two promising lines mentioned in last year's report (*Ann. Rep. 1976–77*, 28.) The results of these trials are summarised in Table 1. The dry matter yields of the two inbred lines were satisfactory compared to those of the controls and their high dry matter content is a valuable characteristic. Both lines were free from "raan" and internal browning; no assessment for powdery mildew (*Erysiphe cruciferarum*) was possible because of the very low incidence of this disease in 1977.

TABLE 1

Performance of two inbred lines of Swede, Da 9939 and Da 9943 and of five cultivars at the Murrays and at Cockle Park, Northumberland. Yields are given as a percentage of those of Bangholm Ruta

	The Murrays			*Cockle Park*		
	Dry matter yield	*Dry matter %*	*Fresh weight yield*	*Dry matter yield*	*Dry matter %*	*Fresh weight yield*
Bangholm Ruta	100	10·6	100	100	10·8	100
Da 9939	104	12·0	92	100	12·4	86
Da 9943	103	12·3	89	98	12·6	84
Bangholm Magres	99	11·8	89	87	11·0	85
Wilhelmsburger Sator	107	11·0	92	85	11·7	79
Marian	102	10·3	105	96	9·9	104
Doon Major	101	9·1	117	103	8·9	124
Control yield t ha^{-1}	10·5	—	98·7	10·5	—	97·3
SE difference ($p \leqslant 0{\cdot}05$)	NS	0·32	3·10	4·81	0·27	4·45
coef. of variation	8·6	4·2	4·4	7·0	3·5	6·5

Selected plants from trials in 1976 were selfed and multiplied in insect-proof cages in 1977. It was not a good year for seed production and some selfings and multiplications may have to be repeated.

Isabel K. Munro

In an attempt to produce quick growing swedes with high yields of foliage, crosses between Canard rape and six swede cultivars were made. Selected plants will be transplanted to insect cages to produce F_2 seed in 1978. Some of this material could also be useful for transferring desirable characters from swedes to rape, *e.g.*, resistance to powdery mildew.

From the results of the F_1 hybrid trial in 1976, twelve hybrids were selected and transplanted to insect cages. F_2 seed from these lines will be sown in observation plots in 1978.

Nearly 2,000 F_2 plants were planted out for observation and selection. Nineteen different lines were involved, mainly from crosses between Doon Major and APZ (*Ann. Rep. 1971-72*, 24) with high yielding cultivars. Some other crosses of interest were included because of their disease resistance. Good powdery mildew infection was obtained and several lines showed resistance. Plants with Doon Major in their parentage were lifted in November and transferred to cold frames as they may be of low dry matter content and not completely winter hardy. The other lines are being left in the field to allow selection for winter hardiness.

These F_2 lines were delayed a year because of lack of vernalisation in the glasshouse resulting in failure to flower. The gap in the breeding programme was filled by resowing F_2 seed from crosses made in 1966 and 1967. Thirteen lines had sufficient viable seed for sowing observation plots, but one of these was badly infected by both powdery mildew and viruses and was discarded. Selections were made in March, after a severe winter, and transplanted for bag selfing. Over 500 plants were selected and these were scored for seven "bulb" characters. Although the selected plants appeared sound and healthy, about half of them rotted before setting seed, leaving approximately 250 F_3 lines for sowing in 1978 trials.

The F_3 trial sown at the Murrays was a generalised lattice design with two replicates of sixty-four lines and controls. These lines were derived from crosses between Bangholm Ruta and seven other cultivars. The full analysis has not yet been completed, but a preliminary analysis as for a randomised block design shows that none of the F_3 lines outyielded Bangholm Ruta.

S. Gowers

INBREEDING WITHIN CULTIVARS

The main aim of selfing commercial cultivars is to produce high-yielding inbred lines for the F_1 hybrid programme. To this end, selfed progenies of eight cultivars were sown out for selection, and plants of another nine varieties have been bag-selfed.

Work on lines from three other cultivars is continuing. Second generation inbreds, from selected families of the cultivar Scotia, were sown in trial. A preliminary analysis shows the overall mean of the lines to be almost identical to that of the Scotia control. This would appear to show that inbreeding with selection has avoided any drop in yield of the inbred lines.

A multiplication of the highest yielding Scotia family, from the I_1 generation, was included in the Field Trials Unit trial, along with three lines from

Bangholm Dima (BD) and two lines from Criffel (CR). There were no significant differences in dry matter yield between the lines and the best controls. CR5, however, had the highest fresh weight yield, and BD9 was significantly higher in dry matter content ($p < 0.01$). From observations made at Headley Hall and Cambridge, BD20 appears to have good resistance to turnip crinkle virus and powdery mildew.

High and low selections for yield characters of BD and CR were bag selfed for a selection experiment. The seed set on the BD lines was satisfactory, except for one low dry matter content line, but the seed yield from some of the CR lines was very poor. The effects of selection will be examined using the BD lines only, with the top CR lines being used for selecting a high-yielding inbred line.

SELECTION FOR HIGH DRY MATTER CONTENT

Of fifty plants selected for high dry matter content, twenty-five produced sufficient seed to sow in trial. Ten plants from each of four replicates were sampled for each line and a regression analysis of dry matter percentage on fresh weight was made. Fifty plants were then selected on their deviation from the regression line. Twenty-eight of these plants were from a line selected from Bangholm Wilby which appears very promising. This line was included in the Field Trials Unit swede trials and gave dry matter yields equal to those of the control varieties, whilst having a dry matter content 20 per cent higher than the highest controls (Wilhelmsburger Sator and Bangholm Magres).

INTROGRESSION OF CHARACTERS FROM TURNIP

Selected plants from forty-eight lines, derived from turnip × swede hybrids, were left to flower in the field and scored for pollen fertility. These lines were from parents previously selected for high pollen fertility, their chromosome numbers being unknown. Out of 296 plants scored, 108 had pollen fertilities of over 80 per cent. Seventy-five plants were bag selfed, after the open flowers had been removed; thirty-six produced sufficient seed for trials in 1978.

Progenies of plants with similar parentage to those above, but which were screened for chromosome numbers by the Cytology Unit, are also being examined. Fifty plants, from self-fertile thirty-eight chromosome parents, have been grown on for bag-selfing in 1978. The possibility of obtaining fertile, stable aneuploids is also being examined. Progeny from a $2n = 37$ chromosome plant, with $2n = 36$ and $2n = 38$ chromosomes were not stable at meiosis; these will be tested agronomically before an attempt is made to stabilize cytological behaviour by selection. The progeny of a highly fertile $2n = 36$ chromosome plant, with $2n = 34$ and $2n = 38$ chromosomes, have been grown on for selfing.

S. Gowers

Swede Genebank

In recent years many old cultivars of swede (*Brassica napus* ssp. *rapifera*) have disappeared and others are in danger of doing so. This is largely due to the replacement of old cultivars by better, newer material; nevertheless many old varieties possessed valuable characteristics which might be of use in future breeding programmes and for this reason a collection of seed of old cultivars is being assembled at SPBS. It is intended that seed stocks of material in the collection should be renewed, in rotation, at regular intervals by multiplication in isolation and that varietal characteristics be recorded from material in field plots.

Valuable assistance has already been received from DAFS (Scientific Services) who have donated all their stocks of old cultivars. It is hoped, eventually to include other forms of *B. napus* in the collection.

SPBS would welcome any donation of seed of material suitable for inclusion in the collection. All contributions will be acknowledged.

Isabel K. Munro

Kale Improvement

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 for yield of digestible organic dry matter.

In the 1976 trial of single-plant polycross progenies produced in 1975 (*Ann. Rep. 1975–76*, 12), significant differences were found between families in the yield of digestible organic dry matter. Where possible ten plants from each of the fifteen highest yielding families (top 10 per cent) were selected from observation plots in the spring of 1977 and transplanted to an isolation cage. In the autumn seed was obtained from 103 plants. About two-thirds of these plants have given sufficient seed for trial purposes in 1978 (S3 generation). Table 2 summarizes the progress that has been made with this "polycross population", relative to the controls, Maris Kestrel and Canson, as a result of direct selection for yield of digestible organic dry matter, assessed on the performance of collateral relatives.

During 1977 residual seed of the S_0, S_1, and S_2 generations was used to

TABLE 2

Yield of digestible organic dry matter (t ha^{-1}) of kale polycross breeding populations

Year	*Mean of controls*	*Polycross populations*		
		Generation	*Yield*	*% of controls*
1972	3·94	S_0	4·17	106
1974	4·81	S_1	5·84	121
1976	5·23	S_2	6·73	129

compare these populations in the same environment and hence to obtain a direct estimate of the response to selection. The trial was harvested in December but the digestibility analyses have not been completed.

The five "pre-varietal stocks" from S_1 were assessed for a second season by the trials unit at three sites (Ayr, Cockle Park, and the Murrays). In addition, single plant progenies of the two best entries in the 1976 trials were grown as transplants in 1977. Off-types are being discarded so that, if the 1976 results are confirmed, selected plants of one or both stocks can be used to produce a bulk of seed in 1978 for further trials and possible NLT submission.

Four single plant progenies of S_2 were mass multiplied, each in an isolation plot, to produce seed for "prevarietal assessment" in 1978.

No work was carried out in 1977 on the reciprocal recurrent selection programme, but seed from selections will be sown for agronomic assessment in 1978, in preparation for a complete review of the programme.

J. E. Bradshaw

Exploitation of Inter-specific Crosses as Possible Rape Substitutes or as New Forage Species

Some semi-artificial rape lines showed promise in being leafy and almost as high-yielding as the best available commercial Giant rape varieties. A start has been made to develop leafy catch crops, suitable for late sowing and with a reasonably high dry-matter content.

BRASSICA OLERACEA × *B. CAMPESTRIS* HYBRIDS

The production of new, artificially synthesised *Brassica napus*, using embryo culture, was suspended in 1977 because of laboratory alterations.

Artificially synthesised *B. napus* plants, produced in 1976, were treated by what is now the standard method, *i.e.*, colchicine treated, if derived from crosses between diploid parents, self-pollinated and crossed to natural *B. napus*.

Several of the potentially more interesting semi-artificial lines, produced in 1976, were multiplied in insect-proof cages.

Artificial *B. napus* plants, derived from *Plasmodiophora* resistant *B. campestris* (ECD O4), were successfully selfed and used in crosses with rape types and a few swede cultivars (see p. 38).

Carol L. Ross

DEVELOPMENT OF SEMI-ARTIFICIAL RAPES AND CATCH CROPS

In 1974 a single allotriploid hybrid was produced from normal crossing between a diploid stubble-turnip (*B. campestris*) and a tetraploid marrow-stem kale (*B. oleracea*), this hybrid (genomic formula acc, $2n = 28$) was used as male parent in crosses with various rapes. The resultant progeny varied in chromosome number from $2n = 32$ to $2n = 46$. Several plants with $2n = 36$ and

2n = 37 chromosomes were obtained. The majority of these were self-pollinated in 1976, resulting in progeny with the following chromosome numbers; 2n = 35 (two plants), 2n = 36 (eighteen plants), 2n = 37 (sixty-two plants) and 2n = 38 (thirty-five plants). The Cytology Unit undertook the chromosome counts.

The above 117, cytologically examined plants, were raised in the glasshouse. Several were noted to be uninfected by naturally occurring powdery mildew. Mildew free plants were contiguous to heavily infected plants. It is suggested that mildew resistant rapes may be developed from this material in the future. There is a requirement for proper mildew screening, under controlled conditions of inoculation and environment.

Selections were made from an artificial rape, received as breeding material from the Swedish Seed Association, Svalöf. This was derived by hybridizing a tetraploid form of *B. oleracea* (marrow-stem kale) and tetraploid *B. campestris* ssp. *nipposinica*, the leafy oriental, salad vegetable. The latter parent was supplied by SPBS. This promising material showed considerable segregation, and contained a number of leafy, vigorous, branching plants and individuals with stems resembling marrow-stem kale. There was also a number of premature flowering plants.

Selections for leafiness and vigour were made from large F_2 populations of hybrids between a low thiocyanate rape line, also kindly supplied by the Swedish Seed Association, and SPBS breeding lines, with a view to testing selfed progenies for low thiocyanate content.

Fourteen semi-artificial rape lines, of which Nevin was a parent, were compared, in a replicated trial, with Nevin, Canard, Emerald and Lair as commercial controls. The latter three Giant rape cultivars are the highest yielders in the current NIAB list of recommended varieties. Emerald produced the highest dry matter yield but the best of the semi-artificial rapes were only slightly inferior, some were distinctly leafier than the commercial cultivars and with good leaf retention. All but two of the semi-artificial lines outyielded Nevin, the best by almost 35 per cent.

The leafy, grazing turnips, Appin and Ballater, were compared, in late sown trials, with Civasto, one of the highest yielding stubble-turnips. Lair rape and Slobolt and Crail fodder radishes were also included. The trials were carried out by the Field Trials Unit at the Murrays and at Yonderton Farm near Ayr (by courtesy of Sinclair-McGill Ltd.). The results are summarised in Table 3. Both Appin and Ballater performed satisfactorily compared to the stubble turnip Civasto, especially in view of the high wastage rates commonly experienced when grazing stubble turnips due to uprooting of bulbs by sheep.

Appin was reported by WPBS to have aroused considerable interest amongst local farmers when sown on hill land, being almost totally utilized when grazed by sheep. A stubble-turnip control, Marco, had about 30 per cent "bulb" wastage. Regrowth of Appin produced a second crop which was utilized by sheep. Appin was observed to be particularly resistant to pigeon attack. ADAS reported variable results on grazing Appin in 1976.

TABLE 3

Performance of Appin and Ballater grazing turnips and of Crail fodder radish compared with Civasto stubble turnip, Slobolt fodder radish and Lair rape at two sites in 1977. Yields are given as a percentage of the mean for all six entries

	The Murrays		*Yonderton (Ayr)*		*Mean of both sites*	
	Sown 4.8.77	*Harvested* 18.11.77	*Sown* 10.8.77	*Harvested* 23.11.77		
	Dry matter yield	*Dry matter %*	*Dry matter yield*	*Dry matter %*	*Dry matter yield*	*Dry matter %*
Ballater	112	7·6	117	7·9	114	7·8
Civasto	108	7·8	108	8·6	108	8·2
Appin	99	7·3	103	7·7	101	7·5
Crail	99	7·1	101	7·1	100	7·1
Slobolt	97	7·0	88	7·3	94	7·2
Lair	84	8·8	83	9·8	84	9·3
Mean yield t ha^{-1}	5·19	—	3·45	—	4·32	—
SE of difference %	3·5	0·23	5·4	0·38	3·1	0·24
coef. of variation	4·9	—	7·7	—	—	—

Deficiencies in Appin and Ballater appear to be mainly concerned with their relatively low dry matter contents, compared to the highest yielding diploid stubble-turnips, such as Civasto, this is a condition of their being tetraploids. A start has been made to develop leafy hybrids at the diploid chromosome level, with consequent higher dry matter content and, other things being equal, higher dry matter yield. *Plasmodiophora* resistance is an additional consideration.

Low dry matter content may restrict the amount of animal intake on grazing. Experiments, currently being carried out at GRI with Appin, suggest this, the comparison being with rape. Rape, however, normally yields poorly from late sowing. An obvious aim in breeding cultivars for late sowing is rapidity of growth, combined with high dry matter content. It may prove difficult to make significant improvements in this direction since these two traits may be negatively correlated.

I. H. McNaughton

Raphanobrassica—An Inter-generic Hybrid Species as a Club-root Resistant Alternative to Rape

Progress has been made towards developing leafy, biennial radishes from hybrids between fodder radish and wild, sea radish. Seed fertility of Raphanobrassica *(radicole) has shown improvement under favourable conditions, but seed production remains a problem. Dry matter yields of radicoles have been slightly lower than rape in 1977 trials, a reversal of the 1975 and 1976 results.*

Progenies of inter-specific hybrids between *Raphanus sativus*, fodder radish and *R. maritimus*, sea radish, back-crossed to fodder radish, were examined in the field from a late June sowing. Diploid and tetraploid forms have been developed. Slobolt, a commercial diploid fodder radish and Crail, a late-flowering tetraploid, produced by SPBS, were used as visual controls. All Slobolt plants flowered by mid-October and produced capsules by early December. A number of Crail plants also flowered as did some of the diploid inter-species hybrids. Virtually no tetraploid hybrids flowered. Leafy, hardy diploid and tetraploid plants were selected, the latter especially for use as improved parents for future *Raphanus* × *Brassica* crosses.

Many *Raphanobrassica* (radicole) plants, raised as transplants for seed production, lacked winter-hardiness in winter 1976-77. Approximately 75 per cent of radicoles, with thousand-head or curly kale parentage, failed to survive. Over 90 per cent of radicoles, with marrow-stem kale as a parent, were killed. In previous seasons radicoles, with the exception of prematurely flowering plants, had proved perfectly winter hardy.

The high numbers of radicole winter casualties posed problems of adequate seed production of the most promising lines. Seed production, from surviving plants, has proved difficult in the cold, wet conditions prevailing in late summer and autumn 1977. As an insurance the same lines have again been grown for possible seed production in 1978.

It would appear that, if radicoles are to become a commercial proposition, multiplication would have to take place in a more favourable climate.

Under the more amenable conditions of a glasshouse, NSDO, Cambridge, produced eight kilograms of seed from approximately 200 plants, an average of about 40 g per plant. This is indicative of the resolution of the originally very acute sterility problem of radicoles. This particular line had been selected at SPBS for higher seed fertility and for homozygosity of flower colour (white).

NSDO has produced several hundred kilograms of seed from a field multiplication of less highly selected material which is segregating for flower colour. This seed is available for trials and experimental purposes in 1978 but is not considered uniform enough to constitute the basis of a new cultivar. Radicoles in this category have outyielded rape in 1975 and 1976 trials at several sites. *In vitro* digestibility (DOMD per cent) and crude protein contents have been similar to rape. 1977 trials, conducted at several sites, have been less promising. Although fresh weight yields of radicoles were generally higher than Giant rape controls their lower dry matter contents resulted in dry matter yields slightly lower than rape.

Utilization of radicoles by sheep, observed on a small scale only, has been satisfactory. In autumn 1977 The West of Scotland College of Agriculture carried out a more comprehensive and larger scale grazing experiment, involving assessment of live weight gain of animals. Data have not yet been obtained.

Crail, fodder radish, failed to satisfy DUS tests, in the second year, due to segregation for root colour. Selections have been made to remedy this.

I. H. McNaughton

Breeding for Resistance to *Plasmodiophora brassica* (causing Club-root Disease)

A high level of resistance has been successfully introduced into rape and swedes from a stubble turnip line. A start has been made towards developing leafy, catch crops, suitable for late sowing, with the same degree of resistance.

F_5 semi-artificial rape lines, in which Nevin, a cultivar with resistance to a number of UK races of *Plasmodiophora brassica*, was a parent, were examined for "Nevin type" resistance. These lines were selfed progenies of F_4 plants, previously screened as resistant. Several F_5 lines were uninfected, suggesting that they are homozygous for resistance. Larger numbers of seedlings of these lines require to be tested to confirm this observation.

In an attempt to incorporate a higher degree of resistance into rape, breeding lines were hybridized with artificial *Brassica napus*, produced by embryo culture, in which ECD 04, with a very wide spectrum of *Plasmodiophora* resistance, was a parent (*Ann. Rep. 1976-77*, 37). A number of F_1 hybrids tested confirmed that "ECD 04 type" resistance had been incorporated into rape. This resistance is also being introduced into swedes.

Progenies of swede-type material, selected from a previous test, were also tested for "ECD 04 type" resistance. Two lines from the Norwegian cultivar Gry showed resistance, as did lines derived from a turnip × swede cross (Vobra × Chignecto). The turnip × swede hybrids are being back-crossed to swede lines, with selection for plants having the normal thirty-eight chromosome complement of swede.

A similar back-crossing programme has started to introduce "ECD 04 type" resistance into oil-seed rape. Six oil-seed *B. napus* cultivars were back-crossed to their hybrids possessing ECD 04 resistance and progeny obtained, some of which showed resistance.

Spores of *P. brassica* for the above tests, giving the appropriate reactions in terms of ECD hosts, were supplied by Mrs S. Lewis and Dr T. Brokenshire of the Plant Pathology Department, ESCA.

In an ESCA trial at Boghall Farm, Lair rape was heavily infected by club-root and Maris Kestrel kale also showed some infection. One *Raphanobrassica* (radicole) line showed only very slight infection, whilst another was completely uninfected, as were Crail and Slobolt fodder radishes.

I. H. McNaughton
S. Gowers

Breeding Interspecific Hybrids of *Poa* for use in Upland Pastures

Visual assessments of intra-family variability on seedling progenies from third generation hybrids enabled separation of uniform apomictic families from variable families derived from sexually produced seed.

The hybrid progenies were also screened for early germination and seedling vigour. Early season yields from sown microswards were particularly good from a French biotype of Poa pratensis *and from* P. iberica. *There was a very promising response to selection for high seedling fresh weight in hybrid progenies.*

One of the main objectives in this project has been to find methods which will increase the efficiency of handling plant material in the breeding programme. The interspecific hybrids were all derived from at least one parent with apomictic seed production (*Poa pratensis*), and in many cases both parents were apomictic. The F_1 hybrids mostly produced sexual seed but 20 to 40 per cent of second and third generations were apomictic. Since the aim is to produce cultivars which are highly apomictic, only hybrids with this type of seed production are included in microsward trials in which rate of establishment, yield and persistence are assessed at different sites. It would clearly be an advantage to be able to select apomictic families early in the life cycle and before planting out for agronomic assessment in field trials.

An estimate of within-family phenotypic variability in comparison with known apomicts gives an adequate measure of the proportion of sexual seed produced by the maternal parent. Mature spaced plants in progeny rows have previously been used to obtain this estimate. In 1977, for the first time, seedling characters were used to separate the two types of family which can therefore go forward into different field trials.

SELECTION OF THIRD GENERATION HYBRID PROGENIES

Three hundred and seventy individuals were selected from the third generation hybrids on the basis of spring growth (in 1975 and 1976), plant size and habit. Seedling progenies were used to give estimates of within-family variability; twenty unselected seedlings were recorded from each progeny. Twenty-one per cent of the families were uniform and probably apomictic, thirty per cent were very variable and the remaining families were intermediate.

Progeny rows from the 370 populations were also sown in seed trays on 18th April and kept outside. Three cultivars of *P. pratensis* and perennial ryegrass cv S.23 were included as controls. Rate of germination and seedling vigour were recorded. Forty-five of the hybrid progenies germinated and seedlings developed more rapidly than Prato, the most vigorous of the *P. pratensis* cultivars; six hybrids were comparable with S.23. These data were used to select 109 of the phenotypically variable and intermediate families and thirty-two of the uniform families for further assessment in field trials, the former as spaced plants and the latter as microswards.

MICROSWARD TRIALS

Nineteen of the apomictic hybrids which had yields recorded from planted rows in 1975 and 1976 (*Ann. Rep. 1976–77*, 39) were selected for further testing in microsward trials. Seed was drilled, using an eight-row Øyjord drill, in plots two metres long and one metre wide, at two sites; at House O' Muir Farm (by courtesy of HFRO), at an altitude of about 275 metres on 8th July and at Pentlandfield (altitude 160 metres) on 27th July. Five control populations were also sown: the most vigorous Scottish biotype of *P. pratensis*, three *P. pratensis* cultivars and S.23 perennial ryegrass. Establishment was rather uneven at both sites. None of the hybrid or *P. pratensis* populations grew as quickly as did S.23, but ten of the hybrids developed more rapidly than the best *P. pratensis* cultivar (Fylking).

Microswards sown in 1974 also at House O' Muir Farm and at Pentlandfield were harvested in 1975 (five cuts). In 1976 yields were not recorded and in 1977 the Pentlandfield trial was cut four times. Unfortunately because of reseeding operations on adjoining land it was not possible to gain access to the House O' Muir hill site in 1977 for cutting. The nine hybrids included in this trial were apomictic F_1 hybrids which therefore had not been selected for spring growth. Some of the more vigorous *P. pratensis* biotypes (six Scottish and one French), *P. ampla* and *P. iberica*, all of which had been used as parents in the initial crosses were included together with *P. pratensis* cv Troy and S.23 perennial ryegrass. A summary of yields for the two years is shown for the Pentlandfield site in Table 4.

TABLE 4

Dry matter yields (kg ha^{-1}) at Pentlandfield in 1975 and 1977

	1975		*1977*	
	First cut	*Sum five cuts*	*First cut*	*Sum four cuts*
All hybrids (9 populations)	533	5,360	702	7,667
All *P. pratensis*, Scottish (6 populations)	591	5,584	719	7,855
P. pratensis, French	914	5,858	2,138	9,376
P. pratensis cv Troy	921	5,975	1,502	8,395
P. ampla	646	4,989	604	6,564
P. iberica	1,035	5,758	1,863	8,820
Perennial ryegrass cv S.23	1,680	6,780	1,168	9,814

In 1975, S.23 yielded more than any of the *P. pratensis* or hybrid populations at the first harvest, 14th April ($P < 0{\cdot}05$). In 1977 it also yielded more at the first cut on 6th April than the mean of the Scottish biotypes or of the hybrids, but less than the French biotype of *P. pratensis* which yielded more than any population except *P. iberica* ($P < 0{\cdot}05$).

These results indicate the potential for increasing dry matter production in the early season which has been confirmed in the interspecific hybrids following only one cycle of selection (*Ann. Rep. 1976-77*, 39). The relatively slow establishment particularly of indigenous *P. pratensis* biotypes is also demonstrated.

SELECTION FOR SEEDLING VIGOUR

In 1975 seedling progenies from eleven hybrids were grown in a glasshouse trial and individual fresh weights were recorded twelve weeks after sowing.

Thirty-six plants which had high seedling fresh weight were retained, vegetatively cloned and crossed in a polycross type design in 1976. Two clones produced very little viable seed and were omitted from further tests. Seedling progenies from the remaining thirty-four clones and from the eleven parents were sown in July 1977 (*a*) in rows (three centimetres apart) in seed trays, and (*b*) in individual four inch pots. All seedlings were cut to two centimetres after six, nine and twelve weeks; dry matter yield was recorded per row for (*a*) and per plant for (*b*).

Preliminary analyses of data from (*a*) show that the progenies yielded more than the parents at all three harvest dates ($P < 0{\cdot}01$). The percentage increase in dry matter yields of progenies over parents was 113, 91 and 72 per cent from (*a*) and 50, 47 and 56 per cent from (*b*) for first, second and third cuts respectively. This indicates that rapid improvement in seedling vigour as measured by dry matter yield is possible in the hybrid material and that selection of biotypes which will establish more quickly in the field should not be a problem.

Work on the *Poa* breeding programme has been terminated at Pentlandfield due to the ARC rationalisation of plant breeding projects in the UK. Hybrid material is now available which has been selected for both spring growth and seedling vigour and which should be superior in upland conditions to any existing cultivars of *P. pratensis*. Arrangements have been made for the further development of this material by WPBS and for its later evaluation by DAFS at East Craigs.

Cynthia J. Williamson

POTATO DIVISION

Breeding Commercial Potato Varieties

The main objectives continue to be the breeding for high expressions of resistance to the common viruses, to potato cyst eelworm and to blight, each singly and all in a background of adequate resistance to other significant potato diseases, gangrene, scab, skin spot, dry rot, spraing and wart.

In the 1977 crossing programme considerable emphasis has been put on breeding for resistance to the viruses while maintaining breeding lines with resistance to potato cyst eelworm, potato blight and gangrene. Selection of potential varieties was handicapped in some instances by leaf roll infection and in general the growing season was only fair as were yields at the Murrays. The regional trial of main crop selections was affected by disease but analysis and selection proved to be possible among the healthier clones and control varieties. A trial of clones with resistance to potato cyst eelworm was grown on land infested with Globodera pallida. *The results were striking with regard to the efficacy of resistance derived from* Solanum vernei.

THE 1977 CROSSING PROGRAMME

The parent clones for the 1977 crossing programme were again drawn mainly from four sources:—

1. Virus resistant material:

The recent high incidence of leafroll in potato stocks has drawn attention to the lack of resistance to this disease in commercial varieties with the exception of a few—notably Pentland Crown. Considerable emphasis was placed on breeding for virus resistance this year with a total of thirty-two clones being used, each with resistance to either or both of the viruses leafroll and Y. These clones derive resistance from a number of wild species including *Solanum demissum*, *S. phureja*, *S. chacoense*, *S. microdontum* and *S. stoloniferum*.

2. Potato cyst eelworm resistant clones both ex-*S. vernei* and ex-*Andigena* in origin:

Breeding for resistance to *Globodera rostochiensis* and *G. pallida*, particularly the latter, continues to be a high priority, A group of thirty clones was used. Usually there is a gap of at least four years between the initial crossing and the first evaluation of resistance levels in progenies. However, with the development of screening methods suitable for winter use (see page 54) progress in this section of the breeding programme should be significantly improved.

3. Potato blight resistant clones:

In 1974 a group of thirty-six clones, previously untried as parents but with a marked degree of field resistance to foliage blight, were crossed with a few well-tried blight resistant parents. This year thirty of the same clones were used again, crossing both within the group and with the virus resistant group.

4. Material from the third year of assessment at the Murrays in 1976:

All clones in the commercial breeding programme are routinely tested for resistance to gangrene, *Phoma exigua* var. *foveata*. On the basis of two years testing, thirteen clones with good resistance to gangrene were selected from the best M_3 material for crossing with the virus resistant group in 1977.

In addition, seven clones generated from the Neo-Tuberosum programme and two cultivars, Bintje and Redskin (included for their Tobacco rattle virus resistance), were crossed with the virus group. No crosses were made in a first-early breeding programme this year. This will be resumed in 1978.

SELECTION AND EVALUATION

Despite the cold and wet spring conditions, planting at the Murrays was not too seriously delayed and harvesting was completed without hindrance. The latter was due in part to good weather, but also to the use of a 'Famos' oscillating one-row digger machine which proved very suitable for plot work. The ground could be picked cleanly and there was less mixing. The recent purchase of a two-row machine should further improve harvesting in 1978. The level of leafroll and virus Y infection has meant the loss of many stocks and hampered assessment of foliage and yield data. Effective roguing and a rigorous spraying regime should mean a return to the comparative normality of a few years ago by next season.

In the final year of assessment at the Murrays (M_4) the selection of clones for the regional trial in 1978 was biased to some degree by the health record of the seed stocks. This limited the choice to those seed stocks (the produce of 200 tuber plots) which were healthy or nearly so and by implication having also the possibility of some leafroll resistance. Although aphid numbers were low and little or no spread was thought to have occurred, all plots in the seed regime were intensively rogued and sprayed, to ensure the health of trials in 1978.

From the seventy-two clones in the M_4, nine selections were made for inclusion in the regional trial in 1978. Four of these are in trial in Spain and eight are in the NIAB Breeders Observation plots. Ten others of equal promise, other than an indifferent health record, are being re-assessed in 1978 at the Murrays.

The intention is to plant this M_4 material in observation plots at the English regional trial centres in 1978, prior to a full regional trial of those surviving selection, in 1979.

FIRST EARLY PROGRAMME

Interpretation of the data from the replicated trials grown in Wales in 1977 was complicated by shortage of acclimatised seed, due to the severe but necessary roguing of the Radnor multiplication site in 1976. Nevertheless clone 8906abc(11) both in trial versus established varieties and as a control in trials of other clones, still showed much promise. This clone and 7169(10), also a consistently high yielder, have been sent to NIAB for entry into their Breeders Observation plots in 1978.

When the results of the 1978 trials in Wales (using acclimatised seed) and in Scotland, have been analysed it is hoped that a confident decision can be made on whether to enter one or both of these clones for PVR and NLT in 1979.

Seed tubers of the six most advanced clones in the first-early breeding programme have been delivered to Wales, where seed will be produced at Radnor by our collaborators Dr E. J. Allen and colleagues of UCW, Aberystwyth, for trial in 1979.

1977 MAINCROP REGIONAL TRIALS

Nine SPBS clones and seven cultivars were included in the 1977 regional trials. Three randomised complete blocks, with one twenty-plant plot per clone per block were grown at four sites: Gleadthorpe, Terrington and Arthur Rickwood Experimental Husbandry Farms and the Murrays.

The English sites were successfully lifted by Pentlandfield staff using the new 'Famos' lifter, during the week beginning 26th September. The produce of these sites was brought back to SPBS where, subsequent to the lifting of the Murrays site in early October, the tubers were graded, weighed and sampled for qualitative assessments such as cooking and crisping quality.

There were significant differences in incidence of disease (mainly leafroll) between the entries in the trial, consequently quantitative data from the diseased clones could only be interpreted with caution. However, four varieties and four clones were healthy and have provided useful information.

Analyses of variance demonstrated significant differences between clones for all variates relating to yield. The light sandy soil and summer drought at Gleadthorpe led to a severe depression in yield, a high proportion of chats and a severe infection of common scab, all of which served to underline the acknowledged ability of Pentland Crown to produce a reasonable yield of marketable ware under such conditions. It was encouraging to note that the new SPBS variety, Croft, seems similar in this respect, since both it and Pentland Crown suffered the least depression in yield at Gleadthorpe and ranked first and second overall in yield of marketable ware.

Two clones 8990(7) a second early and 7495ab(6) an early maincrop have been selected for retrial and re-entry into NIAB Breeders Observation plots in 1978, along with other selections from the M_4 and M_5 stages of the breeding programme. Both clones have good crisping potential and the latter has a record of high level resistance to foliage and tuber blight. If the 1978 trial data merit it, they will be considered for submission for PVR and NLT in 1979.

SPAIN

A collaborative arrangement was made in 1977, with Matutano SA (NSDO agents for Spain), for the inclusion of SPBS clones under selection in the established variety trials of this organisation. Clones will be evaluated for early ware production in Majorca and for maincrop performance at Burgos in northern Spain. Ten clones have been sent for trial in 1978.

NIAB BREEDERS OBSERVATION PLOTS

The scheme affords the breeder a two-year trial of advanced clones prior to entry to NLT. As well as assessing and reporting on performance the NIAB raise a stock of each clone from stem cuttings in Cumbria. This provides a stock of healthy seed from a common source for future trial work.

Nine clones were entered for observation in 1977. Two are being carried into a second year, namely 7495ab(6) a high yielding crisping clone and 8990(7) a promising second-early. The others have not all been discarded; most will be included again in the Regional trial. There are eight new submissions from the M_4 and two promising first-early clones 8906(11) and 7169(10) referred to above under the first-early programme.

POTATO CYST EELWORM (*GLOBODERA PALLIDA*)

We collaborated with Mr J. M. Holliday of ADAS (Shardlow) in a more elaborate trial of eelworm resistant varieties than had been possible in 1975 (*Ann. Rep. 1975-76*, 21). Again the aim was to compare the performance of clones with resistance to *G. pallida* both with and without nematicide treatment. Six *S. vernei* derived clones were grown with four susceptible named varieties at a *G. pallida* infested site near Skegness. The results are summarised in Table 5.

TABLE 5

Potato cyst nematode multiplication rates

Variety	*Aldicarb treated*	*No aldicarb treatment*
Pentland Crown	2·3	40·9
Maris Piper	1·7	30·6
King Edward	2·9	29·4
Majestic	3·1	31·4
8823(8)	0·5	1·8
8891(28)	0·2	2·2
8898(1)	0·5	7·6
8914(13)	1·0	3·2
8902(1)	0·6	0·5
10017(7)	0·3	2·8
L.S.D. ($p = 0·05$)	1·5	18·7

A significant difference of 1·5 for Aldicarb-treated plots means that all the clones except 8914(13) had PCN multiplication rates significantly lower than Pentland Crown, King Edward or Majestic. If further tests confirm the existence of genotype and nematicide combinations giving eelworm multiplication rates of less than one, it becomes possible to gradually clear *G. pallida* infested land.

Multiplication rates of the eelworm without the use of a nematicide are very significantly lower for the resistant clones than for the susceptible varieties. Considering that with current rotational practice a reduction in the eelworm population through natural death can be expected, the growing of a resistant variety without chemical treatment offers a good measure of control.

However resistant a clone is, it will have no commercial value unless it yields as well as a susceptible variety on infested land. It was very encouraging to note that in this trial resistance and good yield were not incompatible. Despite leafroll infection of 20 per cent clone 8898(1) yielded as well as Pentland Crown in plots treated with nematicide. It appeared to surpass Crown for yield on untreated plots.

COOKING AND PROCESSING

Clones in the four years of assessment at the Murrays are sampled and cooked and crisped on a routine basis along with control varieties from adjacent plots. Comparison is made with commercial varieties for cooking and the cultivar Record is the standard for scoring crisping quality. Three thousand clones annually are stored in a controlled-environment store and cooked and scored in series during the winter. In the past year the average level of quality for direct consumption so far recorded shows that a relatively small proportion fall below an acceptable level. Three good crispers selected from the M_3 in 1976, in part because of this quality, proved in 1977 to be superior to Record in an independently conducted commercial crisping trial using material derived from the four Regional trial centres. Two of the clones were included in Regional trials in 1977.

Links have been re-established with the dehydration section of the Potato Processors Association. This, together with the existing co-operation with Ross Produce Ltd., will allow for more extensive testing for processing quality of material in the regional trials and of those clones entering the National List Trials.

MERISTEM CULTURE

Twenty valuable clones, which had become virus infected, were cleared of disease by meristem culture. It is proposed to develop expertise in this technique as a means of entering valuable but systemically infected material into the seed multiplication regime at Blythbank.

SEED REGIME

In order to isolate the intake of single tubers from the possibility of infection reaching them from older clones at Blythbank a new propagation site was acquired. This policy will be continued in 1978 when both the current intake of 'singles' and the selections from the year before will be grown in isolation.

To clear up the leafroll infection in seed stocks aphicides were applied as granules and as foliar sprays together with early roguing of diseased plants and foliage destruction. Inspection of growing plots of seed stocks in 1978 will reveal the effectiveness of the intensive phytosanitary measures applied in 1977 and should show that the single and three-plant plots may be returned to Blythbank.

T. M. W. Davidson
C. J. W. Torrance
A. W. Macarthur
R. M. Hine
G. R. Mackay

Potato virus resistances

The project consists of breeding and testing for resistance to potato viruses X, Y and leafroll and the spraing viruses.

The programme involves recurrent selection of clones for inclusion in the commercial breeding programme and the assessment of advanced clones as potential cultivars, in their own right, resistant to the major virus diseases.

An increasing number of clones screened for viruses X and Y in the seedling stage in the greenhouse is reaching the field testing stage. As this material has been subjected to inoculation with viruses it is propagated at the Murrays and is kept separate from the material in the general seed growing regime at Blythbank.

In 1977 0·8 hectare were planted with single tubers from the greenhouse and 1·2 hectares from the more advanced three tuber plots. The latter, despite having been subjected to a severe natural attack of leafroll in 1976 as single plants, remained comparatively free from disease. More advanced clones in the programme are included with the general breeding clones for assessment after a preliminary screening for leafroll resistance in England.

FIELD TRIALS FOR RESISTANCE TO LEAFROLL VIRUS AND VIRUS Y

In the 1976-77 field trial, leafroll (PLRV) infection was very extensive; all the plants of Pentland Crown and Majestic were infected, although Pentland Crown has good field resistance in less severe conditions. Even so, seventeen clones (including fifteen bred for virus resistance) appeared to have some resistance.

Virus Y infection was less extensive, with one per cent of Pentland Crown and 51 per cent of the susceptible variety Majestic infected. The trial was a useful test for Y resistance; it revealed eight susceptible clones which had been bred for Y resistance and thirteen from other lines.

SCREENING FOR RESISTANCE TO POTATO VIRUSES X AND Y

Eight thousand seedlings from 103 progenies of crosses for virus X and virus Y resistance were sprayed at the cotyledon stage with sap infected with viruses X and Y. The susceptibles were discarded, and tubers from 3,400 apparent resisters were selected and will be planted in the field as single-plant plots in 1978 for multiplication and selection on other characters.

About 500 other clones from the commercial breeding programme and other sources were screened for virus X and virus Y resistance in the glasshouse, by graft or sap inoculation.

TESTING FOR THE PRESENCE OF VIRUSES X AND Y

Tubers of 350 clones for planting at Drochil Castle were tested by inoculating sap from sprouts on to indicator plants. Fourteen positives were found and withheld from the field.

Field samples of 260 diploid plants were tested to remove those infected with virus Y before testing for potato spindle tuber virus. Fourteen were found to be infected with Y. Plants were also tested for infection with viruses X and Y in connection with meristem culturing.

THE SPRAING VIRUSES

Tobacco rattle virus (TRV)

For the 1977 TRV resistance trial, eighty-one clones from the breeding programme and fourteen named varieties were grown in an infested field at Tayport, Fife. After harvest the incidence of spraing in the tubers was recorded.

As in recent years, the patchy distribution of the virus in the soil proved to be a problem. Duplicate sub-plots of each clone were planted, one at each end of the field plot, but the virus occurred only at one end; at the other there was no spraing in the potatoes and no virus could be recovered by growing bait plants in soil samples taken at planting and during the growing season. Sixteen clones escaped exposure, so only sixty-five were effectively in the trial, with only one sub-plot of each in most cases. Infection levels were low; in sub-plots of the susceptible Pentland Dell the incidence of spraing ranged from zero to 22 per cent. Four clones had more spraing than the worst-affected sub-plot of Pentland Dell, and a further ten (including Strath) also appeared to be susceptible, with more than ten per cent of the tubers in the sub-plot affected. Because of the low infection levels no clones can be reliably classified as resistant.

Potato mop-top virus (PMTV)

In 1976, 133 clones were grown in a PMTV infested field at Braco, Perthshire. After harvest the tubers were scored for spraing, and sixteen tubers from each sub-plot were grown at Pentlandfield in 1977 and scored for haulm symptoms.

In the susceptible variety Arran Pilot, the incidence of spraing in 1976 ranged from zero to 31 per cent. Two other clones had 31 per cent spraing or more, and may be confidently classified as susceptible to PMTV spraing. One of these also had haulm symptoms in all sixteen daughter plants. Another four clones had 15 per cent spraing or more.

The incidence of haulm symptoms in the Arran Pilot sub-plots ranged from zero to 60 per cent. Most of the other clones had no haulm symptoms or few plants affected. Apart from a few obvious susceptibles, therefore, the resistance or susceptibility of the clones in the 1976 trial cannot be reliably assessed.

In 1977, 213 clones were planted at Braco. Soil tests indicated that there was an adequate population of viruliferous *Spongospora subterranea* (corky scab) in the field plot, but there appears to be very little spraing in the tubers. It is possible that the tubers contain PMTV but conditions have not favoured the development of spraing. If this is the case the second year of the trial could still produce good haulm symptom results.

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

Potato Blight Resistance

Resistance to foliage and tuber blight was assessed in routine glasshouse and field trials, and the effect of the age of the tubers on inoculation investigated.

FOLIAGE BLIGHT (*PHYTOPHTHORA INFESTANS*)

The new East Wing glasshouse, used for the first time in 1977, enabled whole plant foliage resistance tests to be carried out under controlled conditions. Plants were inoculated with a zoospore suspension of *Phytophthora infestans* in one of the new constant environment cabinets, transferred to the air-conditioned glasshouse the following day, and incubated at 20°C for six days under high humidity maintained with mist propagation equipment. A score of at least six on a one to nine scale of increasing resistance (Malcolmson, *Trans. Br. mycol. Soc.* **67**, 321-25) was shown by between nine and fifteen per cent of selections from the commercial breeding programme (Table 6).

TABLE 6

Levels of foliage blight resistance in breeders' selections

Breeders' selections	*No. clones*	*Proportion ≥ 6** *No.*	%
Commercial programme:—			
5th year:			
Clones from blight resistant parents	67	18	27
Clones from other crosses	204	22	11
6th year:	174	16	9
Neo-Tuberosum clones	15	2	13

* 1-9 scale of increasing resistance

The high resistance shown in detached leaflet tests by twenty-two dihaploids derived from blight resistant tetraploids, was confirmed in sixteen of the dihaploids in a whole plant test. Sixty-three of eighty-eight similar dihaploids obtained a score of at least six in a detached leaflet test. This level of resistance was also shown by forty-five of 113 mass selected diploids.

Seedlings of 119 progenies derived from proven blight resistant parents crossed with other material in 1974 were screened; forty-eight progenies showed a high level of foliage resistance.

TUBER BLIGHT (*PHYTOPHTHORA INFESTANS*

Freshly harvested undamaged tubers were stood rose end uppermost in plastic trays, inoculated with a zoospore suspension, and incubated in a constant environment cabinet at 15°C for five days before being transferred to an unheated store. The percentage of blighted tubers was scored after two weeks, and resistance expressed on a five-point (one, three, five, seven, nine) scale in comparison with ten standard reference varieties.

The percentages were also used to identify clones as resistant as the resistant control varieties Wilja (early clones) and Pentland Crown (maincrop clones) (Table 7). These two varieties have field resistances of seven and six respectively on a continuous nine-point scale of increasing resistance (*Fmrs Lflt No. 3*, NIAB *1977-78*).

TABLE 7

Levels of tuber blight resistance in breeders' selections

Breeders' selections	*Early* *No. clones*	*Equal to Wilja* *No.*	%	*Early Maincrop* *No. clones*	*Equal to P. Crown* *No.*	%
Commercial programme:						
5th year of selection	53	18	34	175	108	62
6th year of selection	42	20	48	125	35	28
7th year of selection	12	7	58	59	17	29
8th year of selection	5	2	40			
Virus resistant clones	5	2	40	16	7	44

Progenies obtained from crosses between blight-resistant parents in 1974 were screened to identify those with tuber resistance and of thirty-nine progenies tested, fifteen showed resistance equal to or better than that of Record.

Seven of eleven diploid clones were very susceptible but one dihaploid derived from Record and five dihaploids derived from Pentland Crown showed resistance equal to or higher than that of the parent.

Delaying inoculation after lifting was again shown to reduce the number of blighted tubers. The effect was greater with two days delay than with one.

Named varieties, covering a range of susceptibilities, were lifted and inoculated at two-week intervals from August to October. The relative susceptibilities of the varieties varied, Pentland Crown and Record being particularly susceptible at the first lifting. In general, however, susceptibility tended to decrease as the lifting date advanced.

Attempts in the past to assess tuber and foliage resistance at Blythbank have not always succeeded. This year advanced clones from the commercial programme were planted in Ayrshire where the climate is more favourable for the development of blight. A satisfactory level of infection was achieved in the foliage and the highest degree of resistance was exhibited by clone 7495(6) and by Croft, which had 5 per cent blight on the MAFF scale (ADAS Disease Assessment Key No. 2.1.1., MAFF 1976) in early September when King Edward had 75 per cent. However, the overall level of infection in the tubers was too low for resistance to be reliably assessed, although a number of susceptible clones were identified.

H. E. Stewart
R. L. Wastie

Potato tuber disease resistance

Routine disease screening was carried out against gangrene, skin spot and common scab, and possible methods of dry rot screening investigated.

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

The 1976/77 disease screening season was remarkable for the high proportion of apparently gangrene resistant clones among the routine material tested, *i.e.*, clones scoring seven or nine on a five-point (one, three, five, seven, nine) scale of increasing resistance, derived from a continuous index scale which in turn is related to twelve standard reference varieties (*Ann. Rep. 1975-76*, 30). Thus 57 per cent of 302 fifth-year selections, 68 per cent of 142 sixth- and seventh-year clones, 50 per cent of fifty-four virus-resistant clones and 44 per cent of sixteen Neo-Tuberosum clones were rated resistant. Ninety-one of the resistant sixth- and seventh-year clones had been tested the previous year; fifty-six were resistant then also, twenty-three had been placed in the intermediate category (score five) and twelve were susceptible (score three or one).

Although only these twelve clones gave greatly different scores in the two years it is nevertheless apparent that there is a need for repeated testing and further refinement of testing techniques.

Eight varieties of known susceptibility behaved consistently when surface-inoculated with each of eight isolates of *Phoma exigua* var. *foveata*. Pathogenicity varied greatly between isolates, the fastest-growing in culture being generally the most pathogenic.

SKIN SPOT (*POLYSCYTALUM PUSTULANS*)

Artificial inoculation with culture macerate again failed to raise the level of skin spot infection in routine tests, and only natural levels of infection were observed. Clones were recorded as susceptible if they were as severely infected as the cultivar Arran Banner, the most susceptible of the reference varieties. Ninety-one of 125 fifth-year clones on which spotting was observed and twenty-four of forty-eight sixth- and seventh-year selections showed this level of infection.

An experiment to investigate the effect of surface sterilising tubers in two per cent formaldehyde solution before inoculation, showed that this treatment greatly increases the chances of successful inoculation. On an arbitrary 0-24 scale, untreated tubers scored 0·8 whereas sterilised tubers scored 9·8.

COMMON SCAB (*STREPTOMYCES SCABIES*)

The 1976 Archerfield test results allocated 33 per cent of 305 fifth-year clones to the top two resistance categories of the five-point scale, 53 per cent of seventeen Neo-Tuberosum clones and 86 per cent of thirty-six diploids and dihaploids. However, of eighty-four sixth-year clones which fell into classes five, seven or nine in 1975 and which were re-tested in 1976, only forty-one showed the same or an adjacent level of resistance, and forty-three differed by two classes or more. Because of the variation between plots and between years which is a feature of the Archerfield test, scab assessment was attempted at the Murrays in 1977. Polythene tunnels were erected over drills containing three single-tuber plots of sixth- and seventh-year clones, while the Archerfield test was used only for fifth-year material. Low levels of scab were obtained, but the most susceptible reference varieties were infected.

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

A preliminary trial in 1976 with five varieties confirmed that in the absence of wounding no infection results. Inoculation after stab wounding, and incubating either at 10°C for eight weeks or for 4°C for four weeks followed by 10°C for four weeks both resulted in 60 per cent of the wounds becoming infected. Routine dry rot testing commenced on advanced clones in 1977.

WART (*SYNCHYTRIUM ENDOBIOTICUM*)

Single tubers are no longer submitted for test to DAFS; instead an overall assessment of disease resistance is made by DAFS after testing four tubers of each clone. Of 122 sixth-year clones and first-earlies submitted in 1976/77, eighty-one (67 per cent) were rated completely or partially resistant, as were twenty-three (77 per cent) of thirty virus-resistant clones.

R. L. Wastie
H. E. Stewart

Potato Cyst Eelworm Resistance

Four hundred and twenty-six clones were screened for resistance to Globodera pallida *and/or* G. rostochiensis. *Detailed examination of the relationship between external and total cyst counts showed significant positive correlations for three out of the four clones examined. A new method of testing which can be carried out under strictly controlled environmental conditions is under investigation.*

Four hundred and twenty-six clones, mainly derived from *Solanum vernei* or *S. andigena* (CPC 2802) were screened for resistance to *Globodera rostochiensis* and *G. pallida*. The standard glasshouse bed test was applied, but with four replicates of each clone and sixteen of Pentland Crown. In an attempt to overcome the effects of variable moisture levels each replicate was assigned a position on one quarter of the bed within an overall matrix of Pentland Crown in fixed positions. This was designed to act as an indicator of moisture levels within each bed so that if necessary corrections could be made.

Clones were ranked in order of increasing susceptibility and significant agreements were found in the rankings for 1976 and 1977. The relationship between external and total cyst counts made on four clones has been examined over the past two years. Overall there was a significant positive correlation between external and total cyst counts ($r = 0{\cdot}81$ $p < 0{\cdot}001$).

There was also a significant positive correlation between external and total cyst counts in three out of four individual clones examined (Table 8).

TABLE 8

Mean number of cysts on the exterior of the root ball and per pot for 1976 and 1977 and the correlation coefficient for these two measurements

Clone	*No. cysts* *Exterior*	*Total*	*Correlation coefficient*
8806a(25)	63	336	0·56*
8859(1)	127	623	0·67*
8911abc(15)	179	1,221	0·25NS
Pentland Crown	440	2,407	0·52*

* $p < 0{\cdot}001$

Total counts were just as variable as external counts and estimates of susceptibility based on both measures differ little in the same year, with the exception of those for 8911abc(15) where external counts seem to overestimate resistance (Table 9). Unlike the other three clones 8911abc(15) developed large tubers

TABLE 9

	Susceptibility (%)			
	1976		1977	
Clone	*External*	*Total*	*External*	*Total*
8806a(25)	18	21	14	13
8859(1)	32	32	29	25
8911abc(15)	54	76	38	45

at the exterior of the root ball and these may have hidden cysts which would otherwise have been counted.

A new method of testing devised by Foot (*N.Z. J. Zool.* **4**, 183-86) has been used for determining H_1 resistance in 197 clones. Tubers were planted in infested soil in closed clear plastic containers and allowed to grow in the dark where cysts developed normally. After five weeks containers were scored for visible cysts and unequivocal results were obtained for most clones. The possibility of using this method for mass screening of partial resistance in *S. vernei*-derived clones is now under investigation as it seems to offer many advantages over glasshouse tests.

J. M. S. Forrest

Aspects of Potato Cyst Eelworm Biology

Clones with both low and high hatching activity have been found among both Solanum vernei × S. tuberosum *and* S. tuberosum *potatoes. Hatching activity may be related to the rate of root and shoot development.*

In vitro hatching tests with *Globodera pallida* were again carried out using root diffusate from surface-planted sprouts grown for one week in sand. Some previously untested clones derived from *S. vernei* had as high a hatching activity (measured on batches of 100 cysts) as did Home Guard. Conversely, one *S. tuberosum* clone had an activity as low as some *S. vernei*-derived clones (30 per cent less than Home Guard after seven weeks). Low hatching activity is therefore not solely a property of *S. vernei* × *S. tuberosum* clones.

Single-sprouted tubers of both Home Guard and a first-early *S. vernei* × *S. tuberosum* clone with low hatching activity as determined by the above method, were buried approximately fifteen centimetres deep in pots of sand and diffusate was collected separately from each clone after one, two and three weeks. *In vitro* hatching tests of three weeks' duration produced an 80 per cent hatch from Home Guard and a significantly lower hatch of 56 per cent from the *S. vernei*-derived clone. This suggests that a test with surface-planted sprouts might be used to predict the hatching activity of plants developing from buried tubers.

Root and shoot development was also examined over the period of the experiment. The mean dry weight of roots of the *S. vernei*-derived clone (106 mg) was significantly lower ($p < 0.01$) than that of Home Guard (169 mg). After three weeks the shoots had not emerged, whereas those of Home Guard emerged within two weeks and showed considerable extension and leaf expansion. The magnitude and timing of hatching activity of these clones may therefore be related to their initial rate of development.

J. M. S. Forrest

The Commonwealth Potato Collection (CPC)

The nature and function of this Collection was outlined in last year's report. Work on renewing seed of lines inadequately seeded following clearance for PSTV was continued, and renewal of lines finally cleared last season was commenced. Some lines which were tested and seeded before the test procedure was fully developed still require to be sown to permit further testing; space was inadequate this year but it is hoped that they will be dealt with next season.

The receipt, for safe-keeping, of a duplicate of the German-Dutch Potato Collection is still awaited. It appears that difficulty is being experienced in preparing the seed for prolonged deep-freeze storage. As reported previously (*Ann. Rep. 1976-77*, 53-54) seed of the CPC has been sent to the German-Dutch Collection in Braunschweig in Western Germany.

Only small quantities of seed were distributed this year, samples going to Poland, the USSR, the Netherlands, and to two places in Britain.

D. R. Glendinning

South American cultivated Tetraploid Potatoes

The programme outlined last year has been continued, though hampered by virus infection both at the Murrays and at Blythbank. The ability of a range of Neo-Tuberosum parents to transmit leafroll resistance/susceptibility to their progenies was investigated.

In work aimed at broadening the gene-pool, pollinations to secure a third generation from Andigena × Neo-Tuberosum crossings were commenced.

The commercial breeding programme retention rates in Neo-Tuberosum × Tuberosum progenies are, on average, below the mean for Tuberosum progenies but those in progenies involving some Neo-Tuberosum parents substantially exceed the mean. Frequencies of scab and gangrene resistance in Neo-Tuberosum derivatives exceed the mean for Tuberosum progenies.

THE NEO-TUBEROSUM PROGRAMME

The Neo-Tuberosum programme was continued along the lines indicated last year (*Ann. Rep. 1976–77*, 54–55), although severely hampered by virus infection. In that part of the programme carried out at the Murrays, comparison of clones selected in 1975 with commercial controls was made almost impossible by the need for roguing against virus diseases, only eleven of the forty-seven clones having any surviving plants at harvest, and about 70 per cent of the derivatives of the 1976 seedlings were eliminated. Severe roguing was also required among the derivatives of the 1976 single-plant plots at Blythbank; the main virus disease present being leafroll. The proportion of infected plants varied greatly between progenies; a rank correlation of +0·68 was found, for percentage roguing, between Neo-Tuberosum × Neo-Tuberosum progenies and Neo-Tuberosum × commercial progenies having one Neo-Tuberosum parent in common.

Total yields of clones in unreplicated observation plots at the Murrays, grown without controls, tended to exceed those of commercial varieties of comparable maturities in an adjoining planting but to consist of larger numbers of smaller tubers.

Work aimed at establishing a broader gene-pool continued, the production of a third generation by crossing with bulk Neo-Tuberosum pollen being commenced, but, after replanting and sowing further F_2 Andigena × Neo-Tuberosum seed next year, consideration will be given to securing an F_3 by inter-crossing and a back-cross generation by crossing with Neo-Tuberosum. A back-cross progeny should more nearly approach the required commercial standard, but will, of course, have only half the representation of Andigena genes relative to an F_3.

(The symbols F_1, F_2 etc. are used here with the following meanings. An F_1 is the progeny of a mass pollination of Andigena clones with bulked Neo-Tuberosum pollen. An F_2 is a mass multiplication of an F_1 and similarly for F_3 and subsequent generations.)

THE VALUE OF NEO-TUBEROSUM MATERIAL IN THE COMMERCIAL BREEDING PROGRAMME

My colleagues in charge of the cultivar breeding programme have crossed Neo-Tuberosum clones with commercial-type breeding lines in most years since 1969. The resultant progenies are subjected to the same selection process, aimed at identifying potential new varieties, as are progenies obtained by intercrossing such breeding lines. Comparison of the data on the first three batches of Neo-Tuberosum-derived progenies, from pollinations made in 1969, 1970 and 1971, with that on the accompanying progenies provides some indication of the potential of Neo-Tuberosum for use in breeding.

The proportions of the progenies of individual Neo-Tuberosum parents which survived three years of visual selection varied from nil to about double the average proportion in the accompanying progenies, the mean retention rate being about half that in the accompanying progenies. The parents involved had been selected as seedlings between 1965 and 1969, early in the development of Neo-Tuberosum, and better results could be hoped for with current Neo-Tuberosum parents.

In tests of clones remaining beyond that stage of selection, the frequencies of scab and of gangrene resistance were found to be higher than in the accompanying progenies, that of foliage blight resistance being about equal but that of tuber blight resistance being lower. Only a few Neo-Tuberosum clones were used as parents for these progenies and they had not been selected for disease resistance; further information is desirable before generalisations regarding Neo-Tuberosum are made.

A clone derived from the 1969 pollinations is entered for the NIAB Breeders' Observation plots in 1978.

Four Neo-Tuberosum × breeding-line derivatives, from the 1969 pollinations, were used as parents in 1975, and some pure Neo-Tuberosum (not crossed with commercial-type breeding lines) has recently been introduced to the high specific gravity selection programme; it is too early to assess the progress of the resultant material.

D. R. Glendinning

Studies of the potential of South American Diploids and Tuberosum Dihaploids for Potato Breeding

High yields have been obtained from diploid clones. The genetic basis for the production of diploid pollen from diploid parents is under investigation. In 1977 but not in 1976 aneuploids were found among the tetraploids derived from tetraploid × diploid crossing; evaluation of yield of tetraploids obtained in this way has commenced. Dihaploids more resistant to foliage and tuber blight or to eelworm pathotype E than their tetraploid parents have been obtained and are being crossed with selected tetraploids, and treated with colchicine to secure tetraploids.

GENETICS AND BREEDING OF DIPLOID POTATOES (GROUP PHUREJA/STENOTOMUM)

The first stage in the improvement of diploid South American potatoes is through the use of a mass-selection programme (see *Ann. Rep. 1976–77*, 57).

Selections from this programme are intercrossed with the aim of combining valuable characters to produce clones closer to the commercial standard. These clones can be further developed by intercrossing, or can be crossed with material of group Tuberosum parentage. In 1975 the procedure used in the pedigree breeding scheme was changed. Seedlings were no longer planted directly into the field at the Murrays farm which risked incurring substantial losses from drought, rook-damage and early virus infections; instead the young plants were grown on to harvest in a polythene-covered plant house, screened against aphids. Selections from pots were planted in the second season at a "low virus" hill farm (Blythbank). Clones selected at the second harvest were grown as three-plant plots for maintenance at the hill farm and as five-plant plots for evaluation at the Murrays. In 1977 the first batch of such material reached the Murrays. The growing season was a rather poor one owing to late planting, low temperatures and drought, but the provision of frequent control-plots of commercial potatoes throughout the planting enabled useful comparisons to be made. Thirty-three new selections were planted at the Murrays of which twenty-eight survived the virus roguings. Yields for the thirteen clones which produced more than one kilogram per plant are shown in Table 10.

TABLE 10

Mean single plant yields of thirteen *Phureja/Stenotomum* clones grown at The Murrays, East Lothian, in 1977, in unreplicated five-plant plots

Clone No.	*Mean yield (kg)*	*as % control**	*Clone No.*	*Mean yield (kg)*	*as % control**
DB144(27)	1·57	101·3	DB150(19)	1·13	76·9
DB145(33)	1·78	114·8	DB152(31)	1·08	71·9
DB147(33)	2·05	132·3	DB154(9)	1·05	70·1
DB149(32)	1·51	97·7	DB157(23)	1·14	79·8
DB150(13)	1·66	116·1	DB161(10)	1·80	124·5
DB150(15)	1·04	72·4	DB162(28)	1·46	101·9
DB150(17)	1·04	72·6			

* Control cultivar = Pentland Crown

The control cultivar, Pentland Crown, is a modern type recognised to be high yielding, so that the potential of the diploid potatoes as a breeding base would appear to be good. High yields do not necessarily depend on combinations involving Tuberosum germplasm.

In the course of a crossing programme between diploids and commercial tetraploid potatoes (see below) large variations have been noted in the proportion of tetraploid offspring (Sudheer, *Proc. 8th Cong. Eucarpia*, in press). In view of this, and of the difficulty in identifying diploid clones which do not carry the recessive gene, *ps*, for the "parallel spindle" abnormality, a small experiment was set up to investigate the inheritance of the ability to produce tetraploid hybrids. Two diploid clones known to be heterozygous for the *ps* gene were crossed in 1975. Seventy-one F_1 plants from this cross were allowed to flower under glass in 1977 and were scored for the presence of diploid pollen grains (diplandroids). When diplandroids occur in our material, they form between 0·5 and 2 per cent of the total pollen production of a plant. Fifty-three plants had pollen which was either completely normal or, in the case of twelve plants, had a very low proportion of diplandroids (0·1 per cent). The remaining eighteen plants produced more than 0·5 per cent diplandroids. The ratio (53 : 18) is in accordance with the expected ratios of 3 : 1 but the rare diplandroids occurring in the pollen of otherwise normal plants suggests that caution should be used in interpreting these results. Crosses were attempted between thirty-eight "normal" pollen seedlings and *psps* (diplandroid producing) testers. Eleven combinations were successful and should provide firm evidence next season as to the mode of inheritance.

TETRAPLOID HYBRIDS FROM TETRAPLOID × DIPLOID CROSSING

During the first two years of this scheme it was deemed sufficient to identify the ploidy level of the seedlings, *i.e.*, whether triploid or tetraploid, the latter being selected. However, as pollen fertility data from these tetraploids became available, a wide range of variation was found. The pollen mother cell meiosis in tetraploid cultivated potatoes is not entirely regular and the possibility that aneuploid chromosome numbers were present in the offspring had to be considered. Accurate chromosome counts on the seedlings raised in 1976 revealed only eutriploids and eutetraploids. Counts on the 1977 seedlings showed a less satisfactory situation. Since all parental combinations were similarly affected, the data from Pentland Dell ♀ × diploid ♂ crosses will be adequate to illustrate the point (see Table 11). It is possible that, owing to more favourable seed-setting conditions in 1976, more aneuploid zygotes survived to be

TABLE 11

Chromosome numbers in offspring of the cross
Pentland Dell × South American diploid in 1976 and 1977

	2n = 35	36	37	46	47	48	49	50	*Total seedlings counted*
1976	—	6	—	—	—	145	—	—	151
1977	—	4	—	—	9	51	5	1	70

counted than in 1975. In that year an average of 1·18 seeds per pollination was obtained from the Pentland Dell crosses, whereas in 1976 there was an average of 2·43 seeds. Germination of the 1976 seed was slightly lower (76·2 per cent as against 81 per cent) suggesting a small effect of aneuploidy on viability.

Evaluation of yield characters in tetraploid × diploid hybrids at the Murrays farm has begun, but it has not been possible with the limited range of F_1 material so far available to identify particular tetraploid cultivars as superior parents. There is probably a large effect of heterosis in the F_1 (Mok and Peloquin, *Theor. Appl. Genet.* **46,** 307) which, under some circumstances, might conceal the influence of individual parents. It is intended next season to take the material into the second generation by crossing together superior F_1 clones identified in 1977.

C. P. Carroll

PEST AND DISEASE RESISTANCE IN DIHAPLOID POTATOES

This year, the screening of dihaploids for resistance to foliage late blight (*Phytophthora infestans*) was chiefly concerned with retesting clones, derived from highly resistant parents, which had performed well in leaflet tests. Twenty-one such clones were subjected to replicated whole-plant tests in the glasshouse. Ten showed high resistance, four of them being as resistant as their tetraploid parent. Five dihaploids which performed well in glasshouse tests last year were exposed to severe natural blight infection as three-plant field plots at Rosewarne Experimental Horticulture Station in Cornwall where they again performed well. One dihaploid has now been shown to be consistently more resistant than its tetraploid parent in leaflet, whole-plant glasshouse and field tests.

Further testing has confirmed that three out of the fourteen Pentland Crown dihaploids so far assessed are more resistant to tuber blight than their parent.

Crosses were made between dihaploids, showing resistance to tuber blight, foliage blight and common scab, and selected tetraploids in an attempt to produce tetraploid progeny with disease resistance combined with other commercially desirable characters. Seed was obtained only from crosses where the dihaploid was the female parent and germination of the seed has been poor. Of twenty dihaploids obtained last year from tetraploids having both H_1 and *Solanum vernei*-derived resistance to eelworm (*Globodera pallida*) eleven possessed the H_1 gene conferring resistance to pathotype A and one proved to be highly resistant (6 per cent of the susceptibility of Pentland Crown) to pathotype E. Of four dihaploids available from two *S. vernei*-derived parents (two from each), three proved to be more resistant to pathotype E than their parents, confirming last year's results.

Colchicine treatment to double the chromosome number of dihaploids was performed, using Dionne's method (described in Ross *et al*, *Eur. Potato J.* **10**, 37–52) on potato scions grafted onto tomato rootstocks or on stems cut from potato plants and kept in containers of water in the mist propagator. One foliage blight resistant clone was confirmed as having been successfully doubled in all three histogenic layers.

M. J. De, Maine

Biometrical Genetics of Potatoes

Work with multiple mating schemes continued and new work on the design of variety trials began.

The 2 × 15 North Carolina Experiment II referred to last year (*Ann. Rep. 1976–77*, 59) was grown at the Murrays. At the time of writing the harvested material is awaiting examination. A thirteen-parent partial diallel cross was multiplied under aphid-free conditions at Fullarton farm (altitude 300 m) and will be grown for examination in 1978. These two experiments should augment our limited knowledge of the inheritance of some important traits in potatoes.

During 1977 work began on the design of small-scale potato variety trials. This is intended to increase the efficiency of our regional maincrop and early trials in the commercial breeding programme so that advanced selections will have been well tested before submission to statutory trials. There appears to be virtually nothing published on the conduct of such preliminary trials and this new programme aims to define such factors as optimum plot size, number of replicates and choice of site.

A uniformity trial of the cultivar, Corrie, was grown in forty drills of fifty plants each at the Murrays. Each plant was individually harvested and scored for yield and number of tubers. By aggregating scores from adjacent plants into successively larger plots and calculating the corresponding coefficient of variation it should be possible to deduce the size and shape of plot likely to give the lowest residual variance. The trial was affected by leafroll virus and the effect of this is being studied with a view to making due allowance in the analyses.

An attempt was made to examine the need for guard or discard rows surrounding test material. In each of five randomised blocks ten six-tuber plots of Corrie were surrounded by plants of other varieties. The surround and the core plants were harvested separately and scored for number and weight of chats and ware tubers and for specific gravity. Only the specific gravity of the Corrie plants was found to have been affected by the surrounding varieties. On a plot by plot basis the correlation between the specific gravity of the Corrie plants and the yield of their surrounds was $-0{\cdot}451$, suggesting that the higher yielding varieties intercepted more light and so reduced photosynthesis in Corrie, but that competition for water was not so extreme, giving a net lower dry matter content. This obviously requires confirmation but implies that while guard rows may not be necessary for estimation of yield they may be required in relation to quality factors.

R. J. Killick

AGRONOMY DIVISION

The Agronomy Division and Department came into being on the seventh of March 1977 with Dr R. C. F. Macer as Head of Division and with Dr F. J. W. England as Head of Department.

The Department's responsibilities include the management of the research farms at both Pentlandfield and the Murrays and the management of research glasshouses at Pentlandfield and the new glasshouse at the Murrays. The pre-existing Forage Trials Unit is included in the Department, is now called the Field Trials Unit and conducts "contract" field trials for the breeding departments of the Station and also for colleagues at other ARS institutes. Since the first of January 1978 the Department has also assumed responsibility for the Station Statistics and Computing Service.

Field Trials Unit

Assessment trials of the most advanced cereal selections were conducted for the Station's Forage Division. Trials were grown following the established pattern at the regional trial centres and at the Station's experimental centre. Considerable expansion in the exchange of trials with sister Institutes in England and Wales took place in 1977, accounting for approximately one-third of the Unit's effort. The Station joined the ARC/BAPB National List trials scheme for spring barley and winter wheat, the entries being those currently in official National List trials for years one and two.

Winter and spring cereal husbandry was comparatively easy this past season. Drilling and harvests were a little later than average. Pests and diseases were present at extremely low levels and although this saved a considerable amount of data collection it prevented effective scoring for resistance. Bird damage, especially by greenfinches (*Carduelis chloris*) on the borders of plots and particularly on the boundaries of trials, was more severe than usual. Lodging was not present to any extent even in the taller varieties. The inclement weather, particularly towards the end of harvest in late September, produced badly brackled and shed oats and some head loss in the barleys. Harvest was prolonged and tedious with the wet and very windy weather.

The kale and swede trials were badly retarded by the very dry period following drilling in early May. Extremely high levels of flea-beetle (*Phyllotreta* spp.) quickly became established and although not damaging our trial stands necessitated repeated spraying with insecticide. The granular insecticide applied at drilling was not effective because of lack of uptake. Mildew was absent from the Unit's brassica trials and only a very low incidence of raan was noted in the swedes. *Raphanobrassica* was a little disappointing but the leafy stubble-turnips Appin and Ballater continued to be most encouraging.

Yellow turnips were handled by the Unit for the first time and a variety trial was grown at Boat of Garten in Inverness-shire. This trial was drilled with a Webb precision drill on the 20th June, much later than planned because of the very dry conditions that prevailed, and the inability to produce a satisfactory seed bed. The varieties were hand harvested on the 11th November and fresh weights of up to 92·5 t ha^{-1} were recorded. Eighteen varieties were in trial and although basal leaf senescence was apparent in some varieties the bulbs were sound and free from disease, although some entries were becoming woolly.

Bird damage has become a particular problem and the Unit has spent considerable time and effort appraising the relative merits of the bird scaring devices available. Some are quite ingenious; most seem to work, although in many cases only for a short period of time. The "flying lark", and a revolving "fluorescent man" made by the Unit were most effective. We have still not discovered a bird scaring device that will remain effective for more than three or five days, when it becomes necessary to substitute some alternative scaring mechanism.

During the year the Unit moved into accommodation in the new "Speedpak" building. The Unit now has its own office, two laboratories and a small store, all located in the new building. (Previously the Unit had only a small hut at Pentlandfield, a small machinery store at the Murrays and had to share laboratory accommodation with the Cereals Department.)

The Unit obtained a Webb steerage hoe and a lightweight rotavator for field work and an electrostatic air filter for improving the atmosphere in its new labs when doing dusty jobs. A small seed treatment machine for applying powder dressings prior to drilling has been constructed. Many other small improvements have been made to existing machines to improve the reliability when handling experimental plots.

I. M. Chapman

Murrays Farm Unit

The Murrays farm has an area of 133 hectares of which eleven are used for ex-rotational research material such as isolation plots for brassicas and potatoes and to satisfy other requirements which do not conveniently fit into the main rotation. One third of the remaining area of 122 hectares is used for research purposes each year, approximately equal areas being devoted to each of the three main crop groups with which the Station is involved, *i.e.*, cereals, brassicas and potatoes. The remaining two thirds are under semi-commercial cropping to permit restoration of uniformity after trial work. A basic seven-course rotation is used to provide a minimum of six years between successive potato or brassica crops in the same field.

During the past year intensive efforts have been made to correct certain major element deficiencies, particularly of potash, and to control perennial weeds, particularly in field margins.

A new drainage system is being installed; so far approximately 110 hectares have been drained under the supervision of consultants from DAFS; in addition the peripheral watercourses have been cleaned and dredged in collaboration with the neighbouring farms. These operations have caused some inconvenience but no serious disturbance to the research activities.

The farm road system is being upgraded and a programme for the installation of metal gates and posts in place of the existing wooden ones is being undertaken.

The year was marked by the wet, cold spring and for the wettest June since the SPBS began using the Murrays in 1970. The rainfall for the month was four and a half times the mean for the previous five years and two and a half times the thirty-year average for the district. The cold weather delayed germination and growth considerably; brassica crops were particularly badly affected.

The drainage of three fields, Loan, Longriggs and Wall (see map, p. 65) was completed by the end of March. Loan and the northern half of Wall were subsoiled in June and Longriggs was subsoiled in mid-October after the cereal harvest. Sowing of commercial barley crops was delayed in Longriggs by the need to allow land to settle after draining and in Toll by the late harvesting of the overwintered brassica crops. Sowing began in mid-April and was completed by the beginning of May. The area sown was 44·0 hectares. (In addition cereal trials occupied 12·3 hectares.) Midas and Golden Promise, both treated with a mildewicide seed dressing, were the main varieties sown. Fertiliser at the rate of 376 kg ha^{-1} (20-10-10) and 125 kg ha^{-1} muriate of potash (60 per cent) was applied in the seed bed. Yields were good, averaging around 5·25 t ha^{-1}. One area of Golden Promise in Wee Murrays yielded 7·68 t ha^{-1}.

Potato planting started on 15th March with an early potato trial approximately one hectare in area. The remainder of the field was planted in the third week in April. EPTC herbicide ("Eptam") and 880 kg ha^{-1} potato fertiliser (15-15-19) were incorporated in the soil before ridging and phorate granular aphicide ("Thimet") placed in the drills before covering. The total area of potatoes was about 13 hectares. Metribuzin herbicide ("Sencorex") was sprayed as the first shoots emerged.

A very strong emphasis was placed on the prevention of virus (leafroll) spread and aphicide spraying was carried out fortnightly from mid-June to mid-September using a pattern of systemic aphicides. From the end of July, Maneb fungicide was incorporated with the aphicide to control late blight and the non-persistent aphicide, pirimicarb, was sprayed in the intervening weeks. The early potato trial was harvested in August and the main crop was lifted between the end of September and the end of October. After harvest, the field was harrowed with a Vicon vibrating harrow and those tubers which were brought to the surface were lifted. Since then the field has been grubbed

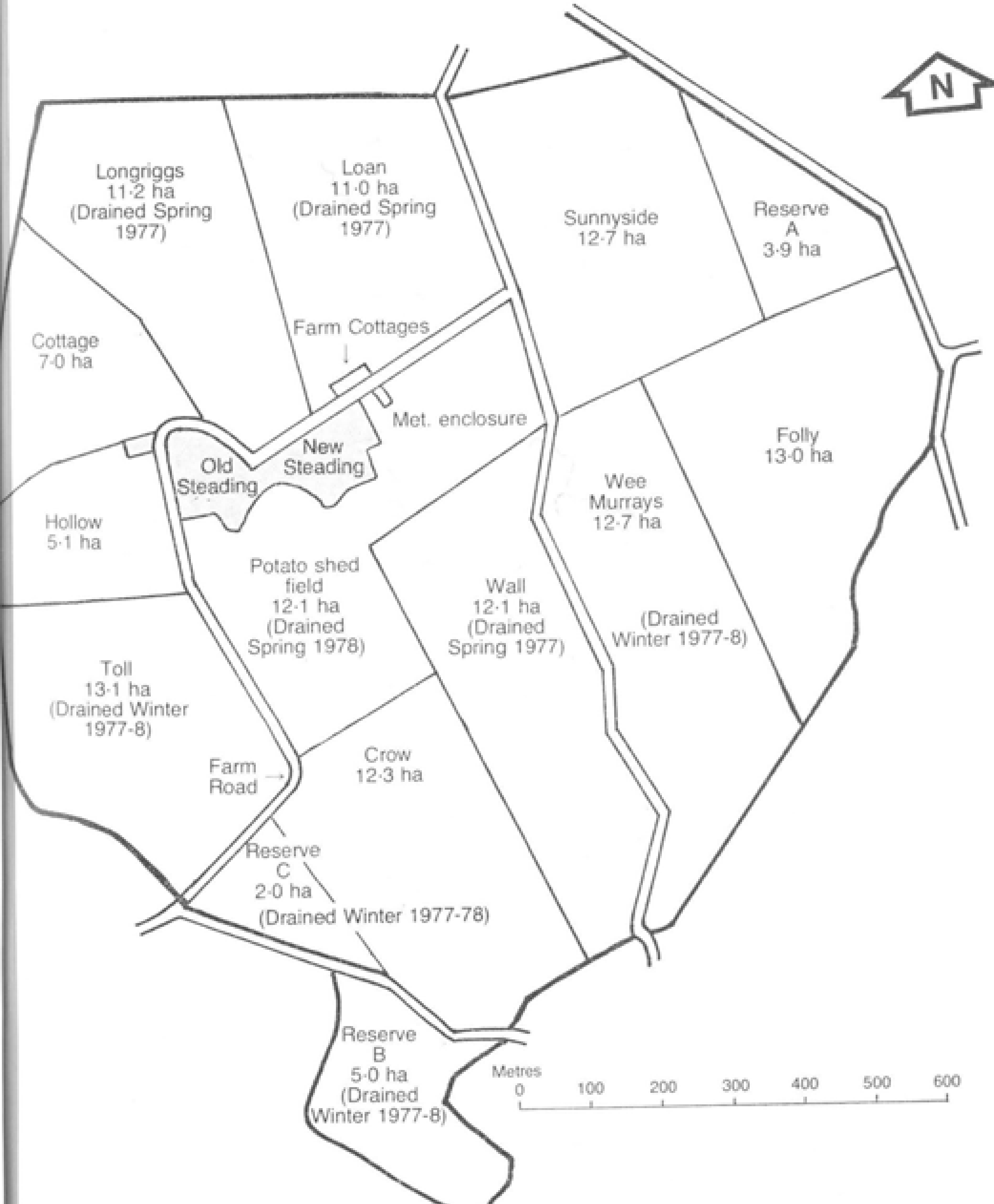

Figure 1. Map of the Murrays showing field areas and progress of drainage operations.

and, during frosty weather, has been chisel ploughed as part of the groundkeeper control programme.

The sowing of brassica trials in Folly started on 12th May and was completed at the beginning of August. Plot surrounds were sown with rape on 23rd August. The field had been rotosprayed with TCA (22 kg ha^{-1}) on 21st and 22nd April. Trifluralin herbicide ("Treflan") and fertiliser were incorporated in the soil before sowing. Fertiliser was applied at the rate of 816 kg ha^{-1} of turnip fertiliser (8-20-16) for swedes and grain fertiliser (22-11-11) for the rest of the field.

The cold spring resulted in slow, uneven brairding and it was late in the season before brassicas recovered from the poor start. Harvesting of most of the trials was completed in December but some plots of swedes have been left until March to assess winter-resistance.

The grass in Hollow and Cottage was top dressed with 376 kg ha^{-1} grain fertiliser (20-10-10) and 125 kg ha^{-1} muriate of potash (60 per cent) at the beginning of March and with 125 kg ha^{-1} "Nitram" at the beginning of May. The fields were cut for hay in the third week of June. The new haymaking equipment enabled our own staff to handle the haymaking and, despite the unfavourable weather, 86 tonnes of good quality hay were sold off the 11·5 hectares. The aftermath was top dressed with 252 kg ha^{-1} "Nitram" and grazed by calves and lambs from ESCA for the remainder of the season.

Sunnyside was fallowed during the spring and "Roundup" applied at the end of June to control couch grass and groundkeeping potatoes.

Wall was sown with a mixture of ryegrass and stubble-turnips at the end of July, ploughed in mid-October and "Score" winter wheat sown on approximately 6·4 hectares in the northern half on 19th and 20th October. The remainder of this field is being used by the cereal department for spring cereal trials in 1978.

Loan was sprayed with aminotriazole ("Weedazol TL") in early summer and ploughed in mid-September, Kinsman winter wheat was drilled on 14th and 15th October, 376 kg ha^{-1} of fertiliser (8-20-16) were broadcast in the seed bed. Both varieties of winter wheat have brairded well.

Draining in Wee Murrays, Crow, Toll, Potato Shed and Reserves B and C was started in December and is now complete. The stone-built drain in Reserve B has been replaced by a concrete pipe drain and the open ditch on the north-western edge has been piped and covered in. The drainage operations have progressed well and the farm will have been completely redrained by September 1978.

The burn on the southern boundary of the farm has been cleaned out and the scrub cleared in co-operation with the neighbouring farmers. This has greatly improved the outfall of existing drains and provided good outlets for the new drains.

A regular programme of hedge cutting and intensive spraying of field boundaries with glyphosate ("Roundup") and paraquat has been carried out as part of a major weed control programme. New equipment has enabled this work to be done by our own staff.

The access to the new glasshouse accommodation and the roads in the Stackyard, the old cottages area and through the farm have been graded and surfaced with hard core.

The new Commodore office building was completed and has been in use since August 1977.

The following haymaking equipment was purchased during the year: a Lister multilevel elevator, a New Holland baler, a Meier bale collector and a bale grab, a Fahr chain mower, an Acrobat hay rake and a Haybob haymaker. In addition, various items of general farm machinery purchased included a Lely Rotera, a Vicon reciprocating harrow, a Chieftain Forge forklift and a Twose hedgecutter. Two Weeks 40-plus trailers were also bought.

G. R. White

Strategic Pathology Unit

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

The re-establishment of the race collection of Phytophthora infestans *was begun.*

In studies on tubers a high incidence of thread-like lesions was noted and the significance of these as a source of blight in potato crops is under investigation.

The special combining ability for blight resistance in foliage was studied in progenies of a North Carolina II mating scheme between parents of Tuberosum, Neo-Tuberosum and Solanum vernei *origin. The need to test adequate samples of leaflets in assessing highly resistant clones was recognised.*

Lack of facilities, due to laboratory changes, severely restricted the programme. It was impracticable to maintain the isolates of *Phytophthora infestans* from Blythbank or from studies of race mixtures (*Ann. Rep. 1976–77*, 46) and therefore not possible to determine their racial composition. Most of the collection of different races of *P. infestans* was lost but a start has been made on re-establishing a collection from which it is hoped that a sufficient range of races will be available to resume studies of interaction between races.

Preparatory to studies of blight in tubers, investigation was made of the effect of time of lifting and time of inoculation. Nine commercially established cultivars were used and inoculation was with a race of *P. infestans* capable of overcoming any R genes present. The trial involved four lifting dates, one week apart and for each lift there were four inoculation dates, also one week apart. Each test was replicated twice and the trial was designed so that interference from lifting neighbouring plots was minimal. The scoring of tubers for infection and recording is still in progress; analysis of the results has not yet been made. The comparatively high incidence of thread-like lesions, similar to those observed in previous studies (*Ann. Rep. 1976-77*, 47) has been of particular interest. Some of these have been observed to develop into gross lesions and the remainder are still under observation. Attempts will be made to isolate *P. infestans* from the thread-like lesions, and some tubers bearing them will be planted to observe whether or not they are a source of blighted plants.

The special combining ability for blight resistance, recognised in earlier work (*Ann. Rep. 1976-77*, 46) was investigated further, in collaboration with the biometrical genetics programme. This consisted of a North Carolina II Experiment involving seventy-eight families derived from five established Tuberosum, blight resistant parents crossed with sixteen recently introduced blight resisters. A similar experiment was conducted with eighty-seven families derived from nine established blight resisters crossed with ten Neo-Tuberosum parents. The tests were conducted on whole plants in the glasshouse and, in addition to assessing the overall effect of infection, details of infection of the leaf (lamina and petiole) and stem were recorded. Analysis of the results is in progress. Samples of the resistant survivors were retained for further study of the nature of their resistance.

A further North Carolina II Experiment was established and is in progress with seventy-four families, derivatives of *Solanum vernei*, of the same origin as those in which special combining ability for blight resistance was first recognised (Killick and Malcolmson, *Physiol. Pl. Path.* **3**, 121-31). Leaflet testing only is involved and again, further study of resistant material is planned.

Leaflet tests to explore the resistance of some of the parental clones in the above experiments, and of supposedly resistant dihaploid clones, showed the need to test an adequate number of samples in assessing highly resistant material. Commonly only two or three out of thirty leaflets of these clones developed active, sporulating lesions. These highly significant lesions did not result from the generation of a new race of *P. infestans* and if they had not been recorded the clones could have been erroneously recorded as extremely resistant. This type of resistance is very different from the more common form also noted, in which active though small lesions developed on all the inoculated leaflets.

J. F. Malcolmson

SERVICE UNITS

Chemistry Laboratory

The work of the Chemistry Laboratory is mainly concerned with routine analyses of quality factors important in plant breeding. Part of the effort is directed towards increasing the accuracy and the speed of routine work. Last year an infra-red reflectance instrument was acquired, the Technicon "Infra-Alyser" which is capable of rapid estimations of factors affecting quality. In the summer of 1977 the "InfraAlyser" was successfully calibrated for the measurement of percentage nitrogen, soluble β-glucan content and the percentage moisture of small barley samples (about 3 g of finely milled flour). All three measurements are completed simultaneously in approximately one minute. After harvest 1,500 samples of barley breeding material were analysed on the "InfraAlyser" in four weeks. Major structural alterations to the Chemistry Laboratories were in progress during that period and temporary power cuts often delayed the work.

Progress was also made in streamlining the data processing aspect of the digestibility work. A data logger has been interfaced with the electronic balance so that all weights plus sample number can be logged directly on to magnetic tape. The raw data is then replayed into a Wang mini-computer which uses a suitable program to calculate the proportion of digestible organic matter in the dry weight. This new system has eliminated transcription errors and, after modifications to the program, can potentially be used for other gravimetric analyses. The Wang has also been programmed to perform simple statistical analysis of the data.

Apart from measurements made on the "InfraAlyser", other routine work included digestibility determinations (1,390 brassica samples); Kjeldahl nitrogen (1,100 and 200 samples of barley and brassicas, respectively); diastatic power and alpha amylase (2,120 barley samples). Estimates of digestibility were also made on 400 brassica samples using a modified pepsin-cellulase method (Allison and Borzucki, *J. Sc. Fd. Agric.* in press). The pepsin-cellulase estimates correlated well ($r = 0{\cdot}87$) with the estimates made using rumen liquor.

A new apparatus for the determination of milling energy (*Ann. Rep. 1976-77*, 60) based on a flywheel system is being developed in collaboration with Calan Electronics Ltd. The new system will be self-cleaning and faster (approximately ten seconds per sample) than the present method. In addition, the electronic measurements of time and speed, controlled by a microprocessor, should give accurate milling energy results.

A time course study of two toxic factors in a range of botanical varieties of *Brassica oleracea* is at present being analysed. The toxic factors are s-methyl cysteine sulphoxide which causes haemolytic anaemia in kale-fed ruminants, and thiocyanates which have goitrogenic effects.

During the year the Chemistry Laboratory facilities improved markedly. The former Cytology Laboratory was converted into an office, a balance room and an auto analyser laboratory. The Cereal Chemistry Laboratory was converted into a washing-up room. In the old Chemistry Laboratory three new fume cupboards with improved safety standards (one with an acid-wash facility) were built into the old balance room. The new developments will improve the safety aspects and efficiency of work in the Chemistry Department.

M. J. Allison R. Borzucki
I. A. Cowe

Cytology Laboratory

This year, in addition to work for the Brassica department and the diploid/dihaploid potato projects, the chromosome numbers of 110 lines of the oat collection were determined and pollen fertility estimates were made for the commercial potato breeding programme.

Work for the Brassica department included screening colchicine-treated material for inclusion in the artificial *Brassica napus* and *Raphanobrassica* breeding schemes. Chromosome counts were made of multiplied seed of *B. oleracea*, *B. campestris* and *R. sativus*; up to 55 per cent of the plants were aneuploid. C_1 generation kale and stubble-turnip plants contained a similar percentage of aneuploids.

The semi-artificial rape plants with 38 chromosomes produced by introgression from *B. campestris* into *B. napus* via the allotriploid hybrid (*Ann. Rep. 1976–77*, 61) were analysed at meiosis. Most plants had regular pairing at first metaphase but quadrivalents and univalents were found in some plants, leading to an irregular number of chromosomes in the gametes. These results may explain some of the irregular chromosome segregations found this year in similar, but more advanced semi-artificial *B. napus* material. Plants with $2n=36$ or 38 derived from selfing 37-chromosome plants were selfed; the progenies were expected to have a stable chromosome number (36 or 38) but varied from 34 to 40. It may be necessary to screen the plants with $2n = 37$ and 38 from the initial cross of allotriploids ($2n = 29$, aac) with *B. napus* ($2n = 38$, aacc) and only use for breeding those plants with a regular meiosis.

Crosses were made in 1977 between allotriploids ($2n = 29$, aac) and *B. campestris* ($2n = 20$ aa) to produce monosomic addition lines ($2n = 21$) of *B. campestris* with an extra *B. oleracea* chromosome. Adequate seed was set, and 21 of the 203 plants examined had 21 chromosomes. The distribution of chromosome numbers in these plants is compared with the expected binomial distribution in Table 12.

TABLE 12

Distribution of chromosome numbers of progeny from crossing 29 chromosome aac plants with 20 chromosome aa plants

	Chromosome counts											No. of progeny
	20	21	22	23	24	25	26	27	28	29	>29	
Expected frequency	0·002	0·02	0·07	0·16	0·25	0·25	0·16	0·07	0·02	0·002	none	
Observed frequency:												
aac as male	0·06	0·13	0·10	0·06	0·09	0·17	0·16	0·15	0·06	0·03	none	150
aac as female	none	0·06	0·06	0·17	0·17	0·25	0·15	0·08	none	0·06	0·02	53

The results are similar to those obtained when the allotriploid is backcrossed to *B. napus* (Mackay, *Euphytica* **26,** 511-19) in that far more plants with extreme chromosome numbers were found than expected. The plants with twenty-one chromosomes will be analysed at meiosis and selfed. Plants with an extra pair of *B. oleracea* chromosomes can then be isolated; if stable these disomic addition lines will afford the opportunity to karyotype the *B. oleracea* genome and in the long term enable genetic analysis of each chromosome to be carried out.

Routine pollen fertility estimates were made of 600 potato clones. Fifty dihaploids were identified in the dihaploid production scheme. Three hundred and forty-four of the 377 plants from the programme to produce tetraploid hybrids by interspecific crosses were tetraploid. More aneuploids at all three ploidy levels were found this year than previously in the progeny of both the dihaploid and tetraploid hybrid production schemes.

The elite diploid pollinators, 13T48 and 13T8 (*Ann. Rep. 1976-77,* 57) were again used on a range of tetraploid clones. Pollen from 13T48, reported last year to contain more apparently diploid grains than 13T8, produced a higher percentage (95 per cent) of tetraploid hybrids than 13T8 (88 per cent) with the same female parents. More diploid elite clones were screened for the presence of unreduced pollen; this is probably the result of parallel spindles at the second anaphase of meiosis (Mok and Peloquin, *Can. J. Genet. Cytol.* **17,** 217-25). A study of the inheritance of this character has been started.

Six dihaploid clones were treated with colchicine in 1976, and the 186 plants produced were screened for tetraploidy in the three histogenic layers. Fifty-two plants were doubled in the innermost layer; twenty of these were also doubled in the outer layer. The middle layer could be checked in only five plants and three from the same dihaploid clone were tetraploid in all layers.

J. A. Fantes

Statistics and Computing Service

The section's work of facilitating data analysis from laboratory, glasshouse and field experiments continued and involved punching and verifying cards, running a variety of computer programs, interpreting results and offering advice on a range of subjects. During 1977 1,697 computing jobs were run at a cost of £4,673. Eighty-seven per cent of these jobs were run on EMAS. This year the Co-ordinated Variety Trials (CVT) package, developed at ARC Unit of Statistics, was extensively used by the Cereal Breeders and the new Wang 2200 system is now used frequently to analyse Chemistry Department data.

Dr England took over responsibility for the Unit on 1st January 1978. We have a new Assistant Scientific Officer and look forward to the early appointment of a new Higher Scientific Officer.

R. J. Killick

Photography and Illustration

The demand for colour photography has increased markedly during the year and for this reason use is being made of the "Cibachrome" technique for routine colour work. To facilitate the use of this process a Durst 605 colour enlarger and processor have been purchased.

A Varafont 3000 murographics printer has been bought and has greatly reduced the time and labour required for the labelling of diagrams, slides and display material and has also proved invaluable for the labelling of equipment throughout the Station.

Other items acquired include a Pentax SP 1000 camera for both studio and location work, an Olympus Trip fully automatic 35 millimetre camera and Polaroid colour camera, both of the latter for general staff use and an Elf sixteen millimetre sound and cine projector.

Geraldine Cruickshank

Library

The Library has undergone a major reorganisation this year after the appointment of an Assistant Librarian last March. This involved a change in the physical layout of what was originally a conference room, in order to facilitate access to material held and to provide areas more conducive to study. Periodical publications were sorted out and arranged in a logical sequence and a List of Journals held in the Library has been issued. The book stock has now been re-classified and catalogued and work has begun on cataloguing the various reprint collections held on the Station. A new loan system has been instituted.

Library finances have been reduced by current spending restrictions. However, fifty-five new books were added to the book stock and four new journal subscriptions were taken out; two subscriptions were cancelled. Further cancellations may be necessary in 1978 and a survey was therefore made to evaluate usage of current journals.

A subscription was taken out this year to the Agriculture, Biology and Environmental Sciences section of *Current Contents* and this has proved a valuable current awareness tool for members of staff. In addition, lists of acquisitions to the Library are now being circulated monthly.

Since August, a literature search service has been provided and in the first five months, twenty-three bibliographies have been compiled on various specific topics.

In November, Dr G. H. Pethybridge's collection of reprints on potato pathology was donated to the Station by Mr Geoffrey Samuel and will be kept in the Library. The collection has been on loan to the Commonwealth Potato Collection and stored on the Station for some years.

TABLE 13

Library Statistics 1977

Library Loans		222	
Inter-Library Loans			
Borrowed—British Library	79		
Other Libraries	67		
	—	146	
Lent		11	
Requests for Reprints		35	
Literature Searches		23	(August-December)
Other Enquiries		5	
Book Acquisitions		55	
New Journal Subscriptions		4	
Cancelled Journal Subscriptions		2	
Courses Attended		1	

The Library contributed to the ARC assessment of the Lockheed DIALOG automated retrieval system by providing a trial search. A Lockheed training course was also attended by the librarian in November and it is hoped that the Library will be able to make use of this system next year.

B. E. Hay

Workshop Report

Work to improve safety standards has continued and much time has been spent inspecting, maintaining and modernising electrical installations. The appointment of a motor mechanic has enabled major repairs, as well as routine servicing, of transport, tractors and motorised equipment to be undertaken and this, with the maintenance and modification of field and laboratory equipment and the development of machines has taken a large proportion of workshop time.

A "flywheel mill" to give a rapid assessment of malting quality, for which the original investigation and development was carried out by the workshop in co-operation with the Chemistry Laboratory, has now been taken up by an outside contractor for further development in continued collaboration with the workshop.

A seed cleaner, incorporating a cyclone, for small samples of brassica seed, was designed and constructed.

The joiners' workshop has constructed many fittings for laboratories, glasshouses and offices in addition to its routine maintenance work.

A. E. Hamilton

Meteorological Summary. The Murrays 1977

TABLE 14

	Mean temperature °C		*Mean soil temperature °C*		*Number of days temperature < 0·0 °C*		*Total rainfall*	*Number of wet days*
Month	*Max.*	*Min.*	*5 cm.*	*10 cm.*	*Air*	*Grass*	*mm.*	*≥ 1·0 mm.*
January	3·9	−0·5	0·5	1·0	14	20	86·9	9
February	5·1	0·7	1·3	1·5	7	15	51·0	11
March	8·6	3·0	4·3	4·8	3	7	52·5	14
April	9·5	3·0	6·3	5·5	5	10	27·0	10
May	13·1	4·3	11·5	9·7	1	7	32·7	7
June	15·4	7·3	14·4	12·9	0	0	110·0	12
July	18·6	10·3	17·2	15·5	0	0	13·3	6
August	17·6	9·4	15·9	15·2	0	0	65·7	12
September	14·5	8·4	11·3	10·6	0	2	59·6	9
October	13·6	7·9	9·1	9·1	0	0	52·5	6
November	7·5	2·1	3·1	3·7	8	13	65·7	13
December	7·1	2·8	2·7	3·2	4	8	33·2	10
Annual (364 days)	11·25	4·90	8·30	7·72	42	82	650·1	119

G. R. White

INTER-SPECIFIC AND INTER-GENERIC HYBRIDIZATION IN THE BRASSICAE WITH SPECIAL EMPHASIS ON THE IMPROVEMENT OF FORAGE CROPS

I. H. McNAUGHTON AND CAROL L. ROSS

Introduction

The object of this article is not to review all the work on inter-specific hybridization within the *Brassicae*, but to outline the range of variation within existing crop plants and to show where improvements have been made, or are being made, through the use of wide crosses. Special emphasis is placed on forage, as opposed to oil-seed plants or mustards, and on work carried out at SPBS.

Several comprehensive review articles on cytogenetic relationships of the *Brassicae* have already been produced (*e.g.*, Mizushima, 1950; Yarnell, 1956; Davey, 1959).

Forage brassicas in Britain are confined to the three species; *Brassica campestris* L., *B. oleracea* L. and *B. napus* L., all are important for various purposes. *Raphanus sativus* is also used as a forage, but is of much less significance. Cytogenetic relationships of the species are shown in Figures 2 and 3.

B. CAMPESTRIS L. (THE TURNIP GROUP)

B. campestris is a variable species in some forms of which the storage organs (so-called "bulbs" or "roots") are used, both as forages and as vegetables, whereas the leaves form the useful part in the oriental salad vegetables. There are several distinct sub-species, some of which are used as oil-seed plants.

TABLE 15

The variation within *Brassica campestris* L.

Subspecies	*Common name*
chinensis (L.) MAKINO	Chinese mustard
dichotoma (ROXB.) OLSSON	toria
eu-campestris (L.) OLSSON	wild type
narinosa (BAILEY) OLSSON	
nipposinica (BAILEY) OLSSON	
oleifera (METZG.) SINSK.	turnip-rape
pekinensis (LOUR.) OLSSON	Chinese cabbage
rapifera (METZG.) SINSK.	turnip, stubble-turnip
trilocularis (ROXB.) OLSSON	yellow-seeded sarson

The above table is based on the classification of Olsson (1954).

Turnips are the only form of *B. campestris* normally grown for forage purposes. Forage turnips are biennial and are divided into two distinct groups; the traditional or Scottish turnips, sometimes referred to as yellow turnips, and the Dutch stubble-turnips. Traditional turnips are normally sown in May in Scotland, to provide autumn forage, mainly for sheep, but also for cattle. Stubble-turnips, on the other hand, are usually used as catch crops and in Holland and elsewhere are frequently drilled between late July and mid-August following cereal harvest.

Wastage on grazing of stubble-turnips can be high, 35 per cent or more (A. Cox, ADAS, personal communication), but they generally show a high degree of resistance to *Plasmodiophora brassicae* (causing club-root disease). Diploid and tetraploid forms are commercially available.

A more comprehensive description of the *B. campestris* group, concentrating on evolution and development, is given by McNaughton (1976b) whilst the turnip is also described in a review article (McNaughton and Thow, 1972).

B. OLERACEA L. (THE KALE GROUP)

B. oleracea is an extremely polymorphic species and has been classified into a number of distinct botanical varieties, many of which are vegetables (Table 16). The important forage forms are the thousand-head and marrow-stem kales; the former are generally utilised as a forage for cattle in late winter or early spring, because of their good winter hardiness and leaf retention. Marrow-stem kales are less hardy and are normally strip grazed by cattle in autumn; improved hardier forms, such as Maris Kestrel, are being produced; this cultivar has also been selected for high stem digestibility.

TABLE 16

The variation within Brassica *oleracea* L.

Botanical variety	*Common name*
acephala DC	marrow-stem kale
botrytis L.	cauliflower
capitata L.	cabbage, savoy cabbage
fimbriata Mill.	curly kale, Scotch kale, Siberian kale
fruticosa Metz.	thousand-head kale
gemmifera Zenker	Brussels sprouts
gongylodes L.	kohl-rabi
italica Plenck	sprouting broccoli, calabrese
sylvestris L.	wild cabbage

The above table was taken from Yarnell (1956).

B. alboglabra should probably now be considered an additional variety of *B. oleracea* since the two "species" have been shown to be completely inter-fertile. *B. alboglabra* is a white flowered, annual plant, important for culinary use in Malaysia and elsewhere.

Haemolytic anaemia of cattle, caused by SMCO (S-methyl cysteine sulphoxide), is a problem in utilisation of kales. Sheep, similarly, may also suffer from "kale poisoning". A range of modern cultivars has been assessed for SMCO content by Whittle *et al* (1976). Work on kale poisoning has been comprehensively reviewed by Smith (1974). Glucosinolates, which can be broken down to produce goitrogenic substances, occur in the kale group as well as other brassicas and there is evidence of variation between kale cultivars in their glucosinolate content (Johnston and Jones, 1966).

Kales suffer less from diseases than do other agricultural brassicas, being reasonably tolerant of *Plasmodiophora* and are seldom infected by powdery mildew (*Erysiphe cruciferarum*).

B. NAPUS L. (SWEDES AND RAPES)

Swedes (ssp. *rapifera* METZ. SINSK.) provide autumn forage for both sheep and cattle. Methods of utilisation vary; the "bulbs" may be lifted and either fed direct to animals or following storage. *In situ* strip grazing is common practice in many areas for sheep. Swedes are valuable sources of energy, having a high soluble carbohydrate content and digestibility. Most cultivars are highly susceptible to *Plasmodiophora* and to powdery mildew, both of which can seriously reduce yields. Susceptibility to internal browning ("raan") is another problem, particularly on high pH soils. Several pathogens cause rotting during storage. Swedes are discussed in the review article by McNaughton and Thow (1972).

Forage rape (ssp. *oleifera* METZ. SINSK.) is almost entirely used as a leafy grazing crop for fattening lambs and the high thiocyanate content of rape is thought to increase the rate of live weight gain. A major problem is low stem edibility, especially from earlier sowings, often resulting in considerable wastage. Almost all rape cultivars are highly susceptible to *Plasmodiophora*. Powdery mildew is less of a problem than in swedes, although palatability of the crop can be impaired and loss of yield sometimes results.

Hungry Gap kale, sheep kale and Siberian kale are rape-like forms of *B. napus* but are of minor importance. Both annual and biennial oil-seed rape forms exist, the latter being particularly important in Northern Europe.

The evolution of *B. napus* is described by McNaughton (1976c).

R. SATIVUS L. (FODDER RADISH)

Fodder radishes (leafier selections from oil-seed radishes) were introduced into Britain from France in the early nineteen-sixties when they were compared in trials with forage rape. Dry matter yields over three times greater than that of rape were obtained in upland areas in Wales (Johnston, 1962). In the West of Scotland yields only slightly exceeded rape (Boyd and Dickson, 1966) and similar results have been obtained at SPBS.

Premature flowering or bolting, resulting in poor utilisation and low digestibility, is a problem with fodder radishes and has led to general lack of interest in them as forages. Modern cultivars show only slight improvement. Fodder radishes have, however, shown marked resistance to *Plasmodiophora* in field trials. These observations have been confirmed in controlled glasshouse tests, carried out by Johnston (1968). It was observed, in early trials, that fodder radishes showed very low levels of infection by powdery mildew. There are, of course, many culinary forms of radish.

Hybridization within the genus Brassica

THEORETICAL METHODS OF USING INTER-SPECIFIC CROSSES IN THE PRODUCTION OF ARTIFICIAL AND SEMI-ARTIFICIAL *B. NAPUS*

B. napus (2n = 38, aacc) has been demonstrated to be a naturally occurring hybrid between *B. oleracea* (2n = 18, cc) and *B. campestris* (2n = 20, aa) (U, 1935), see Figure 2. There is, therefore, the possibility of producing improved forms of *B. napus* either by hydridization between the parental species or by back-crossing to the parents, which have a greater range of variation than does *B. napus*.

Theoretically, variation from *B. oleracea* and *B. campestris* can be incorporated into *B. napus* (swedes and rapes), by a number of methods.

1. *B. napus* may be crossed with one of the parent species. *B. campestris* is shown as the parent in the following examples. The sesquidiploid F_1 material may be used in one of at least four ways:

The F_1 is, itself, the desired end product (2n = 29, aac).

The F_1 may be multiplied and selected over several generations to stabilise the chromosome number and genomic constitution at that of *B. napus* (2n = 38, aacc).

The F_1 may be backcrossed to *B. napus* as the recurrent parent, to give *B. napus* plants with the desired characters from the diploid species. Figure 4 shows the introgression of *B. campestris* characters into *B. napus* (2n = 38, aacc).

The F_1 may be treated with colchicine, to double the chromosome number and restore homologous pairing at meiosis. The auto-allo-hexaploid may be regarded as a new species, *B. napocampestris* (2n = 58, aaaacc), see Figure III. This can be used as a new crop in its own right, or used as a bridge by backcrossing to *B. napus* as the recurrent parent.

2. The two primary species may be crossed to resynthesise *B. napus*. At some point in the synthesis colchicine treatment is necessary, see Figure 5. Artificial *B. napus* (2n = 38, aacc) may be used in the improvement of *B. napus* crops in several ways:

The artificial *B. napus* may be multiplied and selected.

The artificial *B. napus* may be crossed with natural *B. napus* and the progeny multiplied and selected.

Natural *B. napus* may be used as the recurrent parent in a backcrossing programme with artificial *B. napus*.

3. Other systems have been devised, frequently because of difficulties encountered with some of the crosses described in 1 and 2. It has proved more difficult to incorporate the variation of *B. oleracea* than that of *B. campestris*, either by the direct synthesis of *B. napus* or by the *B. napus* × *B. oleracea* cross. Methods to overcome this problem have included the hybridization of *B. napus* with *B. campestris* and the subsequent crossing of either the sesquidiploid, or *B. napocampestris*, with *B. oleracea*.

A BRIEF HISTORY OF THE USE OF INTER-SPECIFIC HYBRIDIZATION IN THE IMPROVEMENT OF *B. NAPUS*

The earliest artificial crosses between the parental species, or between either of them and *B. napus*, were made before the cyto-genetic relationships between the three species were known. Herbert crossed swede and turnip in 1834 (Kajanus, 1913) but the swede was still considered "numerically a tetraploid ($n = 18$) when compared with the cabbage group ($n = 9$)" as late as 1929 (Davey, 1932, referring to Malinowski's review of 1929). In 1934 Morinaga published his conclusions on *Brassica* species relationships and placed *B. napus*, with its correct chromosome number of $2n = 38$, as the natural amphidiploid of *B. oleracea* and *B. campestris*. U (1935) confirmed this relationship by synthesising *B. napus* from the diploid, parental species.

1. *Hybridization between* B. napus *and one of its parent species*

According to Shiga (1970), Japanese oil-seed rape breeding has, since it began in 1930, included the cross between *B. napus* and *B. campestris*, with the main objective of introducing the earlier maturity of *B. campestris* into *B. napus*. Forty-one registered Japanese rape varieties had been bred from such crosses by 1970. The cross *B. napus* × *B. campestris* gives a satisfactory seed set compared with that of most inter-specific crosses. (Shiga quotes 400–500 seeds per 100 pollinations), and it has been used in several other *B. napus* improvement programmes. In New Zealand, Lammerink (1970) transferred resistance to club-root (race E, *sensu* Lammerink, 1965) from Debra turnip (*B. campestris*) to several varieties of swede (*B. napus*).

The cross between *B. napus* and its other parent species *B. oleracea* has proved very difficult. Chiang *et al* (1977) considered the genotype of the *B. oleracea* to be crucial to the success of the hybridization.

The first *B. napocampestris* ($2n = 58$, aaaacc), the hexaploid of *B. napus* and

B. campestris, arose by spontaneous chromosome doubling of the hybrid between a swede and a turnip (Frandsen and Winge, 1932). The plants were true breeding and described as a "new species hybrid". Both swede × turnip hybrids and others synthesised as oil-seed types were inferior in performance to the existing *B. napus* cultivars. Evidence is accumulating that these hexaploids are likely to remain inferior to the amphidiploid *B. napus* (*e.g.* Olsson, 1963). Their lower dry matter percentage is thought to be a consequence of their higher ploidy, possibly a result of larger cell size (Mackay, 1973).

B. napocampestris has been used successfully as a bridge species. Johnston (1974) transferred resistance to *Plasmodiophora* (race 3, *sensu* Johnston, 1968) from the turnip "Waaslander" (*B. campestris*) to "Nevin" rape (*B. napus*) by producing *B. napocampestris* and then back-crossing to "Nevin" for two generations.

2. *Production of artificial* B. napus

2.1. Production of hybrid seed

The direct production of *B. napus* by crossing the parent species has been attractive to plant breeders ever since U's resynthesis of the amphidiploid; the rate of hybrid production, however, is not encouraging. U obtained four seeds from 732 pollinations, the plants were $2n = 19$, 28, 29 and 38 and had the probable genomic constitutions of ac, acc, aac and aacc respectively. In spite of this, plant breeders have continued to make the cross, looking for methods of increasing the number of hybrids and studying the few produced. In 1943 Frandsen succeeded in synthesising appreciable numbers of artificial *B. napus* plants (thirty-seven euploids from 3,000 pollinations) using the tetraploid forms of both parents. His main interest was in confirming the origin of *B. napus* rather than the immediate use of the products in plant breeding (Frandsen, 1947).

Between 1949 and 1957 pollinations were made at Svalöf in Sweden, with the purpose of resynthesising *B. napus* for use in plant breeding. A large number of hand pollinations were required to produce a few hybrid seeds, the frequencies of which were very unevenly distributed over the various combinations of *B. oleracea* and *B. campestris* used. Attempts were made to synthesise oil-seed and fodder rape and swede forms of artificial *B. napus* choosing parents considered to be appropriate to the type required, *e.g.*, using the turnip form of *B. campestris* when attempting to produce a swede. Selection within the artificial material produced oil-seed lines of commercial quality, but the material was also often valuable for the introduction of a distinct character without being worth, itself, cultivating. Crosses involving the turnip gave swede-like artificial *B. napus*, but it did not seem likely that these artificial lines could be improved to commercial standards without crossing with the existing natural *B. napus* cultivars (Olsson, 1963).

2.2. Use of *in vitro* culture of the hybrid embryo

Hakansson (1956) found that, although few inter-specific hybrid seeds were obtained from pollinations between *B. oleracea* and *B. campestris*, embryos were frequently produced, but aborted at an early stage of development. Nishi *et al* (1961) developed a technique for the *in vitro* culture of *Brassica* embryos. Nishi was interested in the introgression of disease resistance from cabbage (*B. oleracea*) into Chinese cabbage (*B. campestris*) via the inter-specific hybrid; one of his crosses, however, produced a heading form of artificial *B. napus* of a type unknown in the natural material and which was itself developed as a crop without backcrossing to Chinese cabbage.

For further information on inter-specific hybridization in the improvement of *B. napus* the reader is referred to the publications of Hoffman and Peters (1958), Davey (1959), Olsson (1960), and McNaughton (1963).

INTER-SPECIFIC HYBRIDIZATION IN THE IMPROVEMENT OF *B. NAPUS* AT SPBS

1. *Hybridization between* B. napus *and* B. campestris

At SPBS hybrids were produced between swede (*B. napus*) and turnip (*B. campestris*) in 1927 and 1928. One of these hybrids, back-crossed to swede and selected and inbred for seven generations, was one of the parent lines of the commercial cultivar "Pentland Harvester".

1.1. The production of *B. napocampestris*

In 1960, crosses were made between *B. napus* and the *B. campestris* sub-species *chinensis*, *pekinensis* and *nipposinica*. The expected sesquidiploids (2n = 29, aac) were produced, but one plant from the *nipposinica* cross was morphologically distinct. It was found to have 2n = 58, with the presumed genomic constitution of aaaacc, and to be of the auto-allo-hexaploid species *B. napocampestris*.

In succeeding seasons, hybrids were produced between a range of *B. napus* rape cultivars and sub-species of *B. campestris*, and treated with colchicine to produce *B. napocampestris*. It was intended to synthesise a substitute for rape, which would combine the winter hardiness of rape with the high leaf to stem ratio of many of the oriental forms of *B. campestris*, particularly that of ssp. *nipposinica*. The genomic constitution was expected to result in a lower seed yield relative to that of rape, but this is not so serious a disadvantage in a forage, as in a seed crop such as oil-seed "rape".

The seed fertility of *B. napocampestris* responded to selection and by 1970 seed yield had reached a level which would be commercially acceptable (McNaughton, 1973a), but the dry matter yields were below those of rape cultivars. The breeding of *B. napocampestris* as a crop was discontinued and the material was used in a back-crossing programme with *B. napus*, to introduce the low, leafy growth habit into the latter, and so reduce the unacceptably high proportion of stem of the fodder rapes.

1.2. The production of the sesquidiploid

During the work with *B. napocampestris* the hexaploids had been compared visually with their respective sesquidiploids (2n = 29, aac) and *B. napus* progenitors, and the sesquidiploids appeared to be consistently the most vigorous. F_1 hybrid forage rape, produced by hand pollination, demonstrated substantial heterosis (Johnston, 1971), but forage rapes (*B. napus*) were generally self-compatible and this prevented the immediate production of F_1 hybrid seed in commercial quantities. However, *B. campestris* possesses a self-incompatibility system and hybridizes readily with rape, and it was decided to test the *B. napus* × *B. campestris* hybrid (2n = 29, aac) as an alternative to the true *B. napus* rape. Exploratory crosses were made using single paired plants of turnip (*B. campestris*) and rape (*B. napus*) cultivars isolated in insect cages.

The resulting hybrids were high yielding, but seed production costs would have been prohibitively expensive for a commercial crop (Mackay, 1973). Functional self-incompatible (S) alleles occur in turnip but not in rape, thus hybrid seed could be produced only from the turnip parent, and it was, therefore, economically essential to introduce functional S-alleles into rape to permit both species to act as seed parents. Self-incompatible rape lines have since been produced, many of which are high yielding. Their self-compatible sib-lines, produced as a by-product of the crossing programme, probably have a future as cultivars in their own right.

Seed production costs preclude the use of single cross hybrids in forage brassicas, even when seed can be obtained from both parents. Maris Kestrel kale, a triple cross hybrid produced from six self-incompatible lines, demonstrates one method of overcoming this problem (Thompson, 1964). A similar system for the production of the sesquidiploid is to use self-incompatible F_1 hybrid turnips (*B. campestris*), and possibly self-incompatible F_1 hybrid rape (*B. napus*), to produce the commercial seed.

The high frequencies (~ 60 per cent) of inter-specific hybrids produced by plants in insect cages, where blowflies are the pollinating agents, have not been achieved in the field. Blowflies distribute pollen at random whereas bees, the usual pollinator in the field, are colour selective, which reduces the frequency of inter-specific pollinations. The ability of the available self-incompatibility systems to prevent self-fertilisation, and to ensure the production of a sufficiently high proportion of sesquidiploid seed, is now in doubt. However, the production of functionally self-incompatible rapes offers the possibility of F_1, or more complex, hybrid rape cultivars.

1.3. The introgression of *B. campestris* variation into *B. napus*

A programme was begun to produce F_1 hybrid swedes, after considerable heterosis had been demonstrated in inter-cultivar swede hybrids (McNaughton and Munro, 1972). This programme required the incorporation of functional S-alleles into swedes, and sesquidiploids were produced between swede (*B. napus*) and turnip (*B. campestris*) cultivars as the first stage in introgressing the alleles from the turnip. However, functional S-alleles were found within other forms of *B. napus* and transferred to swede cultivars (this transfer is described in a later section), making the sesquidiploids unnecessary for this purpose.

Two groups of the sesquidiploid hybrids could be identified as potential bearers of useful genes because of their parentage. Material of these groups was isolated with swedes to increase the number of thirty-eight chromosome progeny recovered from the hybrids, seed being collected from the sesquidiploid plants only.

Several of the sesquidiploid lines had the high dry matter turnip cultivar "May" in their parentage. The progeny of the "May lines" isolated with swedes, have been multiplied and selected for agronomic characters for two generations. A high selection pressure for balanced genomes is expected and the intention is to recover thirty-eight chromosome swedes with a high dry matter yield.

Progeny from the cross (swede cv. Chignecto × stubble-turnip, cv. Vobra) × swede, have been selected for resistance to *Plasmodiophora* and screened cytologically. Three plants have so far been identified with $2n = 38$ and "04 type" resistance to *Plasmodiophora* (see Buczacki *et al*, 1975). The *B. campestris* line used to specify 04 type resistance has proved to be resistant to all known UK races of *Plasmodiophora* and these plants may prove valuable in producing club-root resistant swedes.

2. *The production of artificial* B. napus

2.1. Production of hybrid seed

Crosses between *B. campestris* and *B. oleracea* were made at SPBS for several years and, in 1954, a single seed was produced from a cross between a turnip, cv. "The Bruce", and a kohl-rabi × thousand-head kale hybrid. The resulting plant was weak and, as expected in a haploid plant ($2n = x = 19$, ac), sterile. It was repeatedly treated with colchicine in an attempt to produce artificial *B. napus* and, in 1957, fifteen seeds were obtained by bud selfing. It was also crossed to natural *B. napus*. The derivatives of this artificial *B. napus* were sown out and assessed for their performance as swedes, some had fair-sized "bulbs" but most were fang-rooted, long-necked and had no agronomic potential.

Many thousands of pollinations have been made between the parental species of *B. napus* since 1954. The cross has been made in both directions, at both diploid and tetraploid levels and with and without the use of growth substances at pollination; all with limited success.

One hybrid ($2n = 28$, acc) was produced from 2,600 pollinations of diploid *B. campestris* with pollen from tetraploid *B. oleracea*. This was crossed to various rapes; it was intended to breed to thirty-eight chromosome plants with a more acceptable stem derived from the *B. oleracea* parent, a marrow-stem kale. Although work with this material has continued, the mixed ploidy crosses have not been repeated.

During attempts to produce matromorphic *B. oleracea* plants (a later section in this article deals with the use of matromorphy) by pollinating *B. oleracea* with *B. campestris*, two (2n = 19, ac) hybrids were produced from 8,000 pollinations. Minute quantities of pollen were produced by these hybrids and they were crossed reciprocally with swede and rape, but without success. One hybrid produced seeds apparently spontaneously but the mechanism is not known.

2.2. Use of *in vitro* culture of hybrid embryos

Studies at SPBS on hybrid embryos showed slow development and abortion during the later stages of development. In 1963 the first attempts were made, without success, to culture the aborting embryos by the *in vitro* technique of Nishi *et al* (1961).

Mr D. J. Harberd, working at Leeds University, developed a simple liquid culture technique for raising hybrids from various crosses within the *Brassicae* (Harberd, 1969, 1970). In 1968, he crossed tetraploid *B. oleracea* and *B. campestris* lines supplied by SPBS, and used his method to raise seven hybrids. Four of these, two euploid and two aneuploid, were successfully selfed and the development of this material is described later in this article.

Harberd's technique was adopted for use in the inter-specific hybridization programme, but plants were not raised until 1972, when two were produced from *B. campestris* female crosses, using material closely related to the original tetraploids supplied to Harberd. This success could not be repeated and, since 1974, a solid culture technique based on that of Nishi *et al* (1961) has been used.

At SPBS crosses between *B. oleracea* and *B. campestris* are made at the diploid or tetraploid level, *B. oleracea* always being used as the female parent. The hybrid embryos are extracted and cultured on agar slopes. The system, as first applied, produced two hybrid plants. However, after consideration of the appearance of the part-grown "pseudo-seedlings", which failed to survive, it was decided to modify the basic White's medium of the original technique (Snell, 1978, in press).

A major problem in the embryo culture technique is in the choice of the correct stage of development at which to extract the hybrid embryo. There is great variation in the rate of growth, even within the same fruit. The developing capsules are sampled at intervals around the predicted optimum age for culture. There is also a genotypic effect on the success rate of the pollinations, many crosses producing few embryos, but total failure of a cross cannot, with certainty, be ascribed solely to genotypic causes. The average success rate is eight hybrid plants produced per hundred pollinations.

3. *Artificial* B. napus *in the breeding programmes*

Artificial *B. napus* plants, which, it is hoped, will have greater agricultural merit than existing swedes and rapes have been and are being, synthesised.

Marrow-stem kale and kohl-rabi (*B. oleracea*) are being crossed with turnip (*B. campestris*) to produce a rape with a stem more acceptable to stock.

Turnip cultivars with high dry matter content are being used as the *B. campestris* parent in crosses with *B. oleracea* in an attempt to produce swedes with higher dry matter yields.

Kales have a high field tolerance of powdery mildew and artificially derived *B. napus* based on kale may be expected to show some of this tolerance. This material has not been examined in the field, but it is thought that it will be necessary to provide "resistance" from the *B. campestris*, as well as from the *B. oleracea*, parent.

One of the main reasons for undertaking the programme to re-synthesise *B. napus* was to produce plants having a greater resistance to attack by *Plasmodiophora* than that of existing *B. napus* material. Inter-specific crosses have been made using the resistant 04 differential (*B. campestris*). Crosses, made at the tetraploid level, were complicated by the fact that the plants, which had been colchicine treated, were almost sterile. However, five plants were obtained, two had the euploid chromosome number ($2n = 38$), and have been crossed to swedes and rapes.

Most breeders working with artificial *B. napus* report a low self-fertility on bud pollination and it has become a general practice to cross the artificial material with existing cultivars to restore fertility. It is probable that it will be necessary to treat all the SPBS artificial *B. napus* material used in the breeding programmes in this way and then to select for desirable attributes from the resulting semi-artificial *B. napus*.

A small programme has been set up to produce material for a biosystematic study of the different artificial *B. napus* forms. This involves the crossing of a wide range of botanical varieties of *B. oleracea* with many sub-species of *B. campestris*. These crosses are made at the diploid level, the resulting hybrids, after chromosome doubling, are homozygous and true breeding.

At present, crosses intended for the breeding programmes are made on the assumption that characters, observed in the parental species, will be shown by the amphidiploid. This biosystematic study will test that assumption, build up a body of data from which we may predict what particular combinations of parents will give and provide a gene pool of new characters which may prove useful as crop requirements.

DEVELOPMENT OF SEMI-ARTIFICIAL RAPES AT SPBS

In 1968, Mr D. J. Harberd of Leeds University, in co-operation with SPBS, was successful in producing several artificial *B. napus* plants, using the embryo culture technique, based on a liquid medium, already mentioned (Harberd, 1969). Heterozygous autotetraploid parents, produced at SPBS, were used in this work. F_1 hybrid *B. oleracea* (thousand-head × curly kale) plants were female parents in crosses with F_1 hybrid *B. campestris* (ssp. *oleifera* with both ssp. *nipposinica* and *pekinensis*). Two forms of artificial rape were produced of very similar parentage, differing in that one included *B. campestris* ssp. *nipposinica*, the other ssp. *pekinensis*.

The artificial *B. napus* plants were found to be of moderate fertility on bud-selfing. F_2 plants, grown under field conditions, showed a range of morphological variation and vigour. Selected plants of each of the above origins were transferred to the glasshouse and crossed with a commercial rape, Nevin (used because of its superior resistance to *Plasmodiophora* compared to other cultivars available at that time). The resulting F_1 semi-artificial rapes were placed in insect-proof cages with blowfly pollinators; they proved highly fertile and produced about thirty-three grams of seed per plant, compared with about six grams of seed per plant from straight F_3 artificial rapes multiplied under similar conditions. The relatively low seed fertility of artificial *B. napus* has already been mentioned. Plants grown from residual seed of the two F_1 semi-artificial rapes were compared with their respective parents (the straight artificial rapes and Nevin) in a transplant experiment in 1972. The F_1 semi-artificial rapes populations showed heterosis in outyielding the better parent, Nevin, by 5 per cent in fresh weight and by almost 30 per cent in dry matter. This result supports the findings of Sarashima (1967) who reported that F_1 semi-artificial rapes produced fresh weight yields 56 Per cent better than the superior parent.

The possibility of utilising residual heterosis in semi-artificial rape was suggested by Sarashima (1967) who found fresh weight yields of F_2 plants to be 16 per cent higher than the original superior parent. It was considered by Sarashima that F_3 seed could be used to produce a commercial crop.

In a drilled, small plot experiment, carried out at SPBS in 1973, F_2 semi-artificial progenies (of the two origins) were compared with their respective wholly artificial parents (multiplied to F_3) and with Nevin. Residual heterosis was not shown, dry matter yields of F_2's being no better than Nevin in one instance and 11 per cent lower in the other.

Selections for leafiness and vigour were made from substantial field plots of F_2 semi-artificial rapes and the selected plants seeded in a polycross. F_3 populations were treated similarly. The resulting F_4 bulks, each consisting of a number of closely related individual plant progenies, were compared with leading commercial rape cultivars at several sites in 1976. The best semi-artificial bulk produced dry matter yields, averaged over sites, comparable with commercial rape. In 1977 fourteen F_4 semi-artificial lines (individual plant progenies from polycrosses) were assessed in a single trial along with the three highest yielding Giant rape cultivars included in the NIAB List of Recommended Varieties, *i.e.*, Canard, Emerald and Lair; Nevin was included as an additional control. Emerald rape produced the highest dry matter yield, but the better breeding lines were only slightly inferior; all but two lines outyielded Nevin. Further evaluation is needed but there is promise of at least one new cultivar being developed. Some semi-artificial lines have shown a similar spectrum of *Plasmodiophora* resistance to that of Nevin.

HYBRIDIZATION BETWEEN *B. NAPUS* AND *B. OLERACEA*

This cross is known to be extremely difficult (Yarnell, 1956) and has received less attention than others within the *Brassicae*. Hybrids were reported by U (1935) in his academic studies on cytogenetic relationships and also by Karpechenko (1937).

A single hybrid was obtained in the United States by crossing *B. napus* (York swede) with *B. oleracea* (Greenball cauliflower), in an attempt to transfer resistance to US *Plasmodiophora* race 2 from swede into cauliflower and broccoli. The hybrid flowered profusely over a period of two and a half years and was very vigorous, it was, however, of low fertility and only 100 F_2 seeds were obtained. F_2 plants were tested against an inoculum of race 2 and some proved resistant. Back-crosses of the original hybrid to the swede parent resulted in fertile plants, but back-crossing to *B. oleracea* (broccoli) resulted in very few seeds (Honma and Summers, 1976).

An experiment with similar objectives, *i.e.*, to transfer resistance to race 2 from *B. napus* into *B. oleracea*, was carried out by Chiang *et al* (1977) in Canada. In this instance, swede cultivars (Wilhelmsburger, York and Ditmars S2) and Nevin rape were used as resistant *B. napus* parents, whilst various cabbage lines, including the cultivar Badger Shipper, were used as the *B. oleracea* parents.

In addition to diploids, colchicine doubled forms of cabbage (2n = 36, cccc) were used in the above crosses. The frequency of inter-specific hybrids was extremely low. Nineteen hybrids, at three different chromosome levels (2n = 28, acc; 2n = 37, accc and 2n = 55, accccc) were obtained. All F_1 hybrids proved resistant to race 2, suggesting that resistance is dominant.

B. napus and *B. oleracea* have been successfully hybridized following colchicine-induced chromosome doubling of the parents (Chopinet, 1942) resulting in the hexaploid *B. napo-oleracea* (2n = 56, aacccc), this has also been produced by other workers.

At SPBS an attempt was made to produce *B. napo-oleracea* by crossing *B. napus* (rape) with *B. oleracea* (kale). Approximately 1,000 pollinations were made, almost all using *B. napus* as female parent, without success.

Hybridization between *R. sativus* and Brassica species

HYBRIDIZATION BETWEEN *R. SATIVUS* AND *B. CAMPESTRIS*

This hybridization is known to be very difficult. In attempts to produce new oil-seed plants Japanese workers obtained one hybrid (2n = 28, rra) from the cross *R. sativus* × *B. campestris* (U *et al*, 1937). Diploid hybrids (2n = 19, ra) were also obtained. Detailed cytological studies of the hybrids were made but no suggestions as to their possible value in a breeding programme were given.

A single triploid plant was obtained by Morris and Richharia (1937) from a number of crosses between *R. sativus* and *B. campestris* (turnip). No controlled pollinations were carried out on the hybrid, but a number of seeds, of unknown origin, were obtained. Plants of *B. napus*, *B. carinata*, *B. campestris* and *R. sativus*, flowering nearby, may have provided the male parent. Among the progeny two hexaploid (2n = 56) plants were obtained which resembled the triploid in morphological appearance but were almost totally sterile. The triploid was back-crossed to *R. sativus* and a plant closely resembling radish, but with a single extra *B. campestris* chromosome was obtained.

Amphidiploids (2n = 38, rraa) were successfully produced in Japan from a cross *B. campestris* ssp. *chinensis* × *R. sativus*, their fertility was stated to be very low (Terasawa, 1932, 1933). Terasawa called this new amphidiploid *Brassico-raphanus*, since *Brassica* had been successfully used as the female parent.

F_1 hybrids between *B. campestris* ssp. *nipposinica* and *R. sativus* (a Japanese radish) were found to be completely sterile (Tokumasu, 1970). Amphidiploids were successfully produced, following colchicine treatment of these diploid hybrids. Cytological studies of the amphidiploids were made from the F_1 to the F_3 generation. Euploid (2n = 38) and aneuploid (2n = 37) F_2 and F_3 plants showed meiotic irregularities which included the formation of quadrivalents, trivalents and univalents. Seed fertility was very low, numbers of viable seeds per capsule of F_3 plants varying from zero to 1·7 (Tokumasu, 1976).

Amphidiploids have been obtained at Svalöf from crosses between tetraploid *B. campestris* (oriental sub-species) and tetraploid *R. sativus* (fodder radish). Hybrids were considerably more difficult to obtain than from pollinations between tetraploid *R. sativus* × tetraploid *B. oleracea*, *i.e.*, *Raphanobrassica* synthesis. They were also stated to be even less fertile than early generation *Raphanobrassica* plants (Ellerström and Sjödin, 1973).

At SPBS several thousand pollinations, between tetraploid *R. sativus* (fodder radishes) and tetraploid *B. campestris* (stubble-turnips), were made over a three-year period, in attempts to produce the amphidiploid. These crosses were unsuccessful. One allotriploid plant (2n = 28, rra) was obtained and studied cytologically; it was highly sterile.

HYBRIDIZATION BETWEEN *R. SATIVUS* AND *B. NAPUS*

A few *B. napus* × *R. sativus* hybrids (2n = 38, acr) have been reported (Turesson and Nordenskiöld, 1943), the reciprocal cross also produced a few hybrids. The hybridization is generally considered extremely difficult.

Attempts have been made at SPBS to hybridize *B. napus* (forage rape and swedes) and *R. sativus* (fodder radish) with the particular aim of introducing *Plasmodiophora* resistance into rape and swedes from radish. A large number of pollinations produced approximately 0·4 seeds per pollinated flower. Most of the seed gave rise to matromorphic, rape-like or swede-like plants. A few true hybrids, judged as such on morphological grounds in being intermediate between the parent species, were obtained. These plants were fairly vigorous but entirely male sterile in producing only vestigial anthers. They were not examined cytologically but were presumably triploids (2n = 38, acr). Attempts to double the chromosomes with colchicine and obtain the trigenomic hexaploid ($2n = 56$, aaccrr) were unsuccessful.

HYBRIDIZATION BETWEEN *R. SATIVUS* AND *B. OLERACEA*

A hybrid between *R. sativus* and *B. oleracea* was first reported by Sageret (1826), this plant was vigorous and flowered profusely, but was highly sterile, although a few weak F_2 plants were raised. A hybrid described by Gravatt (1914) was of striking vigour and also flowered abundantly, but was entirely sterile, not even producing capsules. These early hybrids were not cytologically examined, but were presumably diploid ($2n = 18$).

F_1 hybrids were obtained, from crosses between *R. sativus* and *B. oleracea* (Brussels sprouts, cabbage and kohl-rabi), by Karpechenko (1924). Hybrids were only produced when *Raphanus* was used as female parent. Cytological examination revealed that the hybrids possessed eighteen chromosomes and had the genomic formula rc. No chromosome pairing was observed during meiosis. The hybrids varied considerably in vigour and general morphology, some plants being extremely vigorous. They were almost sterile at first whether selfed, inter-crossed or back-crossed to the parent species. Amphidiploid *Raphanobrassica* ($2n = 36$, rrcc) plants later arose spontaneously amongst the F_2 progeny of diploid hybrids (Karpechenko, 1927), see below.

Two *B. oleracea* (cabbage) × *R. sativus* hybrids were obtained by Kakizaki (1927); although initially slow growing, they became very vigorous and floriferous; they were entirely sterile on selfing, inter-crossing and back-crossing to the parental species, only one capsule being obtained, containing no viable seeds.

During the period 1926–1937 Fukushima (1945) obtained F_1 hybrids between *R. sativus* (Japanese radish) and the following species: *B. oleracea*, *B. juncea* and *B. carinata*. The hybrids between *R. sativus* and *B. oleracea* were very vigorous but extremely sterile. One hybrid was obtained with *B. oleracea* as female parent, this is unusual (see above). Fukushima made detailed cytological studies of his hybrids but, as far as can be ascertained, no progress was made in exploiting them to produce new variation in crop plants.

Although Karpechenko reported no chromosome pairing in diploid *R. sativus* × *B. oleracea* hybrids, other authors have found varying numbers of bivalents, trivalents and even an occasional quadrivalent (Richharia, 1937; Howard, 1938; McNaughton, 1973c). It is possible that autosyndetic pairing (involving either *Raphanus* or *Brassica* chromosomes and/or allosyndetic pairing (between *Raphanus* and *Brassica* chromosomes) may occur in diploid hybrids. Should there be any allosyndetic pairing, the transfer of *Brassica* characters into *Raphanus* and vice versa, is a possibility and indeed there is evidence of the former having been successful.

Crosses between *R. sativus* (culinary radishes) and *B. oleracea* (cabbage and kohl-rabi) are reported by Madjarova and Chavadrov (1974). The hybrids showed pronounced heterosis but many possessed morphological anomalies, particularly related to the reproductive organs and were highly sterile. Back-crosses to the parents and inter-crossing of the hybrids led to new forms of radishes with useful attributes such as prolonged periods of economic maturity. A named cultivar, Lyubimi, described as having some intermediate characters of *Raphanus* and *Brassica*, has been produced following back-crossing of diploid inter-generic hybrids to *R. sativus* (Madjarova, 1976).

A single *B. oleracea* (kale) × *R. sativus* hybrid was produced by Honma and Heeckt (1962) with the aid of a growth regulator applied to the flower pedicel at time of pollination. The F_1 plant was very highly sterile but was maintained vegetatively for a period of four years, during which one viable seed was obtained. The F_2 plant proved to be an amphidiploid, *i.e.*, *Raphanobrassica* (2n = 36, rrcc), it failed to produce any viable seed on selfing.

Namai (1976) derived a sesquidiploid hybrid (2n = 37, rrc) from diploid *R. sativus* × 2x *B. oleracea*. All plants obtained from self-pollination, open-pollination or back-crossing of the hybrid *R. sativus* were completely radish-like with 2n = 18 chromosomes. Diploid *R. sativus* × *B. oleracea* hybrids (2n = 18, rc) were also produced. Promising plants resulted from successive back-crossing to *R. sativus*, they were stated to be very vigorous and more resistant to virus and other diseases. Namai concluded that it was possible to transfer characters of economic value from *B. oleracea* into *R. sativus* via their diploid hybrids.

At SPBS back-crossing of diploid *R. sativus* (fodder radish) × *B. oleracea* (kale) hybrids to fodder radish resulted in highly fertile radish-like plants with no apparent new morphological characters.

A BRIEF HISTORY OF *RAPHANOBRASSICA*

In 1922, in the Soviet Union, G. D. Karpechenko, crossed *R. sativus* with three distinct vegetable forms of *B. oleracea*: Brussels sprouts, cabbage and kohl-rabi. Inter-generic hybrids were obtained but only with *R. sativus* as female parent. The hybrids varied considerably in their general morphology and degree of vigour. Some plants were stunted and failed to flower, although others possessed very large leaves and some plants reached a height of 2·5 metres when transplanted to the field. Karpechenko carried out numerous cross-pollinations amongst the hybrids and also back-crosses to the parents. No seed resulted at first (Karpechenko, 1924) but subsequent selfing and inter-crossing of F_1 *R. sativus* × *B. oleracea* plants resulted in F_2 seeds, a few of which gave rise to relatively fertile plants. On cytological examination these proved to be amphidiploids (2n = 36, rrcc), *i.e.*, *Raphanobrassica* (Karpechenko, 1927).

Since complete chromosome pairing was found in *Raphanobrassica* and since there was no segregation in F_2 or F_3 generations, it was considered to be a *species nova*. As far as is known *Raphanobrassica* is an entirely artificial, new genus and does not occur in the wild.

Although Karpechenko was the first person to synthesise *Raphanobrassica*, there are several other reports of its production in the literature (*e.g.*, Richharia, 1937; Howard, 1938; Kondo, 1942; Moskov and Makarova, 1970; Ellerström and Sjödin, 1973; McNaughton, 1973c).

The first *Raphanobrassica* plants created a great deal of academic interest. Detailed morphological and anatomical studies were made (*e.g.*, Karpechenko, 1927; Grebinskaya, 1938) and it has been quoted in several textbooks as one of the classic examples of amphidiploidy.

Raphanobrassica plants, apparently derivatives of Karpechenko's original material, were studied by Crescini (1942); they were very vigorous, but were considered unsuitable for oil-seed or forage production. More recently, marked vegetative vigour of *Raphanobrassica* has been reported by Moskov and Makarova (1970), amphidiploids yielding a mean weight of four kilograms per plant, compared with 2·5 kilograms for the better parent.

As far as can be ascertained from the literature, most *Raphanobrassica* plants have proved unsuitable as crop plants and no real attempt has been made to exploit the agricultural potential of this species until very recently. The capsule (siliqua) of *Raphanobrassica* is particularly interesting and probably unique: the upper portion is indehiscible and resembles that of *Raphanus*; the lower part, separated by a septum, is like that of *Brassica* and readily splits into two valves to release the seed.

CYTOLOGY OF *RAPHANOBRASSICA*

Karpechenko (1927) reported completely normal chromosome pairing and division in euploid plants.

The cytology of a $2n = 36$ F_3 plant was studied by Howard (1938). Univalents, trivalents and quadrivalents were found at metaphase I, with some bridges formed at anaphase. At metaphase II, cells with seventeen and nineteen as well as eighteen chromosomes, were seen, suggesting that aneuploids might occur in the next generation.

Kondo (1942) produced *Raphanobrassica* from 4x *R. sativus* × 4x *B. oleracea* and found complete bivalent formation in euploid plants. A total of twenty-six plants were cytologically examined, twenty-four were euploids and two aneuploid with $2n = 35$ and $2n = 37$ chromosomes.

The cytological behaviour of F_1 *Raphanobrassica*, obtained from crossing tetraploid parents, was studied at SPBS. Thirty-three plants were examined, twenty-seven were euploid and six aneuploid, with $2n = 38$, $2n = 37$ and $2n = 35$ in one, two and three plants respectively. Meiosis in euploid plants was only slightly irregular, of 180 pollen mother cells examined, 161 (94 per cent) possessed only bivalents, the remainder contained seventeen bivalents and two, unpaired, univalents. Segregation of chromosomes, in the later stages of division leading to pollen production, was also fairly regular (McNaughton, 1973c).

STERILITY IN *RAPHANOBRASSICA* AND ITS POSSIBLE CAUSES

Some *Raphanobrassica* plants, obtained by Karpechenko (1927) were of fairly high fertility, yielding nine to ten seeds per capsule. A number of others were, however, of reduced fertility and some entirely sterile.

The most fertile F_3 plant reported by Howard (1938), produced four to five seeds per capsule, but most F_2 and F_3 plants were of extremely low fertility. Howard's most fertile F_5 plant produced eight seeds per capsule, suggesting that fertility could be increased by selection.

Several hypotheses for the causes of low seed fertility in *Raphanobrassica* have been put forward and these have been discussed by McNaughton (1973c) who concluded that the extremely low fertility of his F_1 plants was more likely to be the result of genetic inbalance than of cytological anomalies, which appeared to be of lesser significance. This conclusion was substantiated by Ellerström and Zagorcheva (1977).

At SPBS, normal, fully developed F_2 seeds were derived, at a very low frequency, on selfing or inter-crossing pollen fertile F_1 plants; in addition a much larger number (about 90 per cent of the total) of shrivelled, aborted seeds was obtained. Dissection of semi-ripe capsules revealed that many ovules contained embryos which aborted at various stages of development, undoubtedly due to endosperm deficiency. Similar results had earlier been reported by Howard (1938). These findings were substantiated by Ellerström and Zagorcheva (1977) which prompted them to investigate embryo development. A high frequency of unfertilised embryo sacs, which degenerated at various stages of development, was found. The frequency of unfertilised, aposporic embryo sacs decreased in succeeding generations, from 44·9 per cent in 1970 to only 2·9 per cent in 1975; this was paralleled by an increase in seed fertility from 0·07 to 2·27 seeds per pollination.

DEVELOPMENT OF *RAPHANOBRASSICA* AT SPBS

The objectives of the *Raphanobrassica* programme at SPBS have been to combine the vigour and disease resistance of fodder radish with the hardiness of fodder kale. In 1967 and 1968 a large number of *R. sativus* × *B. oleracea* crosses were attempted, at both diploid and tetraploid chromosome levels (see Figure 6 for methods of *Raphanobrassica* production). Hybrids were fairly readily produced at both chromosome levels, although at a lesser frequency when autotetraploid parents were used (McNaughton, 1973c). Reciprocal crosses, *B. oleracea* × *R. sativus*, were attempted on a small scale at both ploidy levels but no hybrids resulted.

Attempts to double the chromosome number of diploid hybrids met with little success and it was therefore decided to concentrate on producing *Raphanobrassica* by inter-crossing tetraploid forms of the parent species (tetraploid method).

The advantages and disadvantages of diploid and tetraploid methods of producing *Raphanobrassica* were discussed by McNaughton (1973c). The reasons for opting for the latter method are that, once the tetraploid forms of the parents have been established, *Raphanobrassica* can be created at a single step. Other advantages are that the tetraploid forms of *R. sativus* and *B. oleracea* may themselves be useful and that, if heterozygous 4x forms of the parents are used, the cross may produce heterozygous, genetically variable, *Raphanobrassica* from which to select forms of agricultural value.

Two disadvantages of the tetraploid method are that a porportion of chromosomally unbalanced, aneuploid plants are formed and that variation in characters, other than agronomically important ones (*e.g.*, flower colour) may result, posing problems of uniformity and stability.

In the earliest crosses at SPBS the parents were colchicine-induced tetraploid forms of currently available fodder radish cultivars, *e.g.*, Slobolt, and similarly doubled kales; thousand-head, curly kale and hybrids between these two botanical varieties. The intention was to create a gene pool of *Raphanobrassica* from which to select suitable agronomic types. Marrow-stem kale was not used, there being no tetraploid forms then available; it has, however, been a parent in more recent crosses.

The first F_1 hybrid *Raphanobrassica* plants were raised in the glasshouse; they varied considerably in morphology and vigour. About 20 per cent were stunted, chlorotic and deformed, some of these failed to flower. Many, otherwise normal and vigorous plants, produced no pollen, and some had reduced female organs. On selfing or inter-crossing vigorous pollen fertile plants, only 0·07 and 0·08 seeds per pollination were obtained, an average of approximately 0·2 seeds per capsule. The sterility of F_1 *Raphanobrassica* plants therefore posed acute problems. *R. sativus* (fodder radish) capsules normally contain eight to ten seeds, while *B. oleracea* has twenty-five to thirty-five seeds per capsule.

Capsules of F_1 and F_2 *Raphanobrassica*, together with those from *R. sativus*, *B. oleracea* and *B. napus*, were taken from plants at the open flower stage. Counts of the young ovules revealed that the average seed potential (full compliment of seed per capsule assuming no ovule abortion) was eighteen for *Raphanobrassica*, ten for *R. sativus* and thirty for *B. oleracea*. These results are consistent with those obtained at Svalöf by Ellerström and Zagorcheva (1977) who found averages of 17·6 and 18·0 in two different *Raphanobrassica* populations.

Progress towards improved seed fertility has been gradually achieved at SPBS by taking seed from the most productive plants from small polycross populations. In 1975, in which the hot, dry conditions were particularly suitable for seed production, individual F_5 plants, grown as above, produced very variable amounts of seed, but almost sixty grams of seed was obtained from the most productive plant. Plants from one plot yielded an average of twenty-five grams per plant.

In some seasons the indeterminate growth habit, which seems characteristic of *Raphanobrassica*, has been a problem. Considerable regrowth and continuous flowering can retard ripening of capsules resulting from earlier flowering, particularly in a cold, wet, late summer and autumn, such as occurred in 1976.

Environmental effects on seed fertility of *Raphanobrassica* had been noted earlier by Howard (1938). It seems obvious that, if *Raphanobrassica* is to become a crop plant, seed production, on a field scale, would require to be carried out under more favourable conditions than normally occur in Scotland, or possibly any part of Britain. Considerably improved seed production of Svalöf material was achieved from multiplication in Spain, as opposed to Sweden (S. Ellerström, personal communication).

In 1976 NSDO, Cambridge, carried out a glasshouse multiplication of an F_6 family, previously selected for high seed fertility and homozygosity of flower colour (white). From just over two hundred plants eight kilograms of seed was produced, an average of approximately forty grams per plant.

Several hundred kilograms of seed were produced, for trial purposes, by NSDO from a field multiplication at Cambridge, also in 1976. The amount of seed produced per unit area, however, was considerably less than would have been obtained from an established crop plant, such as rape.

The seed in the apical, indehiscible, *Raphanus*-like portion of capsules of *Raphanobrassica* is very difficult to extract. Several hundred capsules were examined at SPBS and about 15 per cent of the seed was located in this portion. Although this is a relatively small fraction it is obviously desirable in a plant, currently only partially fertile, to obtain as many seeds as possible. The use of special seed extraction machinery may be necessary if *Raphanobrassica* (for which the common name "radicole" is proposed) is to become a commercial proposition. The threshability of culinary radishes has been improved by selection (Banga *et al*, 1965), it may also be possible in *Raphanobrassica*.

RESISTANCE OF *RAPHANOBRASSICA* TO *PLASMODIOPHORA BRASSICAE* (CAUSING CLUB-ROOT DISEASE)

In 1972 sufficient seed was available to carry out *Plasmodiophora* resistance tests under controlled conditions. In a small experiment F_4 families proved to be resistant to race N3, *sensu* Johnston (1968), to which Nevin rape is susceptible (McNaughton, 1973b). N3 is equivalent to ECD –/31/–, *sensu* Buczacki *et al* (1975), *i.e.*, attacking all five *B. napus* differentials included in the ECD (European Club-root Differential) host set.

In experiments, carried out at NVRS, Wellesbourne, one *Raphanobrassica* F_6 family was immune to an artificially constituted inoculum, giving an ECD 31/31/31 reaction, *i.e.*, attacking all fifteen ECD hosts. Other families showed a high degree of resistance to this inoculum (S. T. Buczacki, personal communication), details are given by McNaughton (1978, in press).

RESISTANCE OF *RAPHANOBRASSICA* TO *ERYSIPHE CRUCIFERARUM* (POWDERY MILDEW)

Raphanobrassica has shown a very high resistance to powdery mildew in field plots at the Murrays, East Lothian, in 1974, 1975 and 1976. Twenty F_5 breeding lines were comprehensively examined in early sown plots at NIAB, Cambridge, in 1976 and proved highly resistant in comparison with adjacent swedes and rapes, which were severely infected. The leaves of a few *Raphanobrassica* plants showed hypersensitive reactions. Some prematurely flowering individuals were infected (G. R. Dixon, personal communication).

Plants over-wintered in a glasshouse for seed production by NSDO, Cambridge, were quite heavily infected in 1976. Some infection on flowering stems of plants in multiplication plots at SPBS has been noticed on occasions. There is little doubt, however, concerning the field resistance of *Raphanobrassica* when sown on normal dates as a forage crop.

YIELD POTENTIAL OF *RAPHANOBRASSICA*

The vigour of F_1 hybrids between *R. sativus* and *B. oleracea* and of *Raphanobrassica*, has already been referred to. The only report of actual yield assessment of *Raphanobrassica* appears to be that of Ellerström and Sjödin (1973) who found that, in a small, hand-sown trial, *Raphanobrassica* (with marrow-stem kale as a parent) outyielded the best Swedish marrow-stem kale, Tema, at each of three harvest dates. Superiority in dry matter yield ranged from 4 per cent to 75 per cent.

In 1975, thanks to a multiplication carried out in New Zealand by Dalgety Limited, sufficient *Raphanobrassica* seed was available for the first drilled, replicated trials of SPBS material. These were carried out at four sites: one in Northumberland, one in East Lothian and two in North Humberside. There were two sowing dates at each site (early July and early August). Dry matter yields and quality data are given in Table 17. Lair rape (a high-yielding variety), Nevin rape (with club-root resistance) and Ponda stubble-turnip were included as controls.

TABLE 17

Dry matter yield, *in vitro* digestibility (DOMD%) and crude protein content (CP%) of *Raphanobrassica* with rape and stubble-turnip controls

Variety	*DM yield (t ha⁻¹)* Site 1	Site 2	Site 3	Site 4	*DOMD % Mean of sites 1 & 2*	*CP % Mean of sites 1 & 2*
Early July sowing, 1975						
Raphanobrassica (RB4/A)	7·8	4·5	7·0*	4·7	77·2	18·3
Lair rape	6·1	3·4	4·6	4·1*	76·3	15·7
Nevin rape	5·7	3·0	3·5	3·3	77·6	16·7
Ponda stubble-turnip	7·2	3·1	4·0	4·4	77·7	13·4
Early August sowing, 1975						
Raphanobrassica (RB4/A)	3·3	1·3	2·1	1·2*	72·3	20·5
Lair rape	3·0	1·3	2·8	1·1*	72·7	19·5
Nevin rape	3·5	1·0	1·1	1·1*	74·4	20·0
Ponda stubble-turnip	5·3	2·0	3·4	3·7*	75·6	15·2

* Mean of three replicates only.

Results of these trials indicate that *Raphanobrassica* performs very satisfactorily, in terms of both yield and quality, from an early July sowing but much less so when sown in early August. It appears likely that *Raphanobrassica* should be considered as a substitute for rape, rather than for later sown catch crops, such as stubble-turnips.

In 1976 a *Raphanobrassica*, of basically similar origin to that tested in 1975, was sown at two sites, one near Ayr and one in East Lothian. Both trials were sown in early July and harvested in mid-November. Results are summarised in Table 18 and substantiate those obtained the previous year.

TABLE 18

Dry matter yield, *in vitro* digestibility (DOMD%) and crude protein (CP%) of *Raphanobrassica* with rape and stubble-turnip controls

Variety	*DM yield ($t\ ha^{-1}$)* Site 1	Site 2	*DOMD %* Site 1	Site 2	*CP %* Site 1	Site 2
Raphanobrassica (RB4/B)	5·2	5·6	77·6	77·5	25·8	23·7
Lair rape	4·8	4·3	76·0	75·7	20·9	23·0
Nevin rape	4·0	3·5	78·8	76·6	24·2	27·7
Ponda stubble-turnip	3·5	4·4	76·2	71·5	20·6	20·2

IMPROVEMENT OF *RAPHANUS* PARENTS FOR *RAPHANOBRASSICA* SYNTHESIS THROUGH INTER-SPECIFIC HYBRIDIZATION

A number of *Raphanobrassica* plants from the earlier crosses at SPBS flowered prematurely, a weakness undoubtedly inherited from the radishes used in their synthesis. There is obviously considerable scope for improvement in fodder radish, particularly in producing later flowering material.

Rigorous mass selection from Slobolt fodder radish resulted in a strain that showed some improvement over the cultivar in being about two weeks later to flower. This diploid selection was colchicine treated to produce a tetraploid which was even later to flower; in fact (1977 excepted) being virtually non-flowering if sown in late June or early July. This radish, recently named Crail, has been used in new crosses with *B. oleracea*. There seems, therefore, to be an effect of ploidy on flowering, the tetraploid being considerably later to flower than its diploid progenitor. A late-flowering plant, such as Crail radish, although having the advantage of being leafier for a longer period and more edible, is still basically an annual and frost susceptible. Lateness to flower, even from early sowing, creates problems of multiplication, seed sometimes failing to ripen before the onset of adverse weather late in the season.

Work is in progress at SPBS to produce leafy, biennial radishes as improved parents for *Raphanobrassica* synthesis and without the seed production problems inherent in late-flowering annuals.

In 1970, cuttings of the wild sea-radish (*R. maritimus*) were collected in the West of Scotland. The plants failed to flower until spring 1972 when they were crossed reciprocally with *R. sativus* Slobolt and with the late-flowering diploid selection, described above.

R. sativus and *R. maritimus* have previously been reported to hybridize and to possess the same number of chromosomes (Harberd, 1972), although morphologically very distinct in leaf, capsule and flower characters. Hybrids were very easily obtained from hand pollination with *R. sativus* as female, less readily from the reciprocal cross.

F_1 hybrids, together with their parents, were transplanted to the field in July 1973. Fodder radish plants flowered in the autumn and failed to survive the winter. F_1 inter-species hybrids proved leafy, vigorous and winter-hardy. Most sea radishes survived the winter but generally grew poorly; those that died probably did so because of the low salt content of the soil, since they are halophytic.

Meiosis in F_1 hybrids was examined, chromosome pairing in pollen mother cells was complete and segregation perfect (McNaughton, 1976). Pollen fertility was also very high, suggesting that there are no fertility barriers between the two species.

Colchicine-induced tetraploids of *R. sativus* × *R. maritimus* hybrids have been produced. Hybrids have been back-crossed to fodder radish at both 2x and 4x chromosome levels and selections for leafiness and hardiness made from their progenies, the main objective being to produce improved parents for *Raphanobrassica* synthesis. It is possible that leafy, biennial radishes may have some agronomic value in themselves.

Indirect Uses of Inter-specific and Inter-generic Hybridization or Cross Pollination

INTER-SPECIFIC TRANSFER OF SELF-INCOMPATIBILITY FACTORS AS AN AID TO HYBRID PRODUCTION

Considerable heterosis has been demonstrated in F_1 hybrids, obtained by inter-crossing different swede cultivars at SPBS; up to 25 per cent increases in dry matter yield over the better parent are possible. This estimate is based on a comparison of a number of F_1's, derived by hand pollination, with their respective parental cultivars (McNaughton and Munro, 1972). Gowers (1975) obtained similar results.

Swedes are predominantly self-fertilised (Josefsson, 1948) and possess no strong incompatibility system on which the commercial exploitation of hybrid vigour could be based. Natural forms of the closely allied rapes are also highly self-fertile. Some artificial forms of oil-seed rape, produced at Svalöf by inter-specific hybridization, were found to be self-incompatible (Olsson, 1960).

Panter, an artificial oil-seed rape obtained from Svalöf, has been used at SPBS in a programme directed towards the commercial production of F_1

hybrid swedes; three S-alleles (incompatibility factors) have been isolated from this source. One strong S-allele, which could be of value in a hybrid breeding programme, was found in artificial forage rapes derived by embryo culture. Three S-alleles were obtained from a spontaneously doubled, diploid *B. oleracea* × *B. campestris* hybrid, which occurred during an investigation into the possibilities of obtaining homozygous matromorphic kales, following inter-specific pollinations (Mackay, 1972).

Since most of the stronger incompatibility factors have been located in rapes, a complex back-crossing programme is necessary to incorporate them into commercially acceptable swede lines.

Heterosis in forage rape has been demonstrated (Johnston, 1971). The possibility of exploiting this vigour is suggested by the work of Mackay (1977b) at SPBS, who successfully introgressed functional S-alleles into *B. napus* (rape) from the out-breeding species *B. campestris*. Allotriploid hybrids ($2n = 29$, aac) were readily produced from the cross *B. napus* × *B. campestris* and on back-crossing these hybrids to *B. napus*, semi-artificial *B. napus*, with $2n = 38$, were obtained (see Figure 4). The thirty-eight chromosome seeds are generally larger than those with lower numbers and the selection of thirty-eight chromosome plants is facilitated by grading the seed.

The possibility of utilising F_1 inter-specific *B. napus* (rape) × *B. campestris* (turnips or oriental subspecies) hybrids has been investigated at SPBS. The allotriploids showed considerable heterosis (Mackay, 1973).

In order to produce allotriploid seed on a commercial scale it would be necessary to utilise the incompatibility system of one, or preferably both parents. Work on the production of self-incompatible *B. napus* is described above. The identification and isolation of *B. campestris* (turnips), homozygous for S-alleles, is described by Mackay (1977a).

THE DEVELOPMENT OF CYTOPLASMIC MALE STERILITY FOLLOWING INTER-SPECIFIC OR INTER-GENERIC HYBRIDIZATION

It has been observed that cytoplasmic male sterility frequently appears in the progeny of inter-generic and inter-specific crosses and may provide an alternative mechanism, to self-incompatibility, for the production of F_1 hybrids.

Pearson (1972) obtained the amphidiploid, *B. carinata* ($2n = 34$, bbcc), by colchicine treatment of hybrids between *B. nigra* ($2n = 16$, bb), black mustard, and *B. oleracea* (broccoli). By repeated back-crossing, using broccoli as the pollinator, the elimination of "b" genome chromosomes led to the production of plants having the *B. oleracea* genome in *B. nigra* cytoplasm. Sterility manifested itself in the complete absence of stamens, which were transformed to petals, and no nectaries were formed. Difficulties were apparent over the practical use of such "petaloid sterility" in hybrid production, insect pollinators being unlikely to visit flowers possessing neither pollen nor nectar, thus greatly reducing the seed producing potential of the petaloid line.

The artificial *B. carinata*, produced as a by-product of this work, was stated to be very fertile and vigorous and to have some potential as a forage plant (Pearson, personal communication).

Cytoplasmic male sterile *B. oleracea*, in which the anthers remained rudimentary, the plants being otherwise normal, was obtained from back-crossing a partially fertile *B. nigra* × *B. oleracea* hybrid (not colchicine treated) with *B. oleracea* pollen. The above two forms of cytoplasmic male sterility were transferred from broccoli into cabbage lines (Pearson, 1972).

Cytoplasmic male sterility has been discovered in Japanese radish (Ogura, 1968). Workers in France were successful in transferring this sterility to *B. oleracea* (cabbage, etc.). An F_1 hybrid, *R. sativus* × *B. oleracea*, was colchicine treated, resulting in the amphidiploid *Raphanobrassica*. Cytoplasmic male sterile *B. oleracea* was obtained after four generations of back-crossing *Raphanobrassica* to *B. oleracea* as male parent. Cytoplasmic male sterile *B. napus* plants were also produced, via 4x *R. sativus* × *B. napus* (2n = 56, rraacc) hybrids (Bannerot *et al*, 1974). The authors pointed out possible difficulties in utilising cytoplasmic male sterility in plant breeding, *e.g.*, disorders of floral organs other than absence of anthers and stamens.

The possibilities of utilising cytoplasmic male sterility in the production of oil-seed rape hybrids (the *B. napus* form) have been investigated (Heyn, 1976). For a seed crop to be produced restorer genes are essential. Test crosses, using a wide range of *B. napus* cultivars, resulted in male sterile hybrids only. Heyn considered it was highly improbable that restorer genes could be found in *B. napus* or the parental species, *B. campestris* and *B. oleracea*. Research indicated that a suitable restorer could be developed by successive back-crossing of cytoplasmic male sterile *B. napus* with pollen from a *Raphanus* × *Brassica* amphidiploid (2n = 56, rraacc) (derived by Bannerot *et al*, 1974).

INVESTIGATIONS INTO THE POSSIBLE USE OF MATROMORPHY FOLLOWING INTER-SPECIFIC AND INTER-GENERIC HYBRIDIZATION

Inbred lines may be of direct use in species tolerant of inbreeding, *e.g.*, in *B. napus* where uniformity within a swede cultivar is desirable to facilitate mechanical harvesting. Swedes have been shown at SPBS not to suffer from inbreeding depression, even after up to eight generations of selfing.

Inbred lines are obviously essential in the development of F_1, double-cross or triple-cross hybrids in predominantly out-breeding species, such as *B. oleracea*.

Some workers have assumed that matromorphic plants, which sometimes result following inter-specific or inter-generic crosses, are completely homozygous (Noguchi, 1928; Nishi *et al*, 1964; Röbellen, 1966). If this were so the benefits in producing "instant inbreds" would be of considerable value. The production of lines, by normal selfing methods, is a lengthy and laborious process involving five or six generations of inbreeding before a reasonable degree of homozygosity can be attained.

The possibilities for the use of matromorphy have been discussed by Mackay (1969) and by Eenink (1974a) who also gave a comprehensive review of the literature. Eenink (1974a) considered that, besides the level of homozygosity of matromorphic plants, their frequency, from any combination of parents, is important and he carried out a comprehensive series of inter-specific and inter-generic crosses to determine frequencies of matromorphs. The frequency varied considerably, the highest number of matromorphic plants being obtained from *B. oleracea* (cabbage) with *Eruca sativa* as pollinator (Eenink, 1974b).

In work at SPBS the frequency of matromorphs, which developed from a large number of crosses between *B. oleracea* (marrow-stem and thousand-head kales) and a range of *B. campestris* sub-species as pollinators, was very low (Mackay, 1969).

The influence of temperature, growth regulating substances, etc., on frequency of matromorphs has been investigated. Application of the growth regulator, GA3, increased the frequency (Eenink, 1974c).

Mackay (1972) found that the matromorphic *B. oleracea* plants, mentioned above, were heterozygous, since their progeny, derived by selfing, segregated for incompatibility factors (S-alleles) and for hairy first leaf. Hodgkin and Redfern (1971) found matromorphic *B. oleracea* (Brussels sprouts) to be heterozygous for incompatibility factors. Eenink (1974d) concluded, from a study of means and variances of several morphological characters of matromorphic Brussels sprouts and cabbage plants and their progenies, that matromorphs were not homozygous.

As previously mentioned, a large number of crosses have been made at SPBS between *B. napus* (swedes and fodder rape) and *R. sativus* (fodder radish) in attempts to obtain inter-generic hybrids (2n = 28, rac). From *B. napus* as female parent a very few hybrids have been obtained, these were derived only from extremely small seeds. Most of the seed resulting from these pollinations was normal sized and gave rise to plants closely resembling the female parents, *i.e.*, matromorphs.

The importance of uniformity in swedes has already been referred to. Since radish pollen had been shown to be an effective inducer of matromorphic swede plants, it was decided to examine this possible quick method of obtaining homozygosity. F_1 hybrid swedes, obtained from crossing cultivars differing in skin colour, were used as female parents with radish pollinators. The resultant matromorphic plants segregated for skin colour on selfing and were, therefore, not homozygous.

Main Conclusions

Improvements in *B. napus* (rape and swedes) can be made by the introduction of desirable characters from the parent species; *B. campestris* (the turnip group) and *B. oleracea* (the kale group).

It is doubtful whether artificial forms of *B. napus* have agronomic potential in themselves. They are probably best regarded as bridges whereby characters can be introgressed into existing cultivars. Desirable characters include *Plasmodiophora* resistance from *B. campestris* (stubble-turnips) and, in rape, improved stem edibility from *B. oleracea* (marrow-stem kale).

The potential of allotriploid *B. napus* × *B. campestris* hybrids as crop plants *per se* would seem to depend on developing strongly incompatible lines of both parents.

The hexaploid, *B. napocampestris*, does not seem to have any potential as an oil-seed crop nor as a root or leafy forage crop. It may be used as a bridge in transferring useful factors from *B. campestris* into *B. napus*, but there are less involved methods.

Improvements in *R. sativus* (radish) have been made by the introgression of characters from *B. oleracea*, following inter-generic hybridization at the diploid chromosome level.

The amphidiploid, *Raphanobrassica*, shows considerable potential as a new crop plant, in being resistant to *Plasmodiophora* and *Erysiphe*, both of which are problems with *B. napus* crops. It has also shown yield superiority over leading commercial forage rapes. Difficulties remain with regard to seed fertility, which is not yet at a commercial level.

Leafy, biennial inter-species radish hybrids, developed as improved parents for *Raphanobrassica* synthesis, may have some potential in their own right.

Self-incompatibility factors have been successfully transferred from one species to another, *i.e.*, from *B. campestris* into *B. napus*. This may facilitate the commercial production of hybrid swedes and forage rapes in the future. Difficulties have been encountered in the use of cytoplasmic male sterility, induced following inter-specific hybridization. It may, however, be feasible to use cytoplasmic male sterile plants for hybrid production in the future.

Matromorphic plants, induced following inter-specific hybridization, probably have no potential in plant breeding since most of the evidence points to their being heterozygous and not homozygous.

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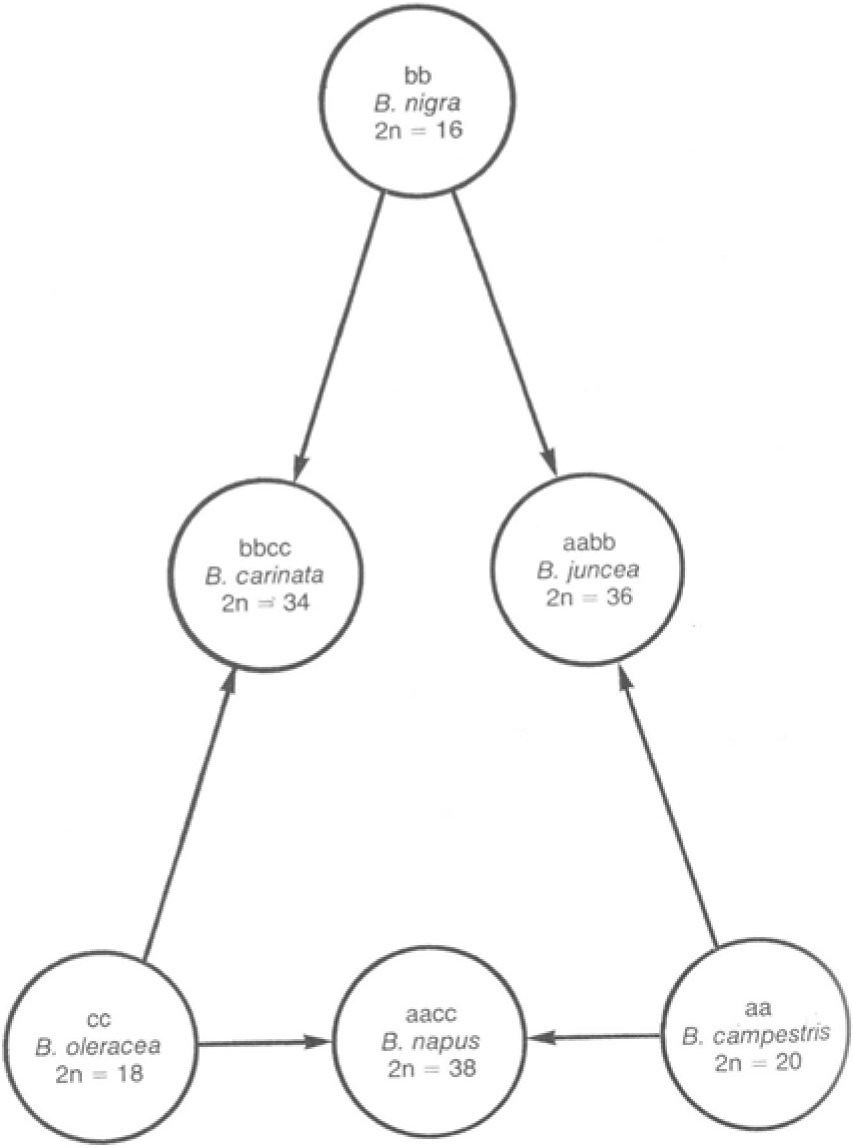

Figure 2. Species Relationships in the genus *Brassica*.

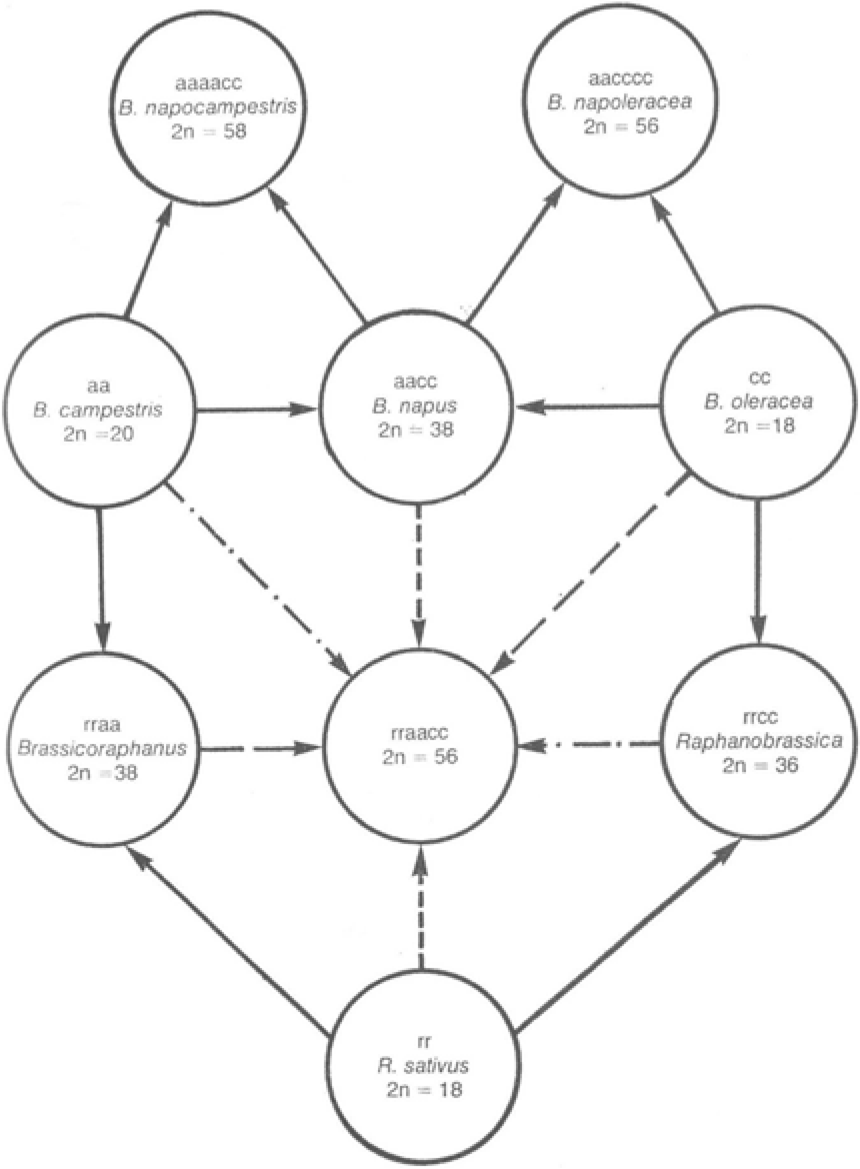

Figure 3. Species Relationships and Amphidiploid production in *Brassica* and *Raphanus*.

Three ways in which genotype rraacc can be derived are indicated thus:

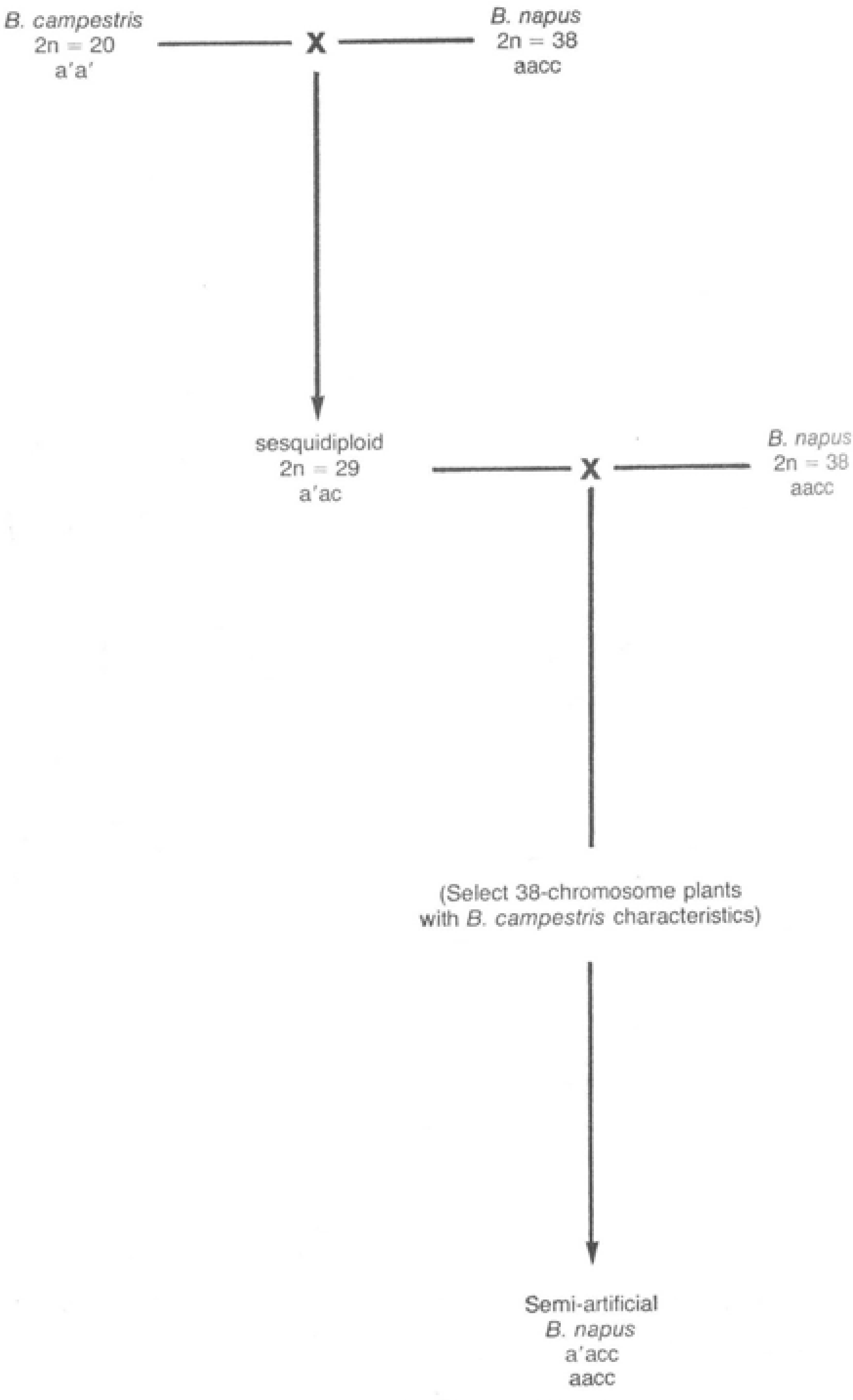

Figure 4. Introgression from *B. campestris* into *B. napus*.

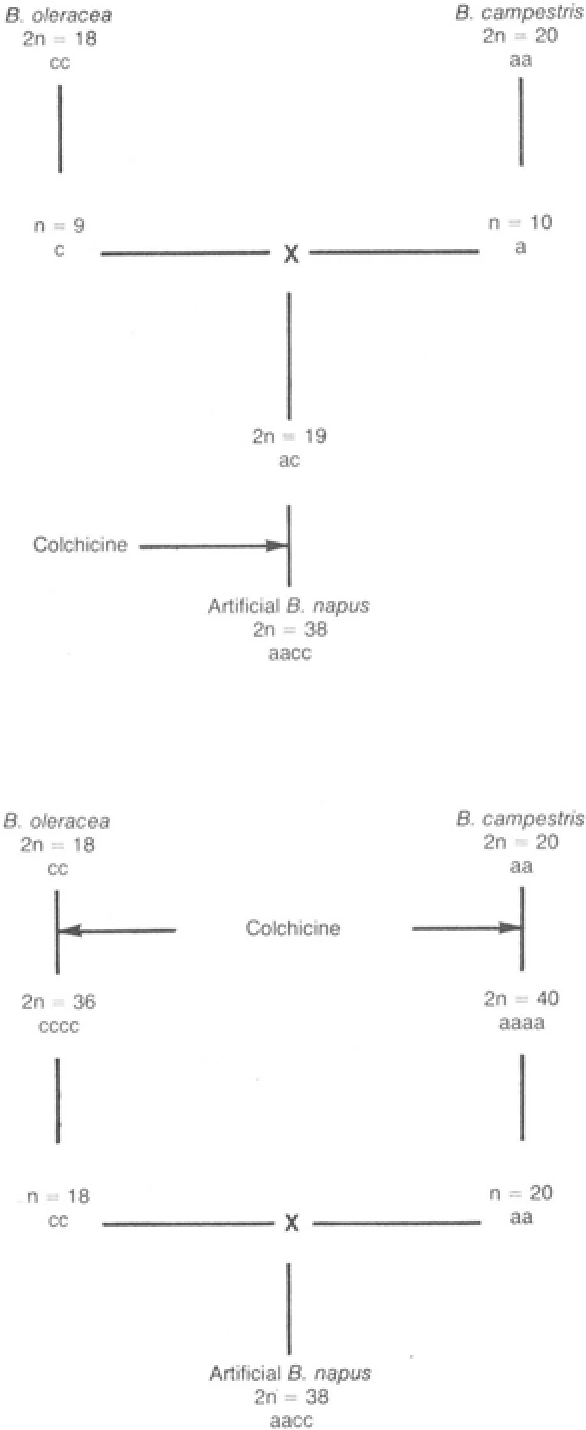

Figure 5. The Diploid (upper) and Tetraploid (lower) methods of synthesising artificial *Brassica napus*.

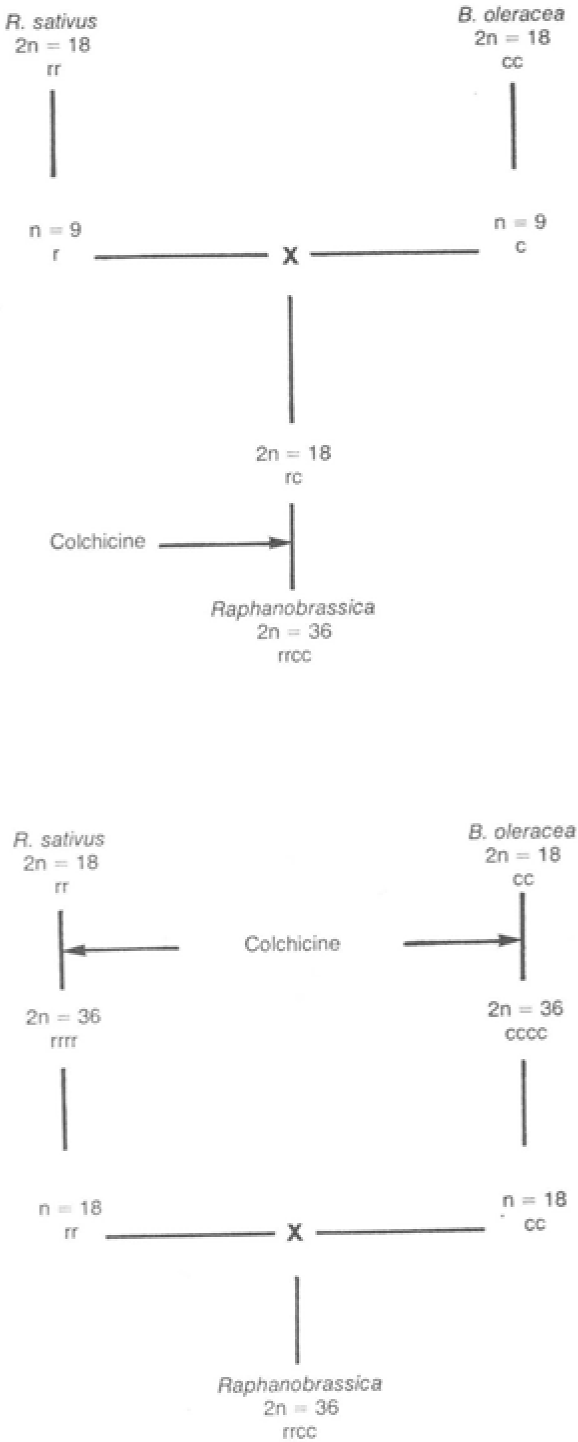

Figure 6. The Diploid (upper) and Tetraploid (lower) methods of synthesising *Raphanobrassica*.

VARIETIES BRED BY THE STATION

The following are commercially available in Britain:

Stubble-turnip
Appin
Ballater

Horticultural kale
Pentland Brig

Oats
Etive*
Leven*

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

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 Pentland Brig, which is a garden variety producing succulent leafy young shoots in early spring, is also in the hands of NSDO. Varieties marked † are on the NIAB Recommended List.

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

Oats Fyne Earn

PUBLICATIONS

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THOMAS, W. T. B. (1977). Variation in wild populations of *Papaver dubium* XII. Direction of dominance during development. *Heredity*, **39**, 305-312.

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
* Rowett Research Institute	Bucksburn, Aberdeen AB2 9SB
* Scottish Horticultural Research Institute .	Invergowrie, Dundee DD2 5DA
* Scottish Institute of Agricultural Engineering	Bush Estate, Penicuik, Midlothian EH26 0PH
Scottish Plant Breeding Station . . .	Pentlandfield, Roslin, Midlothian EH25 9RF

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

REPORT

to the

FIFTY-SEVENTH ANNUAL GENERAL MEETING

of

THE SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING

27th July 1978

by the

BOARD OF DIRECTORS

BOARD OF DIRECTORS

Trustees

H.M. SECRETARY OF STATE FOR SCOTLAND, Scottish Office, New St Andrew's House, Edinburgh EH1 3TB.
JOHN ARBUCKLE, O.B.E., Barony Cottage, Newburgh, Fife KY14 6HL.
W. ANDREW BIGGAR, O.B.E., M.C., B.Sc., F.R.Ag.S., Magdalene Hall, St Boswells TD6 0EB.
G. B. R. GRAY, Smeaton, East Linton, East Lothian.
JAMES GRAY, O.B.E., T.D. (James Gray & Co. (Stirling) Ltd.), Stirling FK8 2DQ.

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

1975

JAMES D. G. DAVIDSON, M.V.O., M.I.Ex., Royal Highland and Agricultural Society, Ingliston, Newbridge, Midlothian.
Mrs B. A. GORDON, B.Sc.(Agric.), Rosefarm, Cromarty.
G. B. R. GRAY, Smeaton, East Linton, East Lothian.
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.

1977

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

Directors Co-opted

O. T. GRIFFIN, B.Sc., Balnafoich, Dores, Inverness-shire.
G. A. STORRAR, M.C., B.Sc., J.P., Rossie, Auchtermuchty, Fife.

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

Professor G. R. DICKSON, B.Sc.(Agr.), Ph.D., F.I.Biol., School of Agriculture, The University, 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.

J. M. TODD, 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.
G. CLAPPERTON.
J. D. G. DAVIDSON.
W. H. M. GILL.
G. B. R. GRAY.
O. T. GRIFFIN.
J. B. D HERRIOTT.
Sir DAVID LOWE.
Sir MAURICE YONGE.
VICE-CHAIRMAN (*ex officio*).

RESEARCH COMMITTEES

Brassicas

J. B. D. HERRIOTT, *Convener.*
G. CLAPPERTON.
A. J. CLARK.
Prof. G. R. DICKSON.
W. H. PORTER.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

Cereals

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

Potatoes

W. H. M. GILL, *Convener.*
J. M. FELL.
Mrs B. A. GORDON.
J. McFARLANE.
J. M. ROY.
C. D. SCOTT.
G. A. STORRAR.
J. M. TODD.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

Farm Advisory

G. CLAPPERTON, *Convener.*
J. McFARLANE.
A. PATTULLO.
C. G. SPENCE.
G. A. STORRAR.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

ADMINISTRATION

Membership

At 31st March 1978 the total membership was 325, comprising 226 Life Members and ninety-nine Annual Members. Fourteen New Members were elected during the year and six died or resigned.

Meetings

The Board met four times during the year, on 7th April 1977, 9th June 1977, 21st July 1977 and 17th November 1977.

The Finance Committee met on 9th June 1977.

The Brassica Research Committee met on 27th October 1977.

The Cereals Research Committee met on 7th April 1977 and 7th July 1977.

The Farm Advisory Committee met on 5th May 1977 and 8th December 1977.

The Potato Research Committee met on 4th November 1977.

Board of Directors

The Board welcomed, on election for the first time, Mr A. J. Clark and Mr G. H. Millar.

Finance

The Abstract of Audited Accounts on pages 140-147 reveals the Society's financial position at 31st March 1978. The cost of the research programme at the Scottish Plant Breeding Station was met by a maintenance grant of £802,000 from the Department of Agriculture and Fisheries for Scotland. Sundry items of income at Pentlandfield amounted to £2,382. The unspent balance of the grant was £480 which has been added to unspent balances from previous years, increasing them to £32,023.

DAFS Grants were received to cover Capital Expenditure at Pentlandfield; these totalled to £152,401, with £32,676 being spent on equipment and £119,725 on building and works. The main items being the completion of the temporary buildings and alterations to the West Wing which has alleviated over-crowding, improving the coal-fired heating system, and the provision of four controlled environment rooms.

The Department also approved the expenditure of £46,607 at the Murrays to provide additional storage space, temporary office accommodation plus a meeting room and to complete the glasshouse. The potato store was fitted with a new roof and walls were rendered to match in with the other farm buildings. In addition, further improvements were made to the field drains and roads. 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 Directors

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

JAMES D. G. DAVIDSON, M.V.O., M.I.Ex., Royal Highland and Agricultural Society, Ingliston, Newbridge, Midlothian.

Mrs B. A. GORDON, B.Sc.(Agric.), Rose Farm, Cromarty.

JAMES MCFARLANE, Kaimes, 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.

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

M. DOUGLAS HENDERSON, Carse Farmhouse, Aberfeldy, Perthshire PH15 2JQ.

W. S. KING, Tignadarroch, Pencaitland, East Lothian.

A. GORDON PORTER, East Scryne, Carnoustie, Angus.

J. RICHARD ROBERTSON, Gallery, Montrose, Angus.

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

FIFTY-SIXTH ANNUAL GENERAL MEETING

MINUTE OF PROCEEDINGS AT THE FIFTY-SIXTH ANNUAL GENERAL MEETING OF MEMBERS OF THE SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING, held at Pentlandfield, Roslin, Midlothian, on Thursday, 21st July 1977.

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

Minute. The Minute of the 55th Annual General Meeting, held at the Scottish Plant Breeding Station on Thursday, 22nd July 1976, having been circulated prior to the meeting, was taken as read and was approved and signed.

Apologies. Apologies for absence were intimated by the Secretary.

Annual Report and Accounts. The 56th Annual Report of the Directors embodying the audited accounts for the year ended 31st March 1977 which had been distributed to members before the meeting was submitted by the Chairman.

After a brief speech the Chairman moved and Mr W. Andrew Biggar, O.B.E., M.C., B.Sc., F.R.Ag.S., Magdalene Hall, St Boswells, TD6 OEB, seconded the adoption of the Report and Accounts and the motion was carried unanimously.

Election of Trustee. The Chairman informed the meeting that Mr R. L. Scarlett had, for health reasons, resigned as a Trustee of the Society. He went on to say that Mr Scarlett had, over the past forty years, been an enthusiastic member of the Society and that he was extremely sorry Mr Scarlett had given up this last active link with the Board.

In response to the Chairman's call for nominations for a Trustee, a motion by Mr James Gray, O.B.E., T.D. (James Gray & Co. (Stirling) Ltd.), Stirling FR8 2DQ, seconded by Sir David Lowe, C.B.E., D.Sc., F.R.S.E., F.R.Ag.S., Elvingston, Gladsmuir, East Lothian, was unanimously adopted to elect Mr George B. R. Gray, Smeaton, East Linton, East Lothian, a Trustee of the Society.

Election of Directors. A motion by Mr D. A. J. Randall, The Miln Marsters Group, King's Lynn, Norfolk, seconded by Mr J. McFarlane, Kames, East

Mains, Leitholm, Coldstream, Berwickshire, was unanimously adopted to elect to the Board of Directors the following members:—

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.), 60 Bogie Street, Huntly, Aberdeenshire.

Appointment of Auditors.

On the motion of the Chairman, seconded by Mr C. G. Spence, Biel, Dunbar, East Lothian, Messrs Brown, McDonald and Fleming were re-appointed Auditors of the Society.

This concluded the business of the meeting.

In the informal part of the meeting, the Chairman in his address to members paid tribute to the late Dr George Cockerham, B.Sc., Ph.D. He said that Dr Cockerham, who was a pioneer of potato virology, had spent a lifetime working for the Society. He had been an eminent scientist and the Station would continue to benefit from his contribution to potato science for many years to come.

The Chairman then welcomed the Director, Dr Macer, to his first Annual General Meeting of the Society and said that he was confident that the Station would make a significant contribution to agriculture under Dr Macer's direction. He went on to thank Dr J. H. W. Holden, who with support from Mr R. N. H. Whitehouse and Mr H. C. M. McLeod, had been acting Director during the interim period between Professor Simmonds leaving and Dr Macer taking up his post.

Mr Arbuckle then referred to the report of the 1975 Visiting Group and said that most of the recommendations and suggestions put forward by the Group had been put into effect. However, as a new Director has been appointed at the Station, and in line with established practice, another Group will visit the Station in 1978, probably during the summer.

The Chairman then spoke of the outcome of the Rationalisation discussions that had taken place between DAFS, ARC and the three Directors of the Plant Breeding Stations in England, Wales and Scotland.

He said that grass breeding at Pentlandfield would cease immediately and that the Welsh Plant Breeding Station would be responsible for producing new varieties of grass suitable for Scotland. DAFS Scientific Services at East Craigs and the Hill Farming Research Organisation would evaluate the new grass material from WPBS. SPBS has had an interesting and successful grass breeding programme from which the Scotia varieties were released and more varieties will possibly be developed from the advanced material. However, the SPBS programme was small and specialised and as grass breeding is a complex, difficult and costly exercise demanding many resources both for breeding and evaluation, he felt sure that Scotland would benefit from the new arrangements and the facilities available at Aberystwyth.

The resources released from grass breeding would be used to strengthen other areas of the Station's activities, particularly the exciting developments in Brassicas.

Mr Arbuckle said he was aware that some members would be concerned at the results of the rationalisation discussions, but he wished to reassure them that "Rationalisation" had not been used as a cloak for contraction. It had been used properly to ensure that the resources available under the present difficult financial situation would be used to the best and fullest advantage of agriculture.

On referring to the Potato Research Programme, the Chairman said that another new variety "Croft" had emerged. This variety has been included in the NIAB recommended list and although it has a harvest yield slightly lower than Pentland Crown, Mr Arbuckle hoped that it would be a successful variety.

The Chairman in thanking his fellow Directors for their continued support said that the Research Committees had performed a useful role. They had monitored the research work of the Station and ensured that it responded to the changing needs of Scottish Agriculture and to the reports of the JCO Boards. A great deal of work had been done and now was the time for consolidation. The Research Committees would continue but as with the activity of the JCO Boards and Committees, on a reduced scale in the immediate future. Because of the ending of grass breeding the Grass Research Committee would be wound up.

Mr Arbuckle thanked DAFS for the continued generous financial support and for the responsive and receptive manner that they adopted to the needs of the Society.

The Chairman concluded by praising the staff for their excellent efforts during the past year.

Dr Macer said that it was an honour to serve the Society as Director and his efforts would be directed to improving the productivity and stature of the Station. He then went on to outline what he considered to be four important points on plant breeding:

1. Plant Breeding is the only applied science that can be used to lift the ceiling of productivity of crops either by improving existing varieties or by introducing new varieties. Irrigation, drainage, fertiliser, herbicide and fungicide technology, for example, only allow the existing genetic potential of crops to be more nearly reached.

2. Successful Plant Breeding depends upon:—

(*a*) carrying out the work on a large scale, it is in part a numbers game; and (*b*) maintaining an adequate level of support science to provide an input of the basic sciences to enlarge the pool of information available to the breeders (genetics, cytology, chemistry, pathology and statistics).

3. Plant Breeding is a very long-term process requiring ten to fifteen years to produce a new variety of most species and twenty to twenty-five years to extract all the potential from a comprehensive breeding programme. It cannot, therefore, thrive in an unsettled environment or stop-go situation.

4. Plant Breeding depends on the dedication, enthusiasm and persistence of the breeders, over many years, and through many periods of doubt and depression as a result of the biological hazards (pest and diseases particularly) that can cause severe problems, of difficulties with trials and with the weather, of the introduction of new regulations, or the changes in the needs of the industry or its ability to appreciate the end product.

Nevertheless in both the public and the private sectors, Plant Breeding has flourished over the past four decades. It has played a major part in the great increases in productivity that has occurred in the arable crops of the United Kingdom and of the world.

Dr Macer then reviewed the effect of rationalisation on the research programme of the Station.

Grass: Grass breeding would be stopped much more quickly than originally anticipated and the resources released from this work used to strengthen the Brassica, Cereal and Agronomy Departments.

Cereals: The oat programme will be renewed to produce a combinable disease-resistant oat suitable for use in Scotland and in the North of England with appropriate quality characteristics. The barley programme will also be expanded to embrace the needs of Scotland and of the North of England for both feeding and specialised quality varieties. There will be no breeding programme on wheat but there would be an expansion of the testing of material developed at sister Stations. This will also apply to field beans.

Potatoes: Pentlandfield will become the centre of excellence for potato breeding with a corresponding build up of the necessary support sciences as and when funds will allow.

Brassicas: The transfer of resources from grass was the start of the anticipated build up into a UK responsibility for kale, fodder roots and the new products of the *Raphanobrassica* programme. Dr Macer said he thought that there was great potential in these crops and that there would be exciting developments in the not too distant future. He went on to thank the staff who had made fundamental changes in their work by transferring to brassica from grass.

Agronomy: This was a new department under Dr F. J. W. England, who had transferred from grass. It was essential to provide the proper environment to enable successful field trials to be carried out. The Agronomy Department will develop and improve the existing trialing system, at the Murrays, Pentlandfield and at our off-Station sites to ensure that trials are carried out under the best possible conditions.

Plant Exploration: This unit, which initially was intended to investigate the potential of new crops, will cease to operate and the resources released will be used to assist the Station to pursue its main strategic research objectives and its variety production programme. However, a watching brief will be maintained to ensure that potentially valuable crops are not overlooked.

The Director then spoke of the improvement that was being made both to the main office/laboratory block and by the provision of temporary buildings. He appreciated that there had been interruption of work and some inconvenience but in the long term this additional space and modernisation would be of great benefit to all the staff. He went on to thank DAFS for providing the funds for these improvements and for the additional equipment that had been purchased during the year. He also asked Mr Lyall to accept his personal thanks and also to convey to his colleagues in Chesser House, Dr Macer's appreciation for the helpful and considerate attention that they had given to him as a new Director.

In concluding, Dr Macer thanked Mr Whitehouse and Mr Glendinning for the work that had been done in producing the 1976-77 Annual Report.

Mr G. G. Lyall of the Department of Agriculture and Fisheries for Scotland in his address to the meeting intimated apologies for Mr J. I. Smith and Mr W. W. Gauld who, because of pressure of work, had been unable to be present. Mr Lyall went on to congratulate Dr Macer on his appointment and said it was refreshing to see problems being attacked by Dr Macer with such "vim and vigour". He went on to say that DAFS had tried to be helpful, they had allowed the complement of the Station to rise with four additional posts (these were the only new posts in SARI during 1976-77), and in addition to the Maintenance Grant had provided £100,000 for Capital Works Expenditure.

Mr Lyall then spoke of his interest in potatoes, which had stemmed from his previous post in the Plant Health Section of the Department. He said that potato growers, although looking for increased yields, were also aware of the need for better quality and greater resistance to pest and disease. He was, therefore, hopeful that the new variety "Croft", which although somewhat lower yielding than Crown, would be successful because of its improved quality and disease resistance. He went on to say that after reading Dr Holden's review article in the Annual Report he was sure that the potato programme would continue to provide new and successful varieties.

A vote of thanks to the Chairman proposed by Mr W. H. M. Gill brought the proceedings to a close.

The Eighth SSRPB Lecture:

STRATEGIES IN HERBAGE PLANT BREEDING

Delivered on the 13th April 1978, by

Professor J. P. COOPER, Ph.D., D.Sc., F.R.S.

Director of the Welsh Plant Breeding Station

Some 60 per cent of the cultivable land in Britain is in grass, while a further one-third of the total land area consists of hill and upland grasslands. The production of utilised energy for livestock from grasslands in Britain increased by over 25 per cent between 1965 and 1974, as a result of improved management, particularly increased fertiliser inputs and stocking rates, and improved herbage varieties to reach a value in terms of ruminant production in 1974-75 of over £1,100 m. Even so, there remains a considerable gap between the maximum levels of production achieved from intensive grassland systems and the average production for the whole country, and a continuing need for improved varieties for both intensive and less intensive systems.

In assessing his future objectives and strategy the breeder must therefore consider the present and future requirements of different grassland systems, bearing in mind that it takes fifteen to twenty years to produce a herbage variety, the sources of genetic variation available, and the techniques of selection and breeding to satisfy these requirements.

BREEDING OBJECTIVES

Most well-established herbage varieties used in Britain, from Aberystwyth and elsewhere, are based largely on an ecological approach which made considerable use of the selective effects of past farming managements in producing locally adapted ecotypes. Potential breeding material of both grasses and legumes was obtained from productive and persistent old pastures or meadows or from adapted local varieties. S.23 perennial ryegrass and S.184 white clover for instance, were based on plants collected from old pastures in Kent and the Midlands of England, and S.123 red clover on the productive local varieties Cornish Marl and Montgomery Red. These initial collections of breeding material were screened as single spaced plants for such characteristics as seasonal production, time and extent of flowering, habit of growth, persistency, degree of leafiness and freedom from disease. The potential parents selected in this way were then progeny-tested often using a polycross technique, and a smaller number selected to form the basic plants of the variety.

In view of the out-breeding and self-incompatible nature of most of the herbage species dealt with, a new variety had to be based on several unrelated parents to avoid the dangers of inbreeding, and subsequent multiplication under isolation was necessary.

This basically ecological approach made it possible to develop a range of improved varieties varying in habit of growth, time and extent of flowering and persistency in most of the important grass and legume species and a similar approach based on productive local material has been used successfully by herbage plant breeders in other parts of north-west Europe. This use of indigenous species or introductions from similar environments elsewhere has formed the basis of the forage breeding programmes in other parts of the world also. Much of the development of varieties of cocksfoot, ryegrass, white clover and subterranean clover for southern Australia for instance, has been based on material introduced from the Mediterranean region, while the breeding programme for sub-tropical grasses and legumes for the more northern parts of Australia has relied heavily on collections from elsewhere in the sub-tropics.

The varieties developed in this way were selected against a farming background of low-medium fertiliser inputs and stocking rates, but many of them have proved highly productive under more intensive systems of management. Current and future changes in grassland farming systems, however, are already demanding additional features in both grass and legume varieties. For more intensive grazing systems for instance, we need varieties adapted to high stocking rates and high nitrogen inputs and for intensive conservation, Italian or hybrid ryegrasses which are persistent for up to three years. For long-term conservation more perennial varieties are required possibly of tall fescue or fescue-ryegrass hybrids. For lower input systems, the development of clover varieties which are competitive with grass at moderate inputs of nitrogen is needed, while improvement of the hills and uplands requires both grasses and clovers capable of growing actively at lower temperatures and under poorer soil conditions.

Looking further ahead, legumes deserve more serious consideration for both intensive and extensive systems because of their nitrogen-fixing ability and also their greater nutritional value relative to grass. In this connection, studies on variation in the effectiveness of different *Rhizobium*/legume associations are important, in order to develop material with improved nitrogen fixation, particularly for the hills and uplands.

Quite apart from the requirements of new grassland systems, recognition of the high potential production of current grass and legume varieties under optimum environmental conditions has focussed attention on the possibility of breeding for improved resistance to or tolerance of such limiting factors as seasonal climatic stress or disease which limit the achievement of this potential. The importance of nutritive quality has also drawn attention to the possibility of genetic improvement in such nutritional features as digestibility, protein and mineral content and those ill-defined characteristics which determine voluntary intake. Finally, good seed production is essential in ensuring that an improved variety is readily available to the farmer; adequate pollination and seed production still present problems in both red and white clover. Many of these new requirements involve a search both for new sources of genetic variation and for the development of new selection criteria.

GENETIC RESOURCES

The search for new genetic resources has again followed an ecological approach, in that plant collecting expeditions have been sent out to those regions where past climatic or agronomic selection might be expected to favour the characteristics required in the breeding programme. In terms of climatic adaptation, for instance, collections from the Mediterranean region and south-west Europe, where winter is the usual growing season, usually show the capacity for early spring growth at comparatively low temperatures, while continental or Scandinavian material is winter-hardy but shows a degree of winter dormancy. Similarly, certain collections of cocksfoot from coastal areas in Spain and Portugal show increased efficiency of water use under drought conditions, as well as a number of important nutritional characteristics.

In terms of past agronomic selection, collections of Italian ryegrass from irrigated areas in the north of Italy which have been used for zero grazing for several centuries show extremely rapid regrowth after cutting and are well adapted to intensive conservation systems, while both grasses and clovers from intensively managed pastures in Britain prove to be adapted to high nitrogen inputs and intensive treading by livestock.

In some cases, the material from these collections can be used directly after preliminary screening and characterisation. Certain cocksfoot collections from north-west Spain, for instance, show valuable grazing characteristics and have formed the basis of the new varieties Cambria and Conrad. Similarly, the tall fescue varieties, Dovey and Conway, are derived from collections from southern France, and the white clover variety Sabeda from material from Normandy.

In many cases, however, the plants collected possess both desirable and undesirable characteristics. The lack of winter hardiness in much of the early-growing Mediterranean material has already been mentioned, and the Italian ryegrass collections from north Italy, while possessing very rapid regrowth after cutting, also suffer from seed shattering and are rather susceptible to rust and other leaf diseases. Similarly, the efficient water use and improved nutritive quality of some of the Iberian cocksfoots is often associated with lower overall production. In such cases, hydridisation with adapted British varieties of the same species may provide a practicable solution. In white clover, for instance, the new variety Katrina with a longer growing season is derived from crosses between the indigenous Kersey and introduced material from Israel and Turkey.

In yet other cases, all the characteristics required in a new variety cannot be found within the same species, and can only be combined by interspecific hybridisation. This requires a knowledge of the cytotaxonomic relationships between the two potential parents, particularly where they form part of a complex polyploid series as in the *Festuca-Lolium* group and various techniques of chromosome manipulation may be necessary in order to combine the required characteristics in a new stable form. A successful example of such inter-specific hydridisation has been the development of stable tetraploid hybrids, such as Sabrina and Augusta, between the two diploids, Italian and perennial ryegrass, which combine the rapid early growth of the Italian parent with a greater degree of persistency from the perennial. Similar stable allo-polyploids have been produced between the diploid meadow fescue and perennial and Italian ryegrass and are at present in National List Trials. Similarly, in cocksfoot, it has proved possible to introduce improved winter growth from the wild Portuguese diploid species *Dactylis lusitanica* into the cultivated tetraploid following initial chromosome doubling of the diploid to produce the varieties Saborto and Calder.

The combination of characteristics from higher polyploid species presents greater problems. Although hybrids between the diploid Italian or perennial ryegrass ($2n = 14$) and the hexaploid tall fescue ($2n = 42$) can be obtained without too much difficulty and the hybrid like its tall fescue parent shows promise as a long-term conservation grass the necessary genetic stability and adequate seed production has not yet been achieved. Similar problems of genetic stability may arise in the use of wide hybrids of *Poa* species for hill and upland conditions, but here stability may be obtained by the introduction of apomixis.

The genetic material from these plant collections, whether used directly as the basis of a new variety or as parents in more complex hybridisation programmes, has already provided a number of new varieties for the farmer. In utilising this material, however, particularly when developing wide inter-specific crosses, the importance must be realised of establishing a sufficiently large gene pool from which to select, of assessing performance in the sward at as early a stage as possible and of checking carefully on stability during seed multiplication.

SELECTION CRITERIA

The usual assessment of breeding material of grasses and legumes has been based on those characteristics which could be readily scored on spaced plants growing in the field. More sophisticated selection criteria are now being developed, based on our increased understanding of the features of the crop which determine its efficient use of the environmental inputs of light energy, water, CO_2 and soil nutrients, and also its resistance to the climatic limitations of temperature and water stress. In addition, since herbage crops are grown as feed for farm livestock, the identification and improvement of those nutritional characteristics which determine efficient intake and conversion by the ruminant are also important. It is now becoming possible to identify several of these physiological or biochemical features which influence plant and animal production, and to develop rapid and reliable screening tests for use in the breeding programme.

Crop photosynthesis: In grassland, as in other crops, the basic climatic limitation to production is the seasonal input of light energy though the conversion of this light energy can be limited by other environmental constraints. The *gross* photosynthetic production of the crop depends on the photosynthetic activity of the individual leaves and on their arrangement in the crop canopy in relation to light interception, but the *net* photosynthesis, as reflected in the harvestable yield, is also influenced by the degree of respiratory loss, which in the grass crop can amount to 50 per cent or more of the initial carbon fixed. Genetic variation has been detected in the ryegrasses for all these photosynthetic components, but selection for maximum photosynthetic rate per unit of leaf area has had little or no effect on the productivity of the plant or the crop, possibly because of an inverse correlation between leaf size and photosynthetic rate per unit area of leaf. On the other hand, selection for longer and more erect leaves, which allow the incoming light to be spread over a greater leaf area, can increase crop photosynthesis particularly during the hight light intensities of summer, and selection lines for this characteristic are already showing improved production in field trials.

The reduction of respiratory losses is another promising approach. Although much respiration is coupled with active growth processes, it has proved possible in perennial ryegrass to select for a lower maintenance respiration, and thereby increase the crop growth rate in the field, particularly during the high temperatures of summer, giving an annual increase of up to 1,000 kg ha^{-1} dry matter in field plot trials.

Climatic stress: Although the *potential* production of the crop is markedly influenced by many of the above photosynthetic or respiratory characters, in practice, the achievement of this potential (up to 20-25 t ha^{-1} harvestable dry matter) is usually limited by the climatic constraints of winter cold and summer drought, by disease or pest attack or by the shortage of soil nutrients, particularly nitrogen.

Adequate winter hardiness is an essential feature in any grass variety, particularly for use in the north and east of Britain. The most obvious selection technique, that of assessing the survival of spaced plants growing in the field, presents certain problems, however; only one cycle of assessment can be carried out each year, and the unpredictability of winter conditions in Britain means that the breeder may well have to wait for several years before obtaining adequate assessment of his material. The development of standard screening techniques at controlled low temperatures has made it possible to distinguish between the cold hardiness of different varieties at an early stage in the life cycle, and offers promise for the selection of more resistant parents.

In contrast, early spring growth is also an important breeding objective, particularly for the western part of Britain, although unfortunately the ability to expand leaf area actively at moderately low temperatures, as found in many Mediterranean collections, is usually correlated with undue susceptibility to freezing temperatures. An important breeding objective is therefore to combine sufficient early spring growth with adequate winter hardiness. In this connection also early seedling tests for leaf growth at controlled low temperatures are being developed for the rapid screening of larger amounts of genetic material at an early stage in the breeding programme.

Although in most herbage breeding programmes understandable emphasis has been given to low temperature limitations both as regards winter hardiness and early spring growth, in practice, annual production is usually limited to a much greater extent by shortage of water in the summer, particularly in the south and east of Britain. The recent GM series of regional trials of perennial ryegrass at different locations in England and Wales for instance, showed availability of water to be the major factor determining differences between sites in summer, and hence in annual production. Considerable variation has recently been detected, even within a single variety, for such leaf characteristics as stomatal size and frequency and degree of leaf ridging, which effect transpiration and water loss. Selection for smaller or less frequent stomata or for a lesser degree of ridging in ryegrass reduces water use by the plant and has been shown to increase dry matter production of the sward during the summer. Studies are also in progress at Aberystwyth on variation in root development in relation to the effective use of water and soil nutrients.

Disease and pest resistance: Although in cereals and potatoes disease resistance has been a major breeding objective for many years, the importance of disease and pest attack in limiting herbage production has been recognised rather more recently. In addition to fungal diseases, such as crown rust in ryegrass, recent surveys reveal an increasing incidence of virus diseases on herbage, particularly ryegrass mosaic, which is reported as affecting about 20 per cent of seed crops in Britain, while certain viruses like barley yellow dwarf can attack both grasses and cereals. Studies on the biology and mode of transmission of these viruses have made it possible to develop rapid screening techniques and these have revealed plants resistant or tolerant to several viruses, including ryegrass mosaic and barley yellow dwarf. It has also proved possible to employ heat treatment of meristem cultures to obtain virus-free material of individual grass genotypes which can then be used to assess the degree of loss caused by virus infection and also to maintain the basic parents of grass varieties. In the herbage legumes, resistance to *Sclerotinia* and eelworm in red clover and to *Verticillium* wilt in lucerne have been recognised as important breeding objectives for some time, but resistance to *Sclerotinia* is now becoming important in white clover also.

The importance of attack by insects and other pests on grassland is still not clear. Certain species play a significant role as vectors of virus diseases while attack by dipterous larvae can cause severe thinning of grass stands, particularly Italian ryegrass, while current studies at the Grassland Research Institute show a marked effect of a blanket application of pesticide on the yield of perennial ryegrass. So far, little is known of the extent of genetic variation in resistance to such pests.

Nutritive value: Many of the agronomic characteristics required in a grass or clover variety can be assessed on spaced plants in the field, although early screening tests in controlled conditions may increase the precision and rate of turnover of the breeding material. For nutritional characteristics, however, small scale laboratory tests are essential since the amount of material required for animal trials is not available in the early stages of a breeding programme and certainly not at the individual plant level.

Rapid laboratory techniques have now been developed for the assay of digestibility in large numbers of small samples of herbage. Initially these tests involved incubation with rumen liquor, but the more recent pepsin-cellulase technique has increased repeatability between runs and does not require the maintenance of fistulated sheep. Rapid analyses for mineral content have been available for some time and are currently being used to assess breeding material of Italian ryegrass for magnesium content, which may be implicated in hypomagnesaemia in dairy cows.

It is becoming clear, however, that one of the most important nutritional features of a grass or clover is its voluntary intake by livestock, and that intake may differ between varieties of the same species even at the same digestibility. The plant characteristics which determine intake are still far from clear, although current evidence suggests that the proportion of cell wall to soluble constituents may be an important feature. Such anatomical features as cell wall thickness or leaf tensile strength are now being used as selection criteria, and contrasting selective lines of several grass species for these characteristics are currently being multiplied to provide material for animal feeding trials.

Few deleterious constituents occur in the grasses, but in the clovers, oestrogenic activity and bloat may be important. Techniques have now been developed for the rapid isolation and assay of the oestrogenic constituents, the isoflavones, in red clover, and considerable genetic variation with a high heritability has been detected even within a single variety. For bloat, however, the active constituent has not yet been identified, although water-soluble proteins may be implicated, and rapid laboratory screening is therefore not yet practicable.

For the operational use of any of the above physiological or biochemical screening tests, however, it is not only necessary that the test should be able to handle large numbers of individuals, preferably at an early stage of the life cycle, but that the results obtained should correlate well with the performance of the material growing in the field, or in the case of nutritive characteristics, with its effect on animal production. In fact, the main problem of the breeder is usually not that of finding sufficient genetic variation for such characteristics, but of deciding which particular features are most important in determining differences in sward performance or in animal production. However, current selections for certain features, including leaf arrangement in relation to light interception, anatomical characteristics of the leaf which influence water use or voluntary intake or for reduced maintenance respiration losses have already shown promise in small plot trials and are currently being multiplied for larger scale field tests.

Many of these characteristics show considerable variation and potential for selection within current agronomically useful varieties. In such selection, however, care must be taken to monitor any undesirable correlated responses such as the negative correlation between winter hardiness and early spring growth in grasses already mentioned. Such correlated responses, however, are not always deleterious. Selection for low leaf tensile strength or reduced cellulose content with a view to improving intake characteristics also appears to increase winter hardiness.

CONCLUSIONS

The productive herbage varieties currently available are based largely on the ecological approach of selecting breeding material from highly productive pastures or meadows or from adapted local varieties. More recently, this approach has been supplemented by the collection and utilisation of genetic resources from a wider range of climatic and agronomic origins often involving the use of interspecific hybridisation, and by the development of rapid physiological or biochemical screening techniques based on our greater understanding of the physiological and biochemical features which determine seasonal production and nutritive quality of the crop. These new approaches should not only improve the potential production of the crop, but also make it able to cope more effectively with such limitations to production as winter cold and summer drought, or the attack of pests and diseases. Even so, however sophisticated the breeding techniques and selection criteria may be, their success can only be assessed by the performance of the resulting variety in the field over a wide range of sites and managements.

In addition to testing our potential varieties in field plots under grazing and cutting and in animal feeding trials at Aberystwyth, we have therefore over the past few years set up farm scale trials on private farms and EHFs covering a wide range of regional environments and farming systems throughout Britain. The establishment, following recent rationalisation discussions of two additional selection and evaluation sites for the earlier stages of the herbage breeding programme, one near Edinburgh for Scotland and the north-east, and the other in the south-east of England, should assist greatly in developing varieties well adapted to contrasting environments and management systems.

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A SHORT HISTORY OF THE MURRAYS

G. R. WHITE

The history of the Murrays farm is closely linked with the history of Ormiston Hall, as it was part of the estate from the twelfth century until 1970. It is situated in East Lothian approximately eight miles west of Haddington (OS map reference NT 411662).

The name Ormiston is claimed to derive from Orme's Toun (toun meaning homestead or land). The Orme family owned Ormiston in the twelfth and thirteenth centuries. The estate then passed to the Lindsay family and in 1368 Sir Alexander Lindsay passed the estate to his son-in-law, John Cockburn, together with the lands of Templehall, Paiston and Muirhouse; the last of which we now know as the Murrays. The Cockburn family owned the estate until 1747 when it was bought by the then Earl of Hopetoun.

The Cockburn family were very much a part of Scottish history and were involved in the political, military and religious life of Scotland for almost four centuries. Two members of the family became Lord Justice Clerks and Sir John Cockburn, who sold the estate in 1747, was a member of the last Scottish Parliament and, after the Union, a member of parliament at Westminster until 1744.

Sir John has been called the "father" of Scottish agriculture. He introduced and encouraged his tenants to use new and improved methods based on his observations and his association with agricultural improvers in England.

Until the end of the seventeenth century the land in Scotland was farmed on the runrig system, which was similar in many ways to the open field system in England. Farms consisted of land, surrounding a hamlet, divided into infield and outfield. The land was divided into strips which were allocated to the tenants, sometimes on an annual basis; in other areas the allocation would be up to five years. The fields were usually worked on a communal basis, but the produce of a tenant's strips was his own property. In East Lothian the infield was usually divided into four breaks. One, which received all the dung, was sown with peas, followed by wheat, by barley and by oats, so that the land was dunged every four years. The outfield was divided into five, six or seven breaks depending on the nature of the land. Of these three were cropped with oats in rotation, the remainder being left for the natural growth of weeds and grass. The only manure was supplied by the stock, which were folded on the break next in rotation for ploughing up and sowing with oats. Beyond the outfield was the roughground only suitable for grazing.

The barley grown was mainly Scottish bere. The oats were the grey or small oat; this was only slowly replaced by the white oat which gave a better yield on moderately fertile ground but was inferior to the small oat on the poorer ground. The whole system of runrig discouraged tenants from attempting to improve their land.

Adam Cockburn (father of Sir John Cockburn), had started improvement at the Murrays by granting a lease of eleven years to Robert Wight in 1698 on condition that he enclosed the farm with a ditch and a hedge. The area would probably have been part of the "muir" which was the poorer ground on the estate. When Sir John succeeded to the estate he introduced a system of longer leases to farmers who enclosed land. The leases were for thirty-eight years in the first instance, subsequent leases were for periods of nineteen years. These leases were automatically renewed provided grassum was paid within a fixed period before the expiry of the lease. The grassum was usually equivalent to one or two year's rent which was fixed. The Murrays was one of the last farms in Scotland where this system still operated, the original long lease having been granted in 1718.

Cockburn kept up a regular correspondence with his tenants, particularly Alexander Wight (son of Robert Wight). This correspondence referred to new methods of husbandry and the new crops then becoming available. In addition to encouraging agricultural development on the estate, Sir John developed the growing of fruit and vegetables for the Edinburgh market. Ormiston Hall had famous fig trees which supplied fruit for the market and Holyrood House. Ormiston became a notable area for strawberries.

To encourage the use of local products Cockburn established a brewery and distillery in the village and he set up a linen weaving factory. He sent the sons of his tenants to England to study agriculture and brought in progressive English farmers to demonstrate the cultivation of turnips, rape and red clover. Alexander Wight grew turnips in 1725 and was probably the first man in Scotland to sow them in drills. In 1736 a turnip weighing 34¾ lbs, grown at the Murrays, was exhibited in Edinburgh.

Sir John founded an agricultural club whose members were local gentry and farmers as well as distinguished gentry from other parts of Scotland. The club met monthly at Ormiston from July 1736 until May 1747.

The improvements carried out on the estate had a profound effect on agricultural development in Scotland. The historian, Patrick Lindesay, writing in 1733 said "the old Estate of Cockburn of Ormiston in East Lothian let to the tenants for three lives is now all enclosed and most of the fences sufficient and the farmers are becoming wealthy, far beyond the common condition of Persons of their Rank".

In the second statistical account (1835), mention is made of the land in the parish brought into cultivation from barren moor by good management referring to the farms of Murrays, Dodridge, Templehall, etc.

Blean's map of East Lothian printed in 1654 shows Moore House but a map printed in the eighteenth century shows Murrays, Big Murrays and Little

Murrays. However, in the various accounts of the area and the parish, only Muirhouse or Murrays are used.

Early in the nineteenth century the Earl of Hopetoun built a "thrashing" machine powered by a water wheel for the use of the tenants. By 1835 most of the tenants had their own water-powered "thrashing" machines, and the tenant of the Murrays had installed a steam engine to drive his threshing machine about 1830.

In the second statistical account a list of crops grown and returns for the parish was as follows:

White crops yielded 5,730 quarters at £1.10.4½d. per quarter.
Beans and Pease yielded 590 quarters at £1.14.6d. per quarter.
Potatoes and turnips covered 206 acres at £10.0.0. per acre.
Clover grass and hay covered 241 acres yielding 180 st/acre at 6d. per stone.
Pasture covered 500 acres valued at £1,333.6.8d.
In addition a considerable acreage of vegetables and fruit was grown.

In the 1835 account there is especial mention of the problems of "mildew" affecting grain crops in the parish. The prevalence of barbery bushes in the area is blamed by local people for the trouble. The "mildew" was probably black stem rust, which still affected oat crops in the area in 1948.

In both the statistical accounts reference is made to the fact that farmers in the parish bought in cattle and sheep in preference to breeding their own stock. In 1791-99 the cattle were commonly native breeds and Holderness. The latter was one of the types of shorthorn developed in Yorkshire and Durham which were beginning to make an impact in Scotland and were the forebears of the Beef Shorthorn. There is no mention of this breed in the 1835 account, the cattle are described as milch cows, Angus × Ayrshire, though there was a tendency to go for pure Ayrshires. Sheep breeds were mainly Leicester-Cheviot crosses and Blackfaces.

It is striking to note how little the general pattern of cropping and stocking has changed from the late eighteenth century to the period of the second world war. In 1950 the agricultural returns for the South-East of Scotland show oats as the dominant white crop with barley and wheat well behind. In the last twenty years the situation has changed dramatically with barley very much the dominant white crop, wheat occupying a much smaller acreage and oats have virtually disappeared. (Beans and peas had almost disappeared by 1950.)

Stocking in the parish is still on the basis of bought-in cattle for fattening and bought-in ewes for fat lamb production. The dung from the cattle is considered essential to maintain fertility and is usually applied to the potato crop, which is still a staple crop in the rotation, as are swedes and turnips.

In the period between 1950 and 1970 the Murrays was run as a cereal and stock farm with little investment in buildings or in the land.

The Murrays, now owned by the Secretary of State for Scotland, was allocated to Scottish Plant Breeding Station as its trials centre in 1970.

At the time it was taken over by the Station it was in a run-down condition. Since 1971 it has been improved by refencing, re-building and draining and a full description of its place in the Station's activities will be given in next year's Annual Report, when the improvements will have been completed.

A map of the Murrays, showing the present field boundaries, appears on page 65 of this report.

ABSTRACT OF ACCOUNTS

INCOME AND EXPENDITURE ACCOUNT

for year ended 31st March 1978

1977					
		Income			
		Department of Agriculture and Fisheries for Scotland—			
£709,000		Maintenance grants			£802,000
118		Annual subscriptions			101
2,205		Other income			2,280
£711,323					£804,381
		Expenditure			
	£408,662	Scientific and technical staff salaries, field staff wages, etc.		£454,850	
	12,089	Implements and apparatus		21,799	
	39,360	Other research expenditure		42,663	
	5,469	Staff recruitment and training		6,648	
	37,512	Additions to fixed assets (note 1)		44,971	
	70,260	Property and buildings (note 2)		88,701	
	28,684	Travel and transport		34,386	
	43,204	Administration and office expenses (including salaries etc. £35,253; 1977 £30,301)		53,018	
	10,896	Pensions and supplementation		12,420	
		The Murrays farm—			
	39,393	Net operating cost	£44,445		
	52,499	Improvements	46,607		
			£91,052		
	(52,499)	Less capital grants from Department of Agriculture and Fisheries for Scotland	46,607	44,445	
695,529					803,901
£ 15,794		Unexpended balance of maintenance grant carried to Balance Sheet (note 3)			£ 480

BALANCE SHEET

as at 31st March 1978

1977					
		Fixed Assets (note 4)			
£709,860		Heritable property			£ 829,585
151,442		Capital equipment			182,594
£861,302					£1,012,179
		Current Assets			
	£ 2,338	Sundry debtors and deposits		£ 2,296	
	34,029	Cash and bank balances		30,825	
	£ 36,367			£ 33,121	
		Current Liabilities			
	£ 4,332	Sundry creditors	£ 606		
	31,543	Department of Agriculture and Fisheries for Scotland — Unexpended maintenance grants (note 3)	32,023		
	£ 35,875			£32,629	
492					492
£861,794					£1,012,671
		Represented by			
£698,430		Funds as at 1st April 1977			£ 861,794
		Add grants received from the Department of Agriculture and Fisheries for Scotland—			
	£103,965	Capital works		£119,725	
	61,678	Capital equipment		32,676	
	£165,643			£152,401	
	2,279	Less fixed assets written off (note 5)		1,524	
163,364					150,877
£861,794					£1,012,671

JOHN ARBUCKLE, *Convener, Finance Committee.*

NOTES TO INCOME AND EXPENDITURE ACCOUNT AND BALANCE SHEET

1. Additions to fixed assets—

Laboratory apparatus	£ 15,818
Implements and equipment	12,353
Safety equipment	979
Library books etc.	2,415
Motor vehicles	7,999
Furniture and fittings	5,407
	£ 44,971

2. Property and buildings—

Rent and rates	£ 17,330
Edinburgh Centre of Rural Economy	7,819
Property improvements, alterations and repairs	20,211
Power, light and heat	43,341
	£ 88,701

3. Unexpended maintenance grants—

Balance brought forward at 1st April 1977	£ 31,543
Addition during year	480
Balance carried forward at 31st March 1978	£ 32,023

4. Fixed assets as at 31st March 1978—

	Cost	*Less charged to Revenue*	*Net*
Heritable property	£ 829,585	—	£ 829,585
Capital equipment	182,594	—	182,594
	£1,012,179	—	£1,012,179
Implements and equipment (including safety equipment)	63,411	£ 63,411	—
Laboratory apparatus	97,980	97,980	—
Vehicles	26,106	26,106	—
Furniture and fittings	22,730	22,730	—
Library books	15,514	15,514	—
	£1,237,920	£225,741	£1,012,179

5. Fixed assets written off (capital equipment)—

I.M.E. programmable calculator, Digicorder programmer and tape reader, decoder (at cost)	£ 1,524

FUNDS AND BEQUESTS

INCOME AND EXPENDITURE ACCOUNT

for year ended 31st March 1978

1977				
		Income		
		Gross interest and dividends on investments (note 1)—		
£ 894		Narrower range		£1,042
882		Wider range		1,036
£1,776				£2,078
42		Interest on bank deposit accounts		46
—		Gain on realisation of investments		448
235		Life subscriptions		220
50		Donations		50
£2,103				£2,842
		Expenditure		
	£ 4	Registrar of Friendly Societies	£ 4	
	50	S.S.R.P.B. lecture	176	
	450	Retirement/resignation presentations	124	
	409	Travel grants and travelling expenses	453	
	200	Donations	180	
	10	Hospitality	32	
	59	Bank charges	75	
1,182				1,044
£ 921		Net revenue carried to Balance Sheet		£1,798

FUNDS AND BEQUESTS

BALANCE SHEET

as at 31st March 1978

1977		*Narrower range*	*Wider range*	
	Assets			
	Investments at cost (note 2)			
£14,704	Life Membership Subscriptions and Donations Fund	£ 6,970	£8,175	£15,145
2,549	W. J. Reid and James Munro Bequests	1,948	607	2,555
600	Dr Wilson Memorial Fund	317	283	600
2,097	J. C. Thyne Bequest	1,049	1,048	2,097
£19,950				£20,397
622	Recoverable income tax			712
—	Sundry debtors			145
1,141	Bank of Scotland—current and deposit accounts			2,257
£21,713				£23,511

	Represented by	*Funds at 1st March 1977*	*Net revenue for year*	
£15,484	Life Membership Subscriptions and Donations Fund	£15,484	£1,556	£17,040
2,890	W. J. Reid and James Munro Bequests	2,890	213	3,103
768	Dr Wilson Memorial Fund	768	46	814
2,571	J. C. Thyne Bequest	2,571	(17)	2,554
£21,713				£23,511

FUNDS AND BEQUESTS

NOTES TO INCOME AND EXPENDITURE ACCOUNT AND BALANCE SHEET

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

	Book value	*Sale proceeds*
Realisations		
£1,361 Stirling County Council 7¾% R/S 1977/79	£1,300	£1,349
£3,116·60 8½% Treasury Loan 1980/82	2,665	3,064
	£3,965	£4,413
Purchases		
£5,660 Agricultural Mortgage Corporation Ltd. 7¾% D/S 1991/93	£4,411	—

APPENDIX

Investments as at 31st March 1978

LIFE MEMBERSHIP SUBSCRIPTIONS AND DONATIONS FUND

	Book value	Market value as at date	Gross interest/dividends for year to date
(Narrower range)			
£1,581·40 6½% Funding Stock 1985/87	£ 1,509	£ 1,289	£ 103
£2,359·35 8¾% Treasury Loan 1997	2,254	1,863	207
£1,648·20 8½% Treasury Loan 1980/82	—	—	140
£1,153·00 Stirling County Council 7¾% Red. Loan 1977/79	—	—	89
£450·00 City of Westminster 13% Red. Stock 1981	445	486	59
£3,545·00 Agricultural Mortgage Corporation 7¾% Deb. Stock 1991/93	2,762	2,517	137
	£ 6,970	£ 6,155	£ 735
(Wider range)			
£1,468·20 8½% Treasury Loan 1980/82	£ —	£ —	£ 125
£450·00 City of Westminster 13% Red. Stock 1981	445	486	58
£1,850·00 Agricultural Mortgage Corporation 7¾% Deb. Stock 1991/93	1,443	1,314	72
413 ord. 25p shares Guardian Royal Exchange Assurance Co. Ltd.	714	929	60
1,980 ord. 25p shares National Commercial Banking Group Ltd.	864	1,445	79
345 ord. 25p shares Shell Transport & Trading Co. Ltd.	1,373	1,822	83
388 ord. £1 stock units Imperial Chemical Industries Ltd.	751	1,377	93
1,420 ord. 50p shares Claverhouse Investment Trust Ltd.	795	1,093	82
830 ord. 5p shares London & Manchester Assurance Co. Ltd.	1,499	1,121	69
1,161 ord. 25p shares Imperial Group	291	871	99
	£ 8,175	£10,458	£ 820
TOTAL	£15,145	£16,613	£1,555

W. J. REID AND JAMES MUNRO BEQUESTS

	Book value	Market value as at date	Gross interest/dividends for year to date
(Narrower range)			
£1,359·29 6½% Funding Stock 1985/87	£ 1,334	£ 1,108	£ 88
£208.00 Stirling County Council 7¾% Red. Loan 1977/79	—	—	16
£150·00 City of Westminster 13% Red. Stock 1981	149	162	20
£215·00 English & International Trust Ltd. 7% Conv. Stock 1986.	259	198	15
£265·00 Agricultural Mortgage Corporation Ltd., 7¾% Deb. Stock 1991/93	206	188	10
	£ 1,948	£ 1,656	£ 149
(Wider range)			
£215·00 English & International Trust Ltd. 7% Conv. Stock 1986.	£ 259	£ 198	£ 15
90 ord. £1 stock units Imperial Chemical Industries Ltd.	199	319	22
£150·00 City of Westminster 13% Red. Stock 1981	149	162	19
	£ 607	£ 679	£ 56
TOTAL	£ 2,555	£ 2,335	£ 205

DR WILSON MEMORIAL FUND

	Book value	Market value as at date	Gross interest/ dividends for year to date
(Narrower range)			
£276·60 6½% Funding Stock 1985/87	£266	£226	£18
£35·00 English & International Trust Ltd. 7% Conv. Stock 1986	51	32	2
	£317	£258	£20
(Wider range)			
133 ord. 25p shares Guardian Royal Exchange Ltd.	£232	£299	£19
£35·00 English & International Trust Ltd. 7% Conv. Stock 1986	51	32	3
	£283	£331	£22
TOTAL	£600	£589	£42

J. C. THYNE TRUST

(Narrower range)			
£1,060·00 City of Westminster 13% Red. Stock 1981	£1,049	£1,145	£138
(Wider range)			
£1,060·00 City of Westminster 13% Red. Stock 1981	£1,048	£1,145	£138
TOTAL	£2,097	£2,290	£276
TOTAL INVESTMENTS	£20,397	£21,827	£2,078 (10·91% on invested capital)

AUDITORS' REPORT

In our opinion the foregoing Income and Expenditure Accounts and Balance Sheets (together with the notes thereon and appendix) give a true and fair view of the state of affairs as at 31st March 1978 and of the income and expenditure for the year ended on that date.

16 Alva Street, Edinburgh.
22nd May, 1978.

BROWN, MACDONALD & FLEMING, *Auditors.*

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

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

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

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

Interior view of the machinery shed at the Murrays.