SCOTTISH PLANT BREEDING STATION

PENTLANDFIELD, ROSLIN, MIDLOTHIAN

REPORT

TO THE

ANNUAL GENERAL MEETING

OF

THE SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING

24th JULY 1969

BY THE

BOARD OF DIRECTORS

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1. REPORT BY THE DIRECTOR

General

The building works mentioned in the last Report were duly completed and five greenhouses, a porch, a bothy and a lean-to shed came into service. The new potato store at Blythbank was also put to use, though several finishing touches are still required. At the time of writing, one building job is in progress, one is about to start and one is being planned. The conversion of the yard (which was roofed over last year) is well advanced and, when complete, will provide reorganised soil and pot storage and potting and workshop space. Planning is complete and work is about to begin on two workers' cottages in Bilston, about half a mile from the station. The cost is being met from the capital resources of the Society, augmented by a grant from the Department of Agriculture and Fisheries for Scotland. Planning of the much-needed new laboratory wing, to go on the west end of the existing building, is well begun and we hope at least to make a start on its construction next year.

At the beginning of the year the Surveyor's Branch of the Department of Agriculture and Fisheries for Scotland intimated that they would no longer be able, because of pressure of other responsibilities, to undertake the design of new building at Pentlandfield. We received the news with regret because we are very conscious of the debt we owe to the Branch for their most generous help and advice over the years. Our indebtedness was acknowledged at the 1968 Annual General Meeting of the Society by the presentation of token gifts to the two members of the Branch staff who had been especially deeply concerned with Station building jobs: Mr F. G. G. Angus and Mr J. Burnett. Happily, Mr Burnett, now in retirement, remains to advise us on building problems on a personal basis. Planning of the new laboratory wing has been entrusted to Mr Alan Elliott of Messrs Solomon & Elliott, Architects.

Our need for a farm on good land remains acute and to this problem no solution is in sight. We examined several possible farms during the year; one would have been acceptable and one ideal, but, for different reasons, neither could be acquired. A combination of administrative difficulties and acute scarcity of suitable farms for sale makes the immediate prospects of success very poor.

The programme of amelioration of the very bad Pentlandfield land with ashes continued: to date 20 acres have been treated.

The scientific staff of the Station are organised into two Departments: Potatoes and Forage Crops. The latter is now up to full working strength of nine Scientific Officers. The Potato Department, having lost Dr Black and

Dr Cockerham by retirement during the year, is much under strength, having five vacancies in a staff of nine S.O.s. Several attempts to appoint a Head of Department have failed and the immediate prospects for development of the potato work are not good. A third department was established during the year: Field and Works, under the headship of Mr G. R. White. Its functions are to run all the various services that support the scientific work of the Station: namely, field, glasshouses, farm (when acquired), workshop, vehicles and general maintenance.

Some advances in the equipment in use in the Station were made during the year. Most notable perhaps is a set of punched-card equipment adapted to data processing by the Edinburgh Regional Computing Centre computer; this comprises an interpreting card punch, a verifier, a sorter and a reproducing punch. This equipment is widely adapted to the varied data-storage and computational needs of workers at the Station. In addition, an electronic desk calculator with attached programming unit was acquired, chosen because it is compatible with the computer. A beginning has been made in equipping a routine chemical laboratory and workshop, both acutely needed facilities. The new greenhouses have been equipped with, in place of conventional benches, trolleys designed in the Station for flexibility of operation and economy of space. A cheap polythene greenhouse designed and built in the Station (see frontispiece) is proving very satisfactory. A new Scottish Plot Seeder is being built commercially and another small-plot combine is being acquired to aid the rapidly-growing cereals research programme.

During the year the Home-grown Cereals Authority undertook to support research at the Station on high diastase barley—a project mentioned in last year's Report, and later in the present one. The Authority is to contribute £2,400 p.a. for three years from July 1, 1968, subject to annual review, accounting and report. We are very grateful for this support of what we believe to be a valuable and interesting project.

We reported last year that we were negotiating with the National Seed Development Organisation on the subject of commercial exploitation of varieties bred by the Station. The outcome was entirely satisfactory; NSDO now holds responsibility for exploitation of such earlier, unprotected varieties as have commercial potentiality and all applications for Rights in new varieties are jointly in the names of the Society and the Organisation.

The Station is to receive an ARC Visiting Group in April 1969; the last one came in 1963. The Group's function is to review the scientific programme of the Station, to assess the performance of scientific staff, and to make recommendations on the Director's proposals for development during the ensuing sexennium. We have, accordingly, been conducting a detailed review of the programme of the Station and shall report further on the subject next year, when the results of the Visiting Group shall have become clear.

Potato Investigations

The year has seen the beginning of a considerable re-organisation of the potato breeding work. The need has arisen largely because of the changing administrative background to the marketing of new potatoe varieties. Station varieties (as noted in the introduction above) are now registered for Rights jointly by the Society and the National Seed Development Organisation.

After consultation with NSDO it was decided not to release Pentland Kappa, but to withdraw it from the Plant Variety Rights scheme, because further tests by Scientific Services, DAFS, had indicated that this variety could not be designated "immune" to wart disease.

Seedling No. 4571ab(4), now called Pentland Lustre, was "commended" by DAFS on completion of its third year of official Merit Trials in 1968. Pentland Lustre is not being released directly to raisers of Virus Tested seed, because V.T. raisers are now advised by DAFS not to accept new material unless it is the produce of tested stem cuttings, and so freed from tuber-borne diseases such as blackleg. Accordingly, 100 tubers of Pentland Lustre were handed over to DAFS for stem cutting tests in 1969, preparatory to commercial release in 1970. Meantime, the Station will ensure that a certified stock of Pentland Lustre is grown with the object of supplying seed to enable trial ware crops to be grown under commercial conditions in suitable regions throughout the country. This will help generate interest in and knowledge of the variety while the initial development of commercial seed stocks is going on.

The official description of Pentland Lustre runs as follows:—

PENTLAND LUSTRE

Maturity First Early, similar to or slightly earlier than Epicure.

Tuber Oval to long oval (pear-shape); skin smooth, parti-coloured pink, mainly at rose end, pronounced at eyes; flesh pale cream; eyes shallow; sprouts pink (carmine).

Foliage Haulm of medium height, vigorous, open; stems erect, internodes faintly pigmented; leaf open, fairly rigid, rachides and petiolules pigmented at stem apices; leaflets medium green, narrow, tending to roll at maturity, terminal leaflet long, only slightly cordate; secondary leaflets numerous and mainly small.

Flower Rare, white, faint colour on backs of petals, inflorescence stalks pigmented; buds generally drop unopened.

Remarks Cropping: good; cooking quality: good; keeping quality: good for an early variety; field-immune from viruses X, A and C; susceptible to gangrene, fairly resistant to dry-rot and to skin spot; resistant to pathotype A of potato root eelworm.

The situation now is that the Station must fully evaluate its new potato cultivars before submitting them for Statutory Performance Trials and Index Trials in connection with Plant Variety Rights. Since the Potato Department was in no position to do this in 1968, no new material was submitted. Of the eight clones which had been submitted the year before, six were re-submitted for a second and final year of trial and the remaining two were withdrawn. This phase of the work is therefore in a state of transition and it will take a year or two to devise a new routine whereby potential varieties are properly tested before submission for Rights. At present we have no land on which realistic potato trials can be carried out.

We are also reassessing our operation at Blythbank, considering both health aspects and the suitability of the site for selection. There is no doubt of the excellence of Blythbank from the point of view of virus control but we have been concerned by the prevalence of blackleg in recent years.

In 1968 the crop at Blythbank included 38 advanced clones, which had come through to the final stage of the combined multiplication and selection procedure: each occupied 1/40th acre, and the mean frequency of blacklegged plants recorded in these plots by the end of the season was 14·2 per cent: 3 plots had over 40 per cent blackleg, only 9 had 5 per cent or less. Blackleg was infiltrating the younger material, which was almost certainly free from the disease when it first went out to Blythbank in the form of tubers from plants raised from true seed in sterilised compost at Pentlandfield. The present tolerance of blackleg in Scotch Seed is 1 per cent in Grade A and 0·25 per cent in Foundation Stocks. It seems quite likely that the digging out of infected plants, which went on throughout the season, damaged the crop and probably helped to spread rather than control the disease. This idea will have to be checked in 1969.

Secondly, too many of the advanced selections tend to be early maturing, as can be seen from the following figures:—

		50-tuber plots at Blythbank		
	Year	*Total*	*Early varieties*	*Maincrop varieties*
Numbers	1968	200	55·5%	44·5%
Numbers	1969	196	58%	42%
Mean yields, lbs.	1968	—	178	140
U.K. acreage	1968	—	17%	83%

A possible reason for the predominance of earlies in the later stages of selection can be deduced from the same table; earlies are not normally expected to outyield maincrops, as happened at Blythbank last year. It may be suspected, therefore, that the growing season at Blythbank, which lies inland at an elevation of about 800 feet, is too short to allow maincrops to develop fully.

We conclude, first, that there are problems enough in maintaining healthy stocks at Blythbank without having to cater for selection by leaving material to grow out and become diseased, instead of burning down foliage as appropriate to a seed crop; second, that Blythbank is not a very suitable place for selecting potatoes anyway; and, third, that the requirements of selection and seed production clash to the detriment of both.

These conclusions lead naturally to the policy, now being developed, of acquiring a farm in a ware potato growing area, where the *critical* phases of selection can be carried out, leaving Blythbank for the job that can be really well done there, namely seed production.

The crop at Blythbank in 1968 covered 15 acres. Planting was started on 29th April and continued for one more day before snow and subsequent flooding made it almost impossible to get implements on to the ground for a fortnight. Further waiting for wet patches to dry out meant that planting continued intermittently until 24th May. Despite a very good growing season the earlies were only beginning to die down in the second half of September, when lifting began. Then the weather deteriorated, and so many working days were lost due to rain that, for the first time, the harvest went on into November. Some tubers of the material lifted on the last day were frosted.

As usual, the 9-tuber, 3-tuber and 1-tuber plots were dug over by hand—a total of 18,200 plants. The produce of the $\frac{1}{10}$th and $\frac{1}{2}$ acre plots was boxed in the field in half-ton pallets, which were stacked in the new store. The changeover to mechanical handling went smoothly, despite the difficult conditions, and the Station wishes to record its thanks to ABRO for supplying two additional tractors and trailers with drivers, and for having a crawler-tractor standing by to pull out trailers which got bogged down.

Potato breeding materials and small samples of clones for trials were sent to a dozen countries overseas during the year. We learned that Roslin Eburu is now the leading variety in Kenya and that seed sent to Kenya in 1963 has yielded advanced selections resistant to bacterial wilt caused by *Pseudomonas solanacearum*.

In breeding with the special objective of resistance to potato cyst eelworm, a programme designed to combine population-specific resistance from Group Andigena and *S. multidissectum* in a background of polygenic resistance stemming from *S. vernei* was completed after 11 years of work; the first progenies which could possibly be expected to include commercial material were raised for selection in the ordinary way at Blythbank. A pilot test of this material indicated that it contained many individuals highly resistant to any population of potato cyst eelworm, due to polygenic resistance from *S. vernei*, this resistance being reinforced by the two population-specific immunity genes. These *vernei* hybrids are attractive in general appearance; time will reveal their commercial potentialities. Even if no usable varieties emerge from these first families it now seems clear that field resistance to eelworms is a practical proposition

As a bonus, it turned out that some of the families carried some field resistance to blight, presumably also derived from *S. vernei*.

The breeding programme especially concerned with resistance to viruses requires that material be exposed to fairly severe infection in the field. Suitable conditions for the transmission of virus Y and leafroll usually obtain at Cambridge, where the rate of spread of both viruses was high in the 1968 trial; it included 101 advanced selections. From this and earlier trials, 20 virus-resistant clones were retained for commercial selection. Eight are resistant to viruses X, Y and leafroll virus, ten are resistant to two of these viruses and two are resistant to virus Y only. A further 15,000 seedlings, 12,000 of them descended from *S. stoloniferum*, were put through initial greenhouse tests for resistance to viruses X and Y. The Cambridge trial also included Pentland Lustre, as one of a group of five clones completing Merit Trials. The new variety became 12 per cent infected with leafroll as compared with 70 per cent in the case of Arran Pilot, the control variety. Both varieties became almost 100 per cent infected with virus Y. On this evidence, Pentland Lustre is fairly highly resistant to leafroll but susceptible to virus Y. As in previous years we are indebted to the Plant Breeding Institute, Cambridge, for running these trials.

At a more fundamental level, the relationships between six different genes controlling various forms of necrotic response to virus X were finally elucidated after many years of experiment. The genes concerned were detected originally in the Andigena Group (two genes), in the Tuberosum Group, and in *S. acaule*, *S. sparsipilum* and *S. chacoense*. Sufficient data have also been accumulated to enable a comprehensive account of nine genes controlling responses to virus Y to be put forward. In this case, the genes were detected originally in *S. chacoense*, *S. microdontum*, *S. demissum*, *S. hougasii* and *S. stoloniferum*.

The Andigena selection experiment, mentioned in last year's Report and elsewhere in this one, was satisfactorily continued at Pentlandfield and Rosewarne Experimental Horticulture Station; as ever, our best thanks are due to Rosewarne. In 1966 the first hybrids of selected Andigena clones (1964 selections) with Tuberosum parents entered the routine at Blythbank and the survivors, in 3-tuber plots in 1968, looked reasonably promising. Meanwhile, new selections made in 1965 and 1966 have been crossed with 11-79, one of the parents of Pentland Crown, and another round of Andigena hybrids will thus start in 1969. In another two or three years we should start to be able to assess the possibilities and so decide how much effort to devote to Andigena crosses.

The need for some resistance to blight is so obvious that it has to be considered in any breeding programme. Indeed, the established selection procedure at Pentlandfield still caters primarily for the production of blight resistant varieties; roughly 75 per cent of the material currently undergoing selection at Blythbank incorporates *R*-genes from *S. demissum*. The presence of these *R*-genes complicates the assessment of the underlying field resistance of much of this material because, paradoxically enough, this assessment cannot be done in the field. Specialised races are needed to blight such material.

Accordingly, some 180 advanced selections and 2,800 seedlings in various breeding families were tested in the blight laboratory last year, using race 1,2,3,4,5,7,8,9 of the fungus. As a result, 60 of the advanced selections were graded Group 1 or Group 2 field resisters. Group 1 denotes a level of resistance equivalent to that conferred by an operative *R*-gene. When it is found, there is always a possibility that it is, in fact, due to an *R*-gene as yet unknown. As a check on this possibility, further material was tested in the Toluca Valley of Mexico, by courtesy of the Rockefeller Foundation. Tubers of advanced selections were sent; several clones were classed as Group 1 and many others were highly resistant and remained unblighted until late in the season. Results of tests at Pentlandfield and Mexico were generally correlated and there is reason to suspect that occasional disagreements are due, as suggested above, to unsuspected *R*-genes. The potato breeder's life would be much easier without *R*-genes and we are planning to breed them out of our stocks so that field resistance can be more efficiently assessed.

Blight resistance in Group Andigena has been further studied during the year with, so far, rather baffling results. At Rosewarne, under heavy natural blight attack, the appearance is entirely one of a variable field resistance but this is not proof of the absence of *R*-genes because surprisingly complex races are present: thus race 1,2,3,4,5,6,7 was identified in 1968. In the greenhouse, occasional clones give a hypersensitive Group 1 reaction, suggesting the presence of an *R*-gene; if so, this would be extremely disappointing because it would imply that the Andigena population had been contaminated by Tuberosum breeding stocks. In fact, the appropriate tests confirm hypersensitivity but not the presence of any known *R*-genes. Similar evidence comes also from Andigena-Tuberosum hybrid families. The conclusion is that we have, in the Andigena Group, a new hypersensitive system of response, as well as field resistance. The picture in the field is complicated by the fact that there seems to be a seasonal shift in the expression of this hypersensitivity; it is clear early in growth but much less clear or even absent later on. This is a matter both of considerable interest and practical importance.

Pentland Dell is $R_1R_2R_3$ and the hypersensitivity to common races of blight so conferred was enough to keep the clone free of disease for several years. Widespread blight appeared in 1967 (as noted in our last Report) and again in 1968. Some 300 samples, mostly from this clone, collected by the NAAS, DAFS and Scottish Colleges, were received in 1968. The races were basically 1,2,3 and 1,2,3,4, as expected, but many were, perhaps surprisingly, much more complex. These results agree with those from Rosewarne samples in showing that blight sometimes produces local races more complex than the known *R*-gene situation demands. A practical convenience emerges: these complex races, being indigenous, are not subject to the quarantine restrictions which attach to similar races of foreign origin.

In testing reaction of advanced selections to common scab, material was again grown in the sandy plots at Archerfield under conditions conducive to severe infection. A considerable range of resistance was again evident, in good agreement with the results of Mr B. C. Knight of the NAAS, Wolverhampton, who tested some of the same material at Burton in Cheshire.

Twelve new dihaploids were obtained and added to the collection, which now numbers 109. Dihaploids tend to be weak. This need not detract from their genetic value, but makes them difficult to manage and particularly difficult to bring into flower on their own roots. The effect of grafting was tried, using rootstocks from several tomato cultivars, non-tubering *Solanum ochranthum* and *S. capsicastrum*, two species of *Physalis*, *Niermbergia frutescens* and *Atropa belladonna*. The latter two perennial species proved to be the most useful. A perennial rootstock has the advantage that it can probably be used to extend the flowering period of the scion. *Atropa* is a fairly easy plant to manage and less liable to disease than tomato.

Material derived from dihaploid × diploid crosses, made at the Plant Breeding Station at Loughgall, Northern Ireland, was evaluated. Several promising lines were selected, although short dormancy, a character typical of the Phureja potatoes, is a problem in this material. A population of diploid stocks was grown and seeded in the field as part of a long-term selection programme started at the John Innes Institute. It will be necessary to select against short dormancy in this material, which contains a good deal of Phureja.

The Commonwealth Potato Collection was maintained on a routine basis, and was augmented by 136 accessions collected by Professor J. G. Hawkes in various countries. Transfer of records to punched cards acceptable by computer is nearly complete and an inventory of the collection is in press.

Forage Crops Investigations

Oat breeding continued along the same lines as established in recent years, comprising pedigree selection, composite cross bulks and selection for resistance to eelworm and to grey speck (manganese deficiency). A bulk of several selections which had given a high yield in 1967 was grown in observation plots on five farms on the Argyll mainland and two on Tiree. On the mainland, comparison with the farmers' own oats favoured the bulk. On Tiree it suffered severely from grey speck unless sprayed with manganese sulphate;

when sprayed, the mixture appeared better than a mixture bulk with resistance to grey speck derived from *Avena ludoviciana*.

The work on high-amylose barley mentioned in the last Report continued satisfactorily. A mutant of Glacier barley (found in our collection at Pentlandfield) has double the normal proportion of amylose in its starch (*Nature* 1969, 221, 482–483). Normal barley endosperm has starch made up of about 20 per cent amylose (straight-chain molecules, completely digestible by diastases) and 80 per cent amylopectin (cross-bonded molecules, incompletely digestible). The mutant has about 40 per cent amylose in its starch and has great economic potential for malting (whether for brewing or distilling), for animal feeding and for industrial products based on starch. In working on it, the Station has collaborated closely with the Glenochil Research Station of Scottish Grain Distillers Ltd., who are interested in the prospect of higher yields of spirit, especially for malt whisky.

The increase in amylose content is accompanied by an increase in the proportion of small starch grains. This difference is much easier to use than chemical tests in genetical experiments, which indicate a single gene difference; heterozygotes are intermediate, both in amylose content and in starch grain size. It is presumed that both effects are controlled by the same gene; they are certainly not independent. Linkage studies have so far failed to show any association with awn texture, rachilla hair length or endosperm colour. Other crosses are under study in an attempt to assign the locus to a linkage group.

Glacier is a North American six-row variety which gives low yields in Scotland. By back-crossing, the character is being transferred to varieties better adapted to Scottish conditions. Since Glacier is very early-flowering there are some difficulties in matching the flowering of hybrids and recurrent parents. On the other hand, the hybrid grains which carry the mutant factor are easily recognised by examining the starch grains; this is done before sowing, the unwanted non-mutant grains are discarded and the backcross programme thus facilitated.

The expression of the high-amylose factor at different stages of endosperm development and in different environments is also under study. As the first known case of a high-amylose mutant in barley, the material has attracted wide interest and seed has been supplied to many plant breeding stations.

Experimental work on the high-diastase barley project mentioned in the last Report was begun during the year. Yields were recorded from trials, at 13 sites in Moray, Fife and the Lothians, of two six-row, high diastase varieties (Olli and Pirrka), two two-row varieties (Maris Baldric and Ymer) and one two-row selection from Cambridge (HB 334/81). Very low yields of the six-row varieties (with Olli averaging 40 per cent and Pirrka 50 per cent of the yield of Ymer) were only partly explicable on grounds of bird damage associated with their early maturity. HB 334/81, the best of about 100 selections received from Cambridge since 1962, was able to outyield Ymer slightly where yields were in the two tons per acre range but on average it fell 4 to 5 per cent below the 30 cwt. per acre of Ymer and Maris Baldric. Grain from these trials has been sent to the Glenochil Research Station for micro-malting tests. Our special interest attaches to the effects of genotypes, environments and their interactions on diastatic properties. The work continues with further trials along the same lines and with the development of rapid laboratory screening methods for assessing diastase activity.

The Swedish barley, Ymer, which has been so successful in Scotland for over 20 years has been made the subject of a long-term genetical study. A collection of stocks from different continents and countries now numbers 24 and unselected inbred lines have been extracted from each to assess variability within the variety and possible signs of divergence and adaptation; plants or progenies not conforming to type are eliminated. Seed from 15 true-to-type accessions was produced near Dunbar in 1967 and used to sow a six-replicate trial there in 1968, using a bulk based on Scottish certified stocks as control. Statistically significant differences were not established, but it was noted that stocks from warmer countries (South Africa, Argentina and Australia) gave the best yields.

Other long-term experiments which were continued were those with mixtures of barley varieties and with barley composite crosses.

The yields from barley mixture trials of 1967 and the diastase trials of 1968 were used to study the feasibility of classifying trial sites by canonical analysis, using variety by site interactions as variates. The attempt with the 1967 results aborted because of large errors within sites. The diastase trials showed that: three sites in Moray were very similar to each other; six sites in the Lothians were very diverse; and four sites in Fife formed two distinct pairs. A close similarity of a site near Dunbar to the Moray group may reflect topographical similarity; the Dunbar site is in about the same relation to the Firth of Forth as the Moray sites are to the Moray Firth. The analysis also showed very clearly that the interaction with sites of the contrast six-row *versus* two-row was much greater than the interaction of any other contrast.

In swedes (*Brassica napus*), kales and other forms of *Brassica oleracea*, a considerable effort has been devoted to attempts to produce "matromorphs". These are plants which result from attempts to make crosses between different species or different genera and yet show no influence of the male parent. By genetical tests they may be shown to be completely homozygous, which distinguishes them from accidental selfs. Presumably, they arise from unfertilised egg cells which have been stimulated into development and chromosome doubling. If the phenomenon can be brought under control, it offers plant breeders a very marked saving of time in producing pure lines; the saving would be especially valuable in biennials such as the Brassicas and matromorphs could be of great importance in exploiting the heterosis in swedes mentioned in the last Report.

In *B. oleracea*, 11 cultivars, representing seven botanical varieties were pollinated by 12 cultivars of *B. campestris*, representing six subspecies. Over 8,000 pollinations yielded 52 seeds; 50 produced plants of the maternal type and two gave true hybrids. The latter were treated with colchicine to produce synthetic *B. napus* (swede-rape). Most of the maternal-type plants were produced by one seed parent and came from pollinations on a couple of days when greenhouse temperatures were low. Whether the pollen parent influences the frequency of matromorphs could not be determined.

Some 200 maternal-type plants were obtained from 4,000 pollinations of F_1 hybrids between swede cultivars with radish pollen. Some of the swede hybrids were also self-pollinated, as were the *B. oleracea* parents above. The practical test of the matromorph method of inbreeding will involve a comparison of normal F_3 progenies with related progenies produced by selfing maternal-type plants.

Improvement of swedes and kales by more conventional methods was also pursued. Selection in F_2 progenies of crosses of Pentland Harvester with other swede cultivars gave basic plants for an inbreeding programme, with uniformity, high yield of dry matter and resistance to internal browning as main objectives. Studies of kale were concerned with techniques; assaying soluble carbohydrate content in stems and petioles with a hand refractometer; vernalisation; non-destructive yield estimation from leaf and stem measurements; and the design of a penetrometer.

The major effort on artificial polyploids was concerned with *Raphanobrassica*. There are basically two ways to make amphidiploid hybrids of radish and kale: (1) to make the cross at the diploid level and then treat the diploid hybrids with colchicine; (2) to make the cross with tetraploid parents. The first method has now been tested on a large scale. Many colchicine-treated hybrids appeared to be amphidiploid, having large flowers and abundant pollen, but seed sets were very low. New crosses were made in 1968, using tetraploid kale to pollinate tetraploid fodder radish; 1,216 pollinations gave 278 seeds, a rate of 0·23 seeds per pollination. At the diploid level, under similar conditions, the rate was 0·38 seeds per pollination. In many of the tetraploid crosses one or both parents were intervarietal hybrids and so there should be scope for selection in the resulting amphidiploids. More autotetraploids of both *B. oleracea* and *Raphanus sativus* have been produced in order to extend the range of potential amphidiploid *Raphanobrassica*.

The hexaploid hybrid *B. napocampestris*, derived from *B. napus*, fodder rape and *B. campestris* ssp. *nipposinica*, gave, in N.I.A.B. trials, lower yields of digestible dry matter than giant rape, but higher digestibility and protein content. A tetraploid hybrid between thousand-head kale and curly kale shows promise as an early spring vegetable crop. It has been handed over to the National Seed Development Organisation for possible commercialisation.

Cocksfoot plants resulting from the first cycle of a large-scale composite (involving 484 accessions) were transplanted to the field to start the second cycle. A few of the accessions were diploid; having been exposed mainly to pollen from tetraploids, they gave very little seed. From their progeny, 26 tetraploid seedlings have been identified for use in further multiplication and selection. In parallel with this work, a 27×27 inter-population diallel cross was attempted. Differences in flowering date prevent all possible matings being made, but a nearly complete set of crosses between 18 populations has been obtained. To multiply the parental material used in the diallel, a set of small pollination chambers with forced ventilation was constructed in a greenhouse; a pollen filter was attached to the air intake. Seed set was fairly good, though it could probably have been improved by the use of a more powerful fan, the better to disperse the pollen within the chambers.

The object of the above project is to allow natural selection to operate on a very heterogeneous interbreeding composite. A smaller composite cross, involving Scotia cocksfoot and 11 other accessions, has the narrower aim of producing material from which to breed a variety with the relatively high digestibility of Scotia but a higher yield. This has also started its second cycle. A full statistical analysis of extensive data from a replicated trial of clones from the 12 populations was completed. Contrary to first impressions (mentioned in last year's Report), *in vitro* digestibility differed significantly only between accessions, not between clones within accessions. Digestibility was associated significantly with scores for heading and for vegetative tillering, but not with scores for leaf characters such as flexibility and roughness.

Attempts to cross indigenous *Poa pratensis* with the North American species *P. ampla* were continued. As both species are highly apomictic, the cross is extremely difficult. Apomixis is a situation in which a plant reproduces by seed but the seedlings are, contrary to usual expectation, asexually generated and identical with the mother plant; they are (like potatoes and other vegetatively propagated crops) clonal. Thousands of seedlings from *P. ampla* exposed to *P. pratensis* pollen have been screened but, so far, only one likely hybrid has been detected. Twin seedlings have been saved for particular study as there is some hope that one member of a pair may be amphimictic. The earliness of spring growth and high productivity it is desired to transfer from *P. ampla* are also found in *P. iberica* and *P. longifolia*, two very similar species which are said to be amphimictic. They also have been pollinated with *P. pratensis*.

Progeny from attempted crosses between better genotypes of *P. pratensis*, *P. angustifolia* and *P. subcaerulea* were examined for possible hybrids. The most promising lots were transplanted to the field for observation. The incidence of mildew and rust was recorded and indications of useful differences in winter hardiness were noted.

For basic genetical studies on breeding methods, short-lived annual plants amenable to culture in growth chambers are required. As an inbreeder, *Arabidopsis* is already available and is well understood as an experimental plant. A comparable outbreeder (preferably self-incompatible) is now needed. Preliminary observations suggest that oil-seed rapes (belonging to *Brassica campestris*) might serve, and also white mustard. A possible candidate among the grasses is *Catapodium rigidum*; seed from seven populations has been sown. Fundamental studies on breeding methods can also be carried out by simulation on a computer, especially when conversational interaction with the computer is possible. This is promised shortly by the Edinburgh Regional Computing Centre and, in preparation, basic parts of a simulation programme have been developed and tested. Other programmes developed and working are one to analyse simple experiments with up to five factors and another which will perform canonical analysis or principal component analysis and tabulate similarities.

2. PROSPECTS OF POTATO IMPROVEMENT

N. W. Simmonds

Evolution in South America

The wild potatoes are distributed in nature from Chile to the middle United States. The basic chromosome number is 12 and diploids, tetraploids and hexaploids are known to occur, having, respectively, 24, 48 and 72 somatic chromosomes. The wild species are ecologically quite variable and they grow from low altitude up to the snow line in the Andes. Most of them are more or less weedy plants of disturbed habitats and they are often characteristic of exposed, unstable rocky slopes. The genus *Solanum* is a huge one, with about 2,000 species: the wild potatoes constitute one relatively small group containing about one hundred species distributed in 17 series. The number of wild species recognised depends somewhat upon taxonomic viewpoint; Hawkes admitted about 100 to his list but other authors recognise many more, and over 300 names have been published. From the point of view of the evolution of the cultivated potatoes most of the wild forms are irrelevant, because, with unimportant exceptions, the cultivars seem to have developed from one or several diploid species within a single series, Tuberosa. This series contains some 20–30 species, all closely related and all interfertile and the problem of deciding which contributed to the cultivars is yet unsolved.

The wild diploid potatoes are nearly all self-incompatible and the majority of those investigated have been found to have an *S*-allele system comparable with that of the diploid tobaccos. The result is that self-pollination fails, cross-pollination usually succeeds and inbreeding (by sib-mating for example) leads to loss of vigour. By contrast with the diploids, the wild tetraploids and hexaploids are inbreeders and are often more or less exclusively self-pollinated. We shall see that the wild diploid out-breeding system was carried over into the diploid and tetraploid cultivars that evolved from them.

We do not know the date of domestication of the potatoes and are unlikely ever to be able to infer it with any accuracy. Certainly, it was many thousands of years ago. As to place of domestication, the wild diploids from which the cultivars arose are native to the central Andes of Peru and Bolivia, and this area (in the general vicinity of Lake Titicaca) is still the area of greatest diversity of the cultivated kinds; with fair probability it was also the centre of origin of the edible potatoes. The crucial first step in the evolution of the cultivars was the elimination of alkaloids from the tubers. These alkaloids, besides making the tubers unpalatably bitter, are quite toxic. Despite the alkaloids, some wild potatoes are gathered and eaten to this day in South and Central America and doubtless have been as long as men have lived there. But they can never have been more than a minor (and slightly dangerous) foodstuff. It is known that there is genetic variation in the alkaloid content of wild potato tubers and, no doubt, knowledge of variation in bitterness acquired at the gathering stage was applied by the first potato selectors. Thus the gathering from the wild of relatively small amounts of bitter tubers was superseded by the cultivation of non-toxic selections.

The first cultivated potatoes were therefore alkaloid-free diploids and human selection was probably next (or concurrently) directed towards increasing yields and tuber size. In the course of time, also, considerable variation in pigmentation developed by mutation and human selection so that, in place of the dull, dirty white or pale purple tubers of the wild species, we have, in the diploid cultivars, a great range of pinks, reds, purples and patterns; primitive agriculturists often favour attractive and brightly coloured plants. The next step in the evolution of the cultivars, a very important one, was the evolution of auto-tetraploidy. The result was the development of a group of cultivars having 48 somatic chromosomes but otherwise similar in general appearance and range of variability to the diploids from which they originated. These tetraploids may be referred to collectively as the Andigena Group and they are now (and must have long been) economically by far the most important group of potato cultivars in South America. The fact that they are very much more abundantly cultivated than the diploids implies that tetraploidy has some advantages in potatoes (as in a number of other crops) but it has to be admitted that we do not know wherein this advantage lies.

In addition to the diploid and tetraploid cultivars just referred to, a few triploids of similar systematic origin are known and, also, a few triploid and pentaploid hybrids with a wild species, *Solanum acaule*. These polyploid hybrids are of great intrinsic interest and of some local importance in South America because they are somewhat frost-resistant; they may have contributed a little genetical material by introgression to the Andigena Group but otherwise they are off the main track of potato evolution and need not concern us further here.

Another significant but yet unimportant local group of cultivars developed in Chile by selection from introduced tetraploid Andigena types. The interesting thing about these Chilean tetraploids is that, as a result of local selection at high southern latitudes, they developed tolerance of long days exactly similar to that developed centuries later by the potatoes of north temperate countries. Indeed, at one time it was thought that these long-day-tolerant potatoes of Chile were the source of the north temperate cultivars but this is almost certainly incorrect. Instead, the Chilean potatoes and those of Europe and North America represent parallel responses to selection by two totally different samples of the Andigena Group. The Chilean potatoes are intrinsically of great interest (and one of them figures in the pedigree of Pentland Crown) but, like the *acaule* hybrids, they are off the main track of potato evolution and have contributed negligibly to our northern stocks. Having said this, we must note that their history suggests that they *ought* to have considerable breeding potentialities. However, this has never been properly tested and observations at the John Innes Institute and Pentlandfield indicate that they are mostly so infertile as to be very difficult to use. On the face of it, the neo-Tuberosum potatoes described later are a more attractive proposition, having, besides long-day adaptation, the blight resistance and fertility that the Chileans lack.

Probably, 80 per cent of the potatoes in an average Andean field or market stall will be Andigenas and the remainder will be a mixture of diploids, triploids and pentaploids. The obvious variability in tuber shape, size and colour is immense. The Andean potatoes have come a long way from the bitter and unattractive tubers of their progenitors which can still be found growing wild in the area.

By the time of the Spanish invasion of South America, the potatoes had long been established as a major food crop and it may be assumed that their distribution then was much as it is today: in the central Andes they are now commonly cultivated from an altitude of about 6,000 ft. upwards and they attain major economic significance where maize cultivation ceases, from 10,000 ft., up to the limits of cultivation at about 15,000 feet. By origin, then, the potatoes are plants of low latitudes and high altitudes; we shall see later how plant breeding in temperate countries transformed them into plants of high latitudes at low altitudes.

Early development in Europe

The first known European encounter with the potato took place in what is now Colombia in 1537, when a Spanish expedition penetrated up the valley of the River Magdalena. The Spanish invaders soon became accustomed to the crop and quickly recognised its virtues as a food for the Indians they put to work in the mines. Potatoes, however, did not penetrate to Europe until some thirty years had passed and the first certain date for their cultivation in the north is 1573, in the neighbourhood of Seville. Salaman's researches have made it very likely that the first stocks were brought from the Bogota area to Cartagena and thence by galleon to Spain in 1569-70. There is an old and persistent legend that Raleigh was responsible for the introduction of the potato to Europe from Virginia but for this story, as Salaman has shown, there is no foundation; Raleigh *may*, however, have introduced the potato to

Ireland (but not from Virginia) about 1586-8, but this was nearly twenty years after the crop had arrived in Spain. So persistent and widely accepted was the Raleigh legend that there is even a small town in Germany, Offenburg, which erected a statue to him in memory of his supposed contribution to agriculture.

The potato first reached the U.S.A. from England via Bermuda in 1621-2 and spread widely in Europe during the 17th century but was regarded largely as a botanical curiosity or as a potentially medicinal plant; it was even thought to have aphrodisiac properties. Except in Ireland, it had no agricultural impact. In Ireland, in contrast to the rest of Europe, it was quickly taken up and had become the staple food crop by the middle of the 17th century. For this, the mild, moist, windy climate of the country was, as Salaman points out, largely responsible. The potato in its then unimproved form was better adapted ecologically to Ireland than to any other part of Europe and it throve accordingly. Also, as Salaman has shown, the cultivation of the crop was encouraged by the political and social circumstances of that unhappy country.

Though quickly established in Ireland, it was nearly two hundred years before potatoes made much headway in the rest of Europe. Only in the latter half of the 18th century did the crop really become established as a significant source of food. When it finally caught on, it did so largely because the rulers of the day (Frederick the Great among them) recognised the crop's capacity to feed armies and burgeoning industrial populations. A curious sidelight on the potato of the times is provided by the War of the Bavarian succession (1778-9); it has been called the Potato War because the Prussian and Austrian armies each consumed the enemy's resources of food and then sensibly went home without having fought the decisive battle. Conservative prejudices against an unfamiliar food broke down and, by the end of the 18th century, named varieties had appeared and the crop was well established. Thomas Malthus recognised that a cheap, abundant, starchy food could contribute to the degradation of the labouring masses, both in agriculture and in industry and, some time later, William Cobbett raged against potatoes on the same grounds. Nevertheless, the political and economic pressures in favour of potato cultivation were too great to be resisted and the crop entered a period of rapid and sustained development.

A few named varieties were extant at the beginning of the 19th century; at the end, modern varieties and something very like modern potato agriculture had become established. One of the crucial events of the century was the potato blight pandemic of the 1840s. This pandemic, perhaps the most damaging outbreak of a plant disease that has ever occurred, took place because: first, the causal fungus, *Phytophthora infestans*, was introduced to Europe and North America from its native home in Central America; second, the potatoes of the time had never been selected for resistance to the disease and were therefore extremely susceptible to it; and third, there was an unfortunate succession of wet summers during the later 1840s. The combination was everywhere serious and locally disastrous. Wherever potatoes were a significant crop, people suffered hardship and, where they were a staple crop (as in Ireland), they suffered famine. By the migration it provoked, blight made a significant contribution to the population of North America. Throughout Europe the Hungry Forties were marked by social disturbance.

Nowadays, and for the last eighty years, blight has been no more than a major nuisance. Chemical spraying has contributed to this but the major reason for the decline in importance of the disease was the production of resistant varieties; the great variety Champion (1876) marked the turning point. More generally, potato breeding was a key process in the development of potato agriculture during the 19th century; without it there would have been no significant developments, blight or no blight. To this subject, the breeding and evolution of the crop in Europe in the 19th century, we must now turn.

The heyday of potato breeding

We have seen that the potato in north temperate countries (other than Ireland) made little progress for 200 years after its introduction but developed very rapidly thereafter being, in effect, transformed during the 19th century. How was this achieved? Salaman's careful studies of the early potatoes of Europe, as revealed by the herbals, suggest very strongly that there were but few original introductions (probably less than a dozen clones) and few later additions to their numbers. All the north temperate potatoes are tetraploids and it is reasonably inferred (though can hardly be proved) that the original introductions were all tetraploid members of the Andigena Group; certainly they closely resembled Andigenas in morphological characters and were quite different from modern north temperate potatoes. Typically, members of the Andigena Group tuber only in short days, have many thin stems, many small leaves, many small bumpy tubers, long stolons and abundant flowers and berries; they are also generally highly susceptible to the major potato diseases, especially viruses and blight. Of all these characters, the day length reaction is of the greatest agronomic importance since it means that Andigenas in general either set no tubers at all or set them very late in the long days of a north temperate summer; probably, it was the mild autumn weather of Ireland that was the most important factor in permitting the establishment of potatoes as a crop in that country; elsewhere, the very late maturing (and poorly cropping) early introductions and their descendants, would have been frosted too early to yield useful crops.

The early potato breeders, from the later 18th up to the early years of this century, grew seed from open-pollinated berries of varieties that they fancied as parents. Sometimes this seed would have been self-pollinated (since the tetraploids, though outbred, are self-fertile), sometimes cross-pollinated by bees. From the families so raised, the breeders selected and propagated clones, the best of which were multiplied as named varieties. So long as there was genetic variability for day-length response, the mere act of growing seedlings and selecting for cropping capacity automatically ensured selection for tolerance of long days. This is a reasonable *a priori* inference which has also been experimentally tested, as we shall see later. Along with selection for long-day tolerance and cropping capacity, the 19th century breeders also selected for short stolons, few large tubers, smooth tuber shape, and probably also for few short stems and large leaves; in addition, there must also have been considerable unconscious selection for disease resistance, the more resistant varieties surviving to become parents more readily than the susceptible ones.

We saw above that there were few original introductions so that 19th-century progress was made on a remarkably narrow genetical base. There were, however, a few additions, including one of great importance: Rough Purple Chile, an Andigena from Panama imported to the U.S.A. by Goodrich in 1851, a clone which figures in the pedigree of a great many later varieties by way of its descendant, Early Rose. Another significant importation was that of Daber to Germany in 1830.

The 19th-century potato breeders were immensely successful and, like nearly all the plant breeders of the time, were practical men rather than scientists. Indeed, science had very little to say about plant breeding until well into the 20th century. The great British potato breeders of the time were: William Paterson of Dundee (1810–70), who bred Paterson's Victoria (1856); Robert Fenn of Sulhampstead (1816-1912), who bred International Kidney (1879); James Clarke of Christchurch (1825–90), who bred Magnum Bonum (1876), Abundance (1886), Epicure (1897), marketed by Sutton's; John Nichol of Arbroath (1830–90), who bred Champion (1876); Archibald Findlay of Auchtermuchty (1841-1921), who bred Up to Date (1891) and Majestic (1911); and the anonymous Northumbrian gardener who produced King Edward in 1902. Breeders in continental Europe and North America were also active and Russett Burbank, still an important variety in the United States, was bred before the turn of the century and Bintje was marketed in Holland in 1910. Several of the notable varieties named above are, though 60–80 years old, still of agricultural importance. The reason for their long survival we must examine in the next section.

The heyday of potato breeding may be said to have ended about 1910. From around that time onwards scientific research began to have an ever-increasing impact upon potato breeding and potato production. There were five major influences, often, as we shall see, interrelated. They were: wart disease, war, viruses, blight and certification. The First World War provided a powerful stimulus to efficient potato production which, in turn, demanded the development of healthy stocks of reliably identified varieties. The early recognition by Gough in 1908 of the fact that some varieties were immune to wart disease and others susceptible to it lent urgency to the need. Valuable work was done by the Potato Synonym Committee, which was set up in 1919. In a few years, the potato variety situation in Britain had passed from a state of extreme confusion to one of fair order: Salaman noted that over 200 names had been applied to the one variety Up-to-Date alone. In 1918 the Board of Agriculture for Scotland started a potato certification scheme. The scheduling of wart-infected land and the recognition of resistant varieties which could safely be grown upon it meant that the disease virtually disappeared. The Wart Disease of Potatoes Orders of 1918 and 1923 must have been some of the most successful bits of phytosanitary legislation ever passed.

As to the viruses, it had been known since the late 18th century that potato varieties in many areas "degenerated" and that the condition known as "the curl" was associated with degeneration. "The curl" is now thought to have been a combination of leaf roll and virus Y infection. The growers of that period knew that it was advantageous to obtain, from time to time, new seed stocks from high, cold areas. So the Scottish seed potato trade had its beginnings in the 19th century and from about 1860 onwards there was a considerable flow of seed to the south. It was not, however, until the 1920s that the biological nature of virus diseases was established and the scientific bases for producing healthy seed stocks were understood; science, in fact, rationalised and improved upon what was already established agricultural practice. Health grading of Scottish certified stocks started in 1932.

As a result of all these changes, stimulated largely by disease and war, as well as by general technological advance in agriculture, excellent progress was made. By the late 1930s the health of stocks had risen enormously and, with good management, wart and virus diseases had been greatly reduced. Further progress has been made in the years since the Second World War but the details lie outside the scope of this review. In general, it may be said that phytosanitary techniques, agronomic good sense and genetic resistance to wart have collectively reduced what were once very damaging diseases indeed to an almost trivial level. Successful virus control, however, imposes a continued economic burden upon potato production: on the assumption that the ware grower purchases fresh seed for alternate crops, seed costs per acre are about £15 or roughly 25 per cent of the variable costs of production. The potato viruses are still a costly nuisance.

One result of these successes was, paradoxically, to reduce the need for potato breeding; an excellent variety could be kept in good health indefinitely, or nearly so. Nevertheless, scientific potato breeding started about the same time and continued alongside the pathological work which, to some extent, diminished the demand for its products. In the past sixty years the private breeder in the old sense has almost disappeared; he was replaced by large-scale professional commercial breeding (as in Germany), by breeding in State institutions (as in Britain and the U.S.A.) or by State institutes guiding and collaborating with private selectors (as in Holland). We have no idea of the total scale of operation of the private breeders of the 19th century but it is certain that the numbers of seedlings raised by the more scientific breeders of recent years have been vastly greater than in the heyday of potato breeding. A current estimate is that several (perhaps six) million seedlings are raised annually in north temperate countries; West Germany alone produces three million. There is at least one single German commercial firm which raises about 300,000 seedlings per year.

The total potato breeding effort of the last 60 years has therefore grown enormously, so it is perhaps surprising that the results do not seem to have been commensurate with the efforts. It is true that a number of notable varieties have been produced, for example: Lorch in the U.S.S.R. (about 1922); Katahdin in the U.S.A. (1932); Ackersegen (1929) in Germany; Voran (1936) in Holland; and Arran Pilot (1930) which was produced by one of the last of the great British private breeders, Donald McKelvie of Arran.

Even now, in the late 1960s, many old varieties survive in cultivation, despite competition from the more recent products of potato breeding: Russet Burbank, Bintje, Majestic and King Edward come to mind. Certainly, surveying the recent scene in cereal breeding, where the turnover of varieties is much more rapid, it looks as though potato breeding has generally been rather unsuccessful. Howard noted that yield advances for several crops during the period 1930–60 were two or three times as great as for potatoes, largely, though not entirely, a reflection of varietal changes.

The reason for this comparative failure—which is world-wide—is certainly not simple. Conservatism among the growers is probably partly responsible and must be related to the fact that to change a potato variety is a more complex and expensive operation than to change a variety of a seed-propagated crop; potato growers have reason to be cautious. Also, there has been the decreased stimulus to the adoption of new varieties that resulted from ever-rising standards of health and certification. Further, a great deal of potato breeding effort went into the search for immunity to blight, so that the breeders' attention was, so to speak, diverted to what we can now see (but only with the benefit of hindsight) to have been an impossible objective. Again, there have undoubtedly been changes in the past ten years so that the potato variety situation may be on the threshold of a general move. But, even when all these factors are allowed for, the fact remains that old varieties do survive and it still looks as though progress has been unduly slow. The reason most probably lies in the narrowness of the genetic base of our north temperate breeding stocks. We saw above that there were very few original Andigena introductions from South America; that there were few subsequent additions; and that potato breeding made immensely rapid progress during the 19th century. All genetic experience goes to show that good progress under selection is followed by a slowing down as the genetic materials of response are exhausted. This principle is now being recognised in many plant breeding situations and it alone appears able to account for the rather poor results of potato breeding, in relation to the effort applied, during the past half-century. If this be accepted, the question obviously arises: what should be done about it? The obvious (and surely, the correct) answer is to return to the Andigena group, the source of our modern potatoes; we shall come back to this subject in the next section.

To return now to blight. We saw above that the Andigena potatoes are extremely susceptible to blight and that this was one of the major reasons for the catastrophe of the 1840s. We saw also that breeding during the following thirty years produced (by 1876) a modest level of resistance to the disease which, as much later experience has shown, was sufficient to prevent further disasters. Nevertheless, despite some resistance in standard varieties and despite the general adoption of foliar spraying, blight has continued to exact a toll of the crop, partly by destroying foliage before the completion of bulking, and partly by rotting the tubers themselves. It has been argued (and was indeed argued as long ago as 1910) that blight, which is worst in wet years when crops are heavy, tends to stabilise potato production from year to year and is thus an economic blessing in disguise. There is no doubt some truth in this, but it would seem better to control the disease effectively and regulate the economics in other ways.

We saw that a sizeable part of the potato breeding effort since 1920 has been devoted to the search for immunity to blight. By the early 1920s it was clear that a spectacular immunity was available in the wild Mexican species, *Solanum demissum* (a hexaploid) and breeders in continental Europe, Britain and the U.S.A. successfully transferred this immunity by backcrossing to cultivated stocks. In the early 1930s, in several places at more or less the same time, it became probable that this approach had failed. Immune varieties, when grown on the field scale, were attacked by new races of the blight fungus, thus providing a new example of a situation which was already known to occur among the cereals. Much subsequent experience confirmed the early results: specific resistance genes, whether solitary or multiple, fail because the fungus evolves the appropriate new pathogenicity. The effect of many years of *demissum R*-gene breeding was, therefore, to divert attention from other, and perhaps more important, features of potato performance. Many modern breeding stocks (indeed probably a majority) carry small amounts of genetic material of *Solanum demissum* incorporated in them as a result of this episode; there is no reason, however, to suppose that *demissum* genes have any useful effect, though the contrary has been claimed by some workers on the grounds that certain *demissum*-bred stocks are unusually productive. The argument however is not compelling and a fair general conclusion seems to be that neither this nor any other wild species has made any significant contribution to the widening of the genetic base. Most modern varieties carry some *demissum* genes because potato breeding history makes them unavoidable, not because they are any use.

In the early 1950s, Niederhauser and his colleagues working in Mexico, the home of the blight fungus, recognised that *R*-genes in whatever combination were ineffective; but they found that the polygenic "field resistance" present in some of the materials they tested was enough to keep the disease under agronomically satisfactory control and, most important, was stable over the years; the fungus did not adapt to clones that had it. There is now a general realisation among potato breeders the world over that these results apply generally. Methods of selecting for field resistance are available and the philosophy is thus to contain the disease at an acceptable level rather than to seek immunity—which is almost certainly unachievable. This field resistance is, of course, none other than the resistance shown in some degree by all successful potato clones. Varieties we commonly call susceptible (*e.g.* King Edward and Bintje) are, when compared with Andigena, found to be a little resistant; at least they are resistant enough in the tubers to allow successful commercial cultivation. In practice, therefore, blight resistance breeding is back at the point where the 19th century potato selectors left it, though we do now have a tolerably good understanding of the underlying scientific problems.

No survey of the last 60 years would be complete without reference to the development of potato collections and of the scientific ideas that grew up from the study of them. The first developments were inspired by N. I. Vavilov who organised expeditions to collect economic plants in many parts of the world as part of the work of the Institute of Plant Industry of the U.S.S.R. In the middle 1920s Bukasov and Juzepczuk made the first of many expeditions to South America and their work subsequently laid the foundations for what we now know of the systematics, distribution and evolution of the wild and cultivated potatoes. During the following forty years, expeditions were mounted from many other countries, for example Germany, Britain, Sweden, Holland and the U.S.A. The Commonwealth Potato Collection (C.P.C.), now maintained at Pentlandfield, was initiated by Balls and Hawkes in 1939. It has sometimes been asserted that the potato collections of the world have made important contributions to potato breeding. This is questionable. We have seen above that *demissum*-breeding failed and it is impossible to point to any gene derived from a wild or primitive cultivated potato which has actually had, at the time of writing, significant impact on potato production. However, several eelworm resistances are now entering commercial stocks and it is possible that, in the near future, an immunity to virus Y will also come into practical use. The collections seem therefore to be on the point of *becoming* useful but they have not done so yet. In the longer run it will probably emerge that by far the most important contributions that the collections can make to potato agriculture will lie, not in the wild species, nor in specific resistance genes, but in the base-broadening potentialities of the primitive cultivars.

Wart disease deserves further comment since it provided an important stimulus to potato research. It was known early in this century that, when planted on infected land, some varieties show up as susceptible, others as resistant. By 1930, the genetic basis of resistance was known to be (with certain qualifications) simple: resistance is dominant so breeding is easy. With the example of the failure of *R*-genes against blight in mind, it might be asked whether wart immunity would not also be expected to "break down." The answer seems to be that it would and it has but only slowly. New races of the fungus are known in central Europe to attack clones previously regarded as resistant. But wart is a rare disease caused by a soil-borne fungus, so its opportunities for the evolution of new races are poor. We may find new races in Britain in time; they would certainly be a considerable nuisance but hardly more.

Andigena and Neo-Tuberosum

Unselected Andigena potatoes are, when grown in the field in north temperate countries, a poor lot: they are late, disease-susceptible, poor yielding and generally unattractive. Nevertheless, history, as we have seen above, shows that they gave rise to the Tuberosum Group and therefore must have enormous genetic potentiality for improvement. Potato breeders have known, in a general kind of way for many years, that Andigena-Tuberosum hybrids are often vigorous and productive but that they are generally too susceptible to blight and have too many other bad characters to be of use in potato breeding. Although Andigena parents figure in the pedigrees of a number of recent European potatoes, it is fair to state that the Andigena contribution is small and has been made by accident rather than by design. In recent years, potato varieties bearing resistance to race A of the potato cyst eelworm have been produced in a number of countries; these varieties, which are now becoming commercial in several places simultaneously, derived the resistance from the Andigena parent, CPC 1673. They are all second or later backcross derivatives so, apart from the eelworm resistance, the Andigena contribution is once again small.

Andigena has therefore made but a trivial contribution to potato breeding, despite the repeated observation that early generation Andigena-Tuberosum hybrids may be markedly heterotic. Howard has drawn attention to this point and Rothacker found that first backcross hybrids of CPC 1673, though on average lower yielding than the controls, ranged up to some very high yielding families. There is therefore some residual heterosis even in early back-cross generations; theoretically, the highest potential heterosis is to be had in the F_1, so if potato breeding is to use Andigena hybrids, it would be highly desirable to do so at the F_1 level. We have seen that this is not possible because the bad characters of Andigena (*e.g.* poor day-length adaptation and blight susceptibility) inhibit the expression of yielding capacity. Clearly, if Andigena is to be put to use, it must first be improved so that its bad characters cannot inhibit F_1 performance.

In 1959 a long-term selection experiment was started at the John Innes Institute and is still being carried on at Pentlandfield. The objective was and is twofold: to produce Andigena parents suitable for incorporation in potato breeding programmes and to test the idea that the Tuberosum Group evolved by selection from Andigena. These two objectives ought to be attained if potato populations approximating in performance and appearance to the Tuberosum Group could be created from Andigena by suitable selection; we might call such a population Neo-Tuberosum. The experiment was founded on the same genetical principles that underlay the great Californian composite cross experiment with barley that was reviewed in last year's Annual Report.

The method adopted was based on 19th-century potato breeding practice; it was, quite simply, to grow large populations of CPC Andigena seedlings in the field (thus providing a wide genetic base), mass-select, take open-pollinated seed from isolated plots of selected parents in the next clonal generation, grow another cycle of seedlings and so on. It was assumed that the mere act of selecting for cropping capacity in the field in England, in long days and under attack by blight and virus, would ensure selection for long-day tolerance and disease resistance. Blight resistance was enhanced by growing subpopulations each year at the Rosewarne Experimental Horticulture Station in Cornwall, under very severe natural blight attack; this operation, generously assisted by the Station staff, turned out to be a valuable feature of the experiment.

There were, of course, many minor problems of management to be over-come but in practice these proved to be slight and the experiment has, in fact, been a success. In the late 1960s, 8 years and 4 generations from the start, excellent advances in yielding capacity, maturity and disease resistance have been made. Now, the better Andigena clones are comparable in yielding capacity and maturity with Tuberosum clones and are, on average, somewhat better in terms of blight resistance. Little attention has been paid to tuber characters so the Andigenas are still rather "rough" in appearance, though often of excellent cooking quality. The experiment continues and there is now little doubt that the Neo-Tuberosum potatoes so created will, in a few more generations, match the Tuberosum group in all significant characters. This does *not* mean that we can expect to produce commercially acceptable cultivars in the near future from Neo-Tuberosum alone (though this should ultimately be possible) but it does mean that this material represents a tremendous store of genetic variation in a form potentially usable in potato breeding.

The experiment just described offers powerful support for Salaman's contention that the Tuberosum potatoes evolved from Andigena by selection for local adaptation in Europe. It shows also that the Andigenas carry a large store of genetic variability and that quite crude mass-selection methods without attention to exact pedigrees are highly effective. The practical question now is: do these altered Andigenas show the predicted yield heterosis in crosses with Tuberosum? Two experiments show that they do. Paxman, working at the John Innes Institute, obtained the following figures for yields of seedling families in a diallel cross of four Tuberosum varieties by four selected Andigenas: Tuberosum selfed 51 per cent; Tuberosum crosses 100 per cent; Andigena selfed 46 per cent; Andigena crosses 70 per cent and Andigena × Tuberosum crosses 153 per cent. The expected within-group inbreeding depression and heterosis are apparent; the Andigenas are somewhat inferior to the Tuberosums (as expected); and the between-group hybrids show the predicted heterosis in very high measure. A similar, though perhaps somewhat less dramatic, result was obtained by Glendinning at Pentlandfield in 1967. He compared crosses of 18 Andigena parents to a single Tuberosum parent with 4 Tuberosum control families. He found that the hybrids had an average yield advantage of 13 per cent, the best family exceeding the control mean by 41 per cent. The two groups were closely similar in maturity and tuber size. Collectively, these results show quite clearly that improved Andigenas are capable of giving impressive yield heterosis in F_1 families; it should not be necessary to backcross to Tuberosum, as it is with unimproved Andigena parents.

The breeding possibilities that emerge from this work are very exciting indeed. All the signs are that hybrids with improved Andigenas should give notably high yielding selections having satisfactory field resistance to blight and good cooking characteristics. We may, however, find that such hybrids tend to have unattractive tuber shapes and, if so, it would clearly be necessary to improve the Neo-Tuberosum parents still further in this respect; selection in this direction is now being undertaken. In a few years we should know whether first generation hybrids can, in fact, be used or whether we shall have to sacrifice some heterosis and use instead a later generation. Meanwhile, the prospects of being able to use F_1s seem good. In the longer run, no doubt, Tuberosum and Neo-Tuberosum will become merged in one greatly expanded gene pool, the new genetic base.

Howard wrote that ". . . there would appear to be a high probability of breeding new varieties which could outyield by about 20 per cent the standard Tuberosum varieties" by the use of Andigena hybrids. In plant breeding, experience teaches that it is unwise to be optimistic but it does look as though 20 per cent may yet prove to be an underestimate.

The need for breeding plans

The 19th-century breeders worked by rule-of-thumb; they selected among the open-pollinated progeny of parents that they fancied. Nowadays, crossing is controlled but, for want of effective genetical guidance, fancy is still more important than science in the choice of parents and crossing pattern. This is the outstanding fact about potato breeding plans. Is it unavoidable or could genetics be any use?

We have seen above that the Andigena and Tuberosum potatoes originated by autotetraploidy from self-incompatible parents. As has been found in other plants, autotetraploidy has the effect of suppressing the action of the incompatibility system, so that the tetraploids, if they bear pollen, are self-fertile. Nevertheless, they show inbreeding depression, though the rate of decline of vigour is less than in diploids. The tetraploid potatoes are therefore concealed outbreeders. Successful clones are highly heterozygous and, we must assume, heterotic. Progenies are therefore variable and, indeed, most members of many families are, unavoidably, rubbish. The problem before the potato breeder is therefore how to identify or breed parental clones which combine well genetically to give excellent progenies in which there is a high frequency of desirable heterotic segregates. Generally, high mean family performances are desirable, though variability within families is obviously also relevant.

In framing the objectives of a potato breeding programme the first requirement is realism. The "perfect potato" does not exist and there is good reason to think that it never will. The reasons for this statement are as follows. Consider, for example, the breeding of a maincrop ware variety. A population of seedlings of the appropriate maturity range is selected for a number of characters of economic importance; the characters are assumed to be genetically independent. Suppose we select at the 10 per cent level for the following seven characters: yield, tuber shape, cracking, cooking quality, blight resistance, leaf-roll resistance and scab resistance; at the 20 per cent level for the following seven characters: tuber size, foliage type, flesh colour, resistance to gangrene, resistance to skin-spot, resistance to dry-rot and resistance to black leg; and at the 50 per cent level for three characters: skin colour, resistance to wart and resistance to virus Y. The severest selection here is at 10 per cent, which is quite weak; and yet a clone which would satisfy all these 17 criteria would emerge only once in about ten million million seedlings. If, by contrast, all 17 characters were selected very weakly at the 50 per cent level, then one selection would emerge in about 150,000 seedlings (which represents about four years' production at Pentlandfield). The conclusion is clear: even moderately rigorous selection for a large number of characters is statistically impossible; one must either select for fewer characters or select less intensely. Negative correlations between characters would make effective selection even more difficult.

Obviously, not all characters are equally important and the problem of deciding what level of expression of a character is economically acceptable or, more generally, of deciding the economic worth of various levels of expression is an acutely difficult one. To illustrate this statement, consider field resistance to blight. For a maincrop variety extreme susceptibility (reaction grade 5) would be quite unacceptable; susceptibility grade 4 (as in standard varieties) is tolerable; grade 3 (a medium resistance) would be very useful but not essential: higher resistance (grades 2 and 1) would be nice to have but would economically hardly be an advance on 3. Clearly, the relation between expression and value is a curve, not a straight line. We might assign values thus: grade 5, −50; 4, 0; 3, +5; 2, +6; 1, +7. Ultimately we should be able to use values calculated from economic analysis rather than these guessed assigned values. On this basis, the realistic procedure would be to eliminate grade 5 ruthlessly, prefer 3 to 4 but put no resources into doing better than 3. This problem, the economic design of potato breeding objectives, is a new field of work and one which promises to be interesting and rewarding, however intricate.

The argument just outlined leads to the idea that a realistic objective for a potato breeding programme would be the not-very-imperfect variety rather than the ideal (but impossible) perfect one. Consideration of the characters of established potato clones supports this idea. Great potato varieties, those that survive in large-scale cultivation for many years, are good all-rounders; they are generally unremarkable in individual characters but are markedly defective in none; in short, they are not-very-imperfect. Majestic and King Edward are good examples; they both have some good characters and several minor defects but no major deficiencies. Majestic is immune to no disease but is slightly resistant to all. This conclusion is supported by several significant failures of varieties which seemed destined for successful careers, for example: Doon Star and Pentland Falcon, both highly promising clones which failed because of unforeseen susceptibility to latent tuber diseases. There is also another important but almost intangible characteristic required of a successful clone and that is reliability; the ability to perform consistently well over a variable range of sites and seasons is certainly a genetic characteristic but one about which we unfortunately know very little; field resistance to sporadic diseases may well be a component of it. It would be very hard to select for reliability in any systematic way but there is no doubt that it is a significant factor in influencing the farmer's choice.

We have, so far, been discussing the objectives of a potato breeding programme and have stressed the need for realism. Let us turn now to the question of methods. There are two basic requirements in designing a breeding programme, once realistic objectives have been set; first we need a rational choice of parents and of breeding patterns and second we need efficient selection methods. Most of the characters with which the plant breeder is concerned are under polygenic control and so obey biometrical rather than Mendelian rules. A few oligogenically controlled characters are, of course, known in potatoes and they are relatively easily dealt with by well understood methods: wart resistance, some virus resistances and skin colour are examples. It is unfortunately true that we have virtually no knowledge of the biometrical genetics of polygenically controlled economic characters in potatoes; we therefore have no basis for a rational choice of parents or breeding patterns. Potato breeders in general, lacking biometrical guidance, have had to proceed largely by instinct, "crossing the best with the best and hoping for the best" as Harland said. However, any choice of parent or pattern implies some underlying genetical hypothesis. The breeder who crosses favoured parents with a wide range of other clones assumes a fairly high level of general combining ability (GCA); the breeder who explores large numbers of more or less random crosses on a small scale and then selects a few for intensive exploitation thereby assumes specific combining ability (SCA). At present, we simply have no good evidence as to which of these approaches is best and only a serious biometrical-genetic analysis of economic characters in potatoes can provide the necessary guidance. A similar approach is needed to evaluate the possible use of inbreeding (which has been advocated and which has certain theoretical advantages) and to assess the potential rewards of heterosis in Andigena-Tuberosum hybrids. Clearly there is here a large and exceedingly important field of work of fundamental significance for the rational design of potato breeding programmes.

As to the need for efficient selection techniques, the prime requirement, once again, is realism. Ideally, one would classify large populations for all the characters for which selection was to be practised and then decide, on the basis of a suitable selection index or weighted economic index, which individuals were to be kept. In practice this would be impossibly laborious and it becomes essential to select sequentially, taking the easy characters first and the difficult ones later. This is not an ideal procedure but it is a realistic one. Throughout, there will be need to use rough measurements and quick approximations, whenever these are well enough correlated with the character being selected. With many thousands of seedlings to be screened in short periods of time, crude methods are unavoidable.

To summarise the foregoing rather complicated argument, we may say that the potato breeder aims to produce heterotic clones; that he must have a realistic objective, namely the not-very-imperfect potato; that he needs a rational choice of parents and breeding plans which can only be based on biometrical genetic analysis; and that he needs streamlined selection methods.

The potential of dihaploids

Dihaploid plants are diploids derived from the unfertilised egg cells of tetraploid mother plants; they are, therefore, a special kind of diploid. A few have been known in potatoes since the late 1930s but it was not until 1958 that Hougas and his colleagues at Wisconsin initiated a study of their economic potentialities. This work stimulated wide interest and there are now several thousand potato dihaploids scattered round the potato laboratories of the world, including some at Pentlandfield.

They are easily, although laboriously, produced. If tetraploid plants (with 48 chromosomes) are pollinated by diploids (with 24 chromosomes) the expectation is that triploid progeny (with 36 chromosomes) will be produced and so they are, but in surprisingly small numbers; instead, a majority of the progeny are tetraploid (the products of selection of occasional diploid pollen grains), some are the expected triploids and a minority are diploid (*i.e.* dihaploid), with 24 chromosomes. These diploids can be proved genetically to be maternal in origin; that is, they are derived from unfertilised egg cells which have developed parthenogenetically. They represent, one might say, a gametic sample of the mother plant. It is general experience that the cross tetraploid female × diploid male is rather infertile (for reasons which are not well understood), so that many pollinations fail; nevertheless, the production of dihaploids in quantity is a practical proposition. Hougas and his colleagues got 28 from 6,041 pollinations of Tuberosum clones, and other workers have found similar frequencies. At Wisconsin it was later found that the best parental combinations under the best conditions could yield as many as 80 dihaploids per 100 fruits but this is, of course, exceptional. Of the first 28 dihaploids, the great majority were weaklings, as would be expected from what we know of the genetical history of the tetraploid potatoes. One or two were quite vigorous, indeed about as vigorous as the mother plant, the variety Katahdin. Most dihaploids, in this and other experiments, have been found to be slightly female fertile but nearly all have a particular kind of male sterility which may prove to be a serious barrier to their utilisation. An interesting discovery that emerged from study of the breeding behaviour of dihaploids is that certain incompatibility genes (*S*-alleles) have been proved identical as between the cultivated diploids and Tuberosum clones; this is excellent evidence in favour of the view of potato evolution outlined earlier in this article.

The observation that rare dihaploids are about as productive as their parents is obviously of some practical interest; it raises once again the question of the effect of tetraploidy in the potatoes and at once suggests that we might perhaps return from tetraploidy to diploidy in our commercial stocks if there were any practical advantage in doing so. Rowe has found that there was little difference in productivity between various diploids derived from dihaploids and tetraploids made from those same diploids with the aid of colchicine and that what little difference there was tended to favour the diploids. Further, the Wisconsin work has also shown that hybrids between dihaploids and South American cultivated diploids (genetically analogous to the Andigena-Tuberosum hybrids discussed earlier in this article) are often vigorous and highly productive. On balance, then, the evidence, though admittedly indecisive, suggests that diploids may be not at all inferior to tetraploids and that they may indeed have a practical future. If this is so, the success of the Andigenas in South America at the expense of their ancestral diploids remains as much of a mystery as ever.

It has been argued above that the genetic base of the Tuberosum potatoes is too narrow; on this basis, then, obviously, a population of dihaploids derived from them could at best be equally narrowly based and so would have little potentiality for improvement. Therefore, a deliberate attempt to provide more genetic variability along the lines of the Andigena programme is clearly necessary. Such a programme was started at the John Innes Institute some years ago and is now being carried on at Pentlandfield. Essentially, the plan is simply to mass-select in a widely based population of South American diploid stocks in just the same way as was done in Andigena; good progress is being made.

The outcome of this attempt to reduce the chromosome number of our cultivated potatoes is quite uncertain and will not become apparent for a good many years. The attraction of the approach is that it would tend to make for easier and more efficient breeding. But the key question remains to be answered. Although it is possible that diploids are potentially as productive as tetraploids, it is yet unknown whether the complex and subtle balance of numerous characters that is necessary in a successful potato clone can be attained at the diploid level. Time alone will show. Certainly, no great advances can be expected unless the genetic base of diploid breeding populations is effectively widened.

It may well turn out in the long run that the chief use of dihaploid Tuberosum potatoes will be to provide a quick and elegant means of synthesising specialised tetraploid breeding stocks. Thus, a dihaploid clone known to contain several desirable genes (for example for disease resistance) will yield, by the use of colchicine, a tetraploid clone known to be either duplex or quadruplex for those desirable genes. It can easily be shown that multiplex breeding stocks of this kind offer considerable gains in breeding efficiency in comparison with the simplex clones which are commonly available to the breeder.

The potato dihaploids then are of great scientific interest; they will certainly have their uses in developing refined potato breeding stocks; and they may possibly (but perhaps improbably) themselves have a commercial future. At all events, every serious potato breeding programme must take them into account.

The programme at Pentlandfield

The Potato Department of the Scottish Plant Breeding Station is the leading potato breeding and potato genetics research group in Britain. Over the past 40 years the Station has made notable contributions to our knowledge of potato breeding in relation to potato diseases (*e.g.* wart, blight, viruses and eelworms) and has bred a number of commercial varieties of which one, Craigs Royal, is well established as the leading second early and another, Pentland Crown, is now emerging as an important maincrop clone. The names of Dr W. Black and Dr G. Cockerham are justly well known, the one for breeding and blight studies, the other for virus investigations. The potato research group at the Station has, however, always been small, having exceeded five scientific officers for only a short period. Clearly, a major increase of the effort put into potato breeding and genetics is now needed because: first, the potato is a major crop in Britain (650,000 acres, 6·5 m tons, worth about £90m); second, the British potato breeding effort is numerically almost trivial in comparison with the continental and we cannot rely on continental varieties to succeed here, as they often do in the case of cereals; and third, the genetic basis for a new round of improvement of potato varieties is now apparent, as this essay has sought to show. We now have the breeding stocks and at least a general understanding of how to use them to promote a rapid and sustained advance in potato performance.

The broad aims of the potato breeding programme at the Station are, in order of priority:—

1. Maincrop ware varieties since these are still of the greatest economic importance.

2. Processing varieties (crisping and canning), the demand for which is growing rapidly.

3. Early ware varieties in which there is still a considerable, though probably declining, trade.

4. Overseas varieties, a modest effort justified economically by the currently developing interest in the export of Scottish seed potatoes, especially to warm countries, *e.g.* in the Mediterranean.

The scientific studies necessary to support and extend the breeding are as follows:—

(*a*) Continued investigation of the evolution of the cultivated potatoes because here lies the key to the exploitation of the Andigena Group, an understanding of the effects of polyploidy, the problems of exploitation of diploids and dihaploids and, at one further remove, the use (if any) of wild species.

(*b*) Study of the biometrical genetics of economic characters in the cultivated potatoes because this is the only possible foundation for rational breeding plans.

(*c*) Economic analysis of economic characters and, ultimately, the whole phenotype of potato clones because this is the route to realistic breeding objectives.

The more practical needs, generally closely interrelated with the foregoing, are as follows:—

(*a*) Greatly increased numbers of seedlings, not because there is any intrinsic merit in quantity, but because the elementary arithmetic of multiple selection shows it to be necessary; success is proportional to number.

(*b*) Realistic objectives which imply an effort to avoid economic faults rather than to achieve a statistically impossible perfection.

(*c*) Exploitation of a greatly expanded genetic base founded on Neo-Tuberosum.

(*d*) Some further refinement of screening methods, necessary if more characters are to be assessed and larger populations processed without undue increase in labour.

Some of the essentials of this programme are already under way: we have the CPC work and the first Andigena crosses have entered the breeding programme; we are trying to clear our (as we find) rather muddled ideas on breeding objectives; we are developing new testing and recording procedures. We have yet neither biometrical genetics nor economic analysis and the practical demands of enlarged breeding populations are still well beyond our resources. Given support and some luck, five years should see big changes.

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3. VARIETIES BRED BY THE STATION

The following varieties are on the market:—

Oats	Craigs Afterlea Albyn Donside Albyn Empress Bell	Early Miller Albyn Bard Shearer
Barley	Craigs Triumph	
Bean	Albyn Tick	
Swede	Pentland Harvester	
Grasses	Scotia Cocksfoot Scotia Perennial Ryegrass	Scotia Timothy
Potatoes	Craigs Defiance Craigs Alliance Pentland Beauty Pentland Dell Pentland Falcon* Pentland Hawk* Pentland Javelin* Roslin Eburu	Craigs Royal Pentland Ace Pentland Crown Pentland Envoy Pentland Glory* Pentland Ivory* Pentland Lustre* Roslin Castle*

Varieties marked * have been granted Plant Breeders' 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. Application for licences should be made to the Executive Officer, NSDO Ltd., The Granaries, White House Lane, Cambridge.

The commercial development of the three Scotia Grasses is also in the hands of the National Seed Development Organisation. Elite stocks of the oat Bell are in the hands of Messrs Macfarlan, Shearer & Co., Greenock.

4. COLLABORATORS

The list of collaborators in the work of the Station includes farmers, landowners, colleges and official stations, who have provided field facilities; and workers in university, official and industrial laboratories, who have provided valuable scientific help. We hope the following lists are complete; to all collaborators, named or (perchance) unnamed, we offer our best thanks.

(*a*) Official bodies:—

Animal Breeding Research Organisation, Edinburgh.
Department of Agriculture and Fisheries for Scotland, Scientific Services, Edinburgh.
Forestry Commission, Research Branch, Edinburgh.
Grassland Research Institute, Hurley.
Home-Grown Cereals Authority, London.
M.A.F.F., Plant Pathology Laboratory, Harpenden.
Ministry of Agriculture, N.I., Plant Breeding Station, Loughgall.
National Agricultural Advisory Service.
National Institute of Agricultural Botany, Cambridge.
National Institute of Agricultural Engineering (Scottish Station) Edinburgh.
National Seed Development Organisation, Cambridge.
National Vegetable Research Station, Wellesbourne.
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Potato Marketing Board, London.
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Scottish Horticultural Research Institute, Dundee.
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Welsh Plant Breeding Station, Aberystwyth.

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Department of Brewing and Biochemistry, Heriot-Watt University, Edinburgh.
The Edinburgh School of Agriculture and Edinburgh and East of Scotland College of Agriculture.
The North of Scotland College of Agriculture, Aberdeen.
The West of Scotland College of Agriculture, Glasgow.

(*c*) Industrial Collaborators:—

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North British Distillery Co. Ltd., Edinburgh.
J. & T. Rodger, Cupar.
Ross Foods Ltd., North Walsham, Norfolk.
Scottish Agricultural Industries Ltd., Edinburgh.
Scottish Cooperative Wholesale Society Ltd., Edinburgh.
Scottish Grain Distillers Ltd., Menstrie, Clackmannan.

(*d*) Individual:—

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J. Ballantyne, Balkaithly, St Andrews, Fife.
R. & G. Brown, Crowfoot Bank, Swinton, Duns, Berwickshire.
G. Clapperton, Sheriffhall Mains, Dalkeith, Midlothian.
A. G. Dewar, Hedderwick Hill, East Lothian.
G. F. Duncan, Waterton, Duffus, Moray.
R. Dykes, Myles Farm, Tranent, East Lothian.
G. B. R. Gray, Smeaton, East Linton, East Lothian.
M. J. Hamilton, Muirhouse, Edinburgh, Midlothian.
J. Howie, Newton, Wormit, Fife.
Sir David Lowe, Elvingston, East Lothian.
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6. Dr W. BLACK and Dr G. COCKERHAM

Dr WILLIAM BLACK, O.B.E., B.Sc., Ph.D., D.Sc., F.R.S.E., F.I.Biol.

Dr William Black retired from his post as Deputy Director of the Scottish Plant Breeding Station at the end of September 1968 after 42 years' service.

Son of a West Lothian farmer, he was educated at Bathgate Academy and thereafter at Edinburgh University, where he gained the degree of B.Sc. in Agriculture in 1925. As a temporary inspector of potatoes in his student days he gained an early introduction to the crop which was to command his special attention throughout a long and successful career.

His professional career began in 1926 with his appointment as "Assistant in Charge of Potato Breeding" with the Scottish Society for Research in Plant Breeding and, in 1931, he received the degree of Doctor of Philosophy at Edinburgh University for a thesis based on his early work. Recognition of his continuing contributions to scientific knowledge came in 1946 when the Royal Society of Edinburgh awarded him the Makdougall-Brisbane Prize (1944-46) and later, in 1949, he was elected a Fellow of the Society. For his studies on the inheritance of resistance to potato blight, *Phytophthora infestans*, he received the degree of Doctor of Science at Edinburgh in 1952.

Dr Black established a reputation, as a plant breeder, with the introduction of the "Craigs" series of potato varieties (1937-1949), a reputation which has been enhanced by the "Pentland" and "Roslin" varieties (which presently occupy about 24 per cent of the maincrop acreage in Great Britain) and by varieties such as Craigs Van Riebeeck, Roslin Chania, Roslin Eburu and Roslin Sasumua which have been and still are requested for the more specialised environments of South and East Africa.

Dr Black's own contribution to research has been related to the specific problems created by the blight fungus. His work in this field revealed the relationship between resistance factors and races of blight and so provided the now widely accepted basis for classification of races. He thus became known internationally and, as a consultant on epidemic potato blight, travelled extensively in Europe, East Africa, India, America, Canada and Mexico. In 1957 the Potato Association of America acknowledged his attainments by electing him an Honorary Life Member of the Association, the first time such an honour had been paid to a "man from beyond the seas." In 1968 he was honoured with an O.B.E.

It is not only as a scientist, however, that Bill Black is measured; his personal qualities, his modesty, good humour and friendliness, were in no way surpassed by his academic achievements. Scientific colleagues within and outwith the Station, the many farmers with whom he came in contact and members of the staff of the Department of Agriculture and Fisheries for Scotland with whom he had a long and harmonious association will wish him a long and happy retirement.

J. L. HARDIE.

Dr GEORGE COCKERHAM, B.Sc., Ph.D.

For some years before George Cockerham joined the Scottish Plant Breeding Station as a new graduate in July 1929, spread of virus into the potato seedlings grown at Craigs House, Corstorphine, was a constant nuisance. Having applied successfully to the Empire Marketing Board for money to study the virus problem, the Society acquired a new building with glasshouses and a five-year maintenance grant. Cockerham's appointment as a junior assistant resulted from this, and he was sent to work on leased premises at Gibston, Huntly, where there would be little risk of virus spread. When the grant ended in 1934 so did work at Huntly and Cockerham returned to Craigs House. Nearly 35 years later, on 31st March 1969, his retiral from Pentlandfield gave one pause to think both of his past achievement and of how the future might appraise his work. He had contributed significantly to the development of two subjects that grew up with him—potato viruses and potato genetics; and he had bred qualities of virus resistance into several of the Station's varieties. His idea that virus relationships and evolution might sometimes be discerned through host genetics may prove to be classic.

Cockerham became very broadly interested in potato viruses, mainly to discover whether the diseases could be controlled by breeding; but partly because he was the only continuing specialist on the subject in Scotland for the first half of his career. Early on he tried to define the physiological effects of infection and to discover whether seedlings from a diseased plant were affected —most important for the breeder to know! Virus distribution was then studied, in both the geographical and varietal senses; the latter led to a huge task (which still goes on) of specifying the reaction of varieties, old and new, to six predominant viruses, work for which Cockerham has ever since been blessed by enquirers throughout the British Isles and elsewhere. There emerged the very important finding that extreme sensitivity to infection with virus X was inherited as a dominant character. On this foundation, C. H. Cadman, then working with Cockerham, confirmed that *Solanum tuberosum* is autotetraploid and showed that hypersensitivity to virus X (*i.e.* field immunity from mild mosaic) would thus be easy to breed into new varieties. The more complicated resistances to the Y and leaf roll viruses and other forms of resistance to virus X in the wild and cultivated potatoes have since been at least partly unravelled. And from annual field and laboratory tests for resistance to spread of aphid-borne viruses useful breeding stock has been built up, one practical result of which is seen in some of the Station's recent varieties—*e.g.* Pentland Crown. On the aphid vectors, Cockerham was the first in Scotland to record annual immigration and build-up in crops. Credited to him also, and to his colleague Mairi McGhee, is the discovery of a unique virus disease, potato stunt; but in finding a new virus they were clever enough to choose one that has since disappeared!

Dr Cockerham always sought to specify the genes controlling response to virus infection and he was adept at chasing them through the maze of *Solanum* species. Applying a similar rigour to the viruses he found that genes controlling the reaction of *S. demissum* to virsues A and Y were alleles and suggested that the two viruses were therefore related. He also grouped all known strains of virus X in a logical sequence (which he thought might be evolutionary) according to the response of differently constituted varieties. Considering that viruses are entirely dependent on their hosts, one imagines that the genetical background of response is bound to attract more critical attention in the future—when Cockerham would again be acknowledged as a pioneer.

Dr Cockerham's work and help is acclaimed by scientists and growers throughout the world. He was elected in 1959 to Honorary Life Membership in the Potato Association of America. Through his own and his colleague's efforts one finds that the Scottish Plant Breeding Station is held in respect and affection both at home and far afield. Ultimately his personal qualities are those that count most. One knows him to be sound but not severe; academic without being pedantic; practical; thorough yet with humour; and critical, chiefly of himself. The world needs these qualities and we hope that George Cockerham will enjoy many years of busy retirement in which to practise them

J. M. Todd.

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Sir JAMES DENBY ROBERTS, Bt., O.B.E., M.A., J.P., Strathallan Castle, Auchterarder.

Vice-Chairman

W. ANDREW BIGGAR, O.B.E., M.C., B.Sc., Magdalene Hall, St Boswells.

Ordinary Directors

1966

A. MANTON BAXTER (Baxter & Guion Ltd.), Museum Buildings, Priestgate, Peterborough.
J. LESLIE DAWSON, B.Sc. (S.A.I. Ltd.), West Mains of Ingliston, Newbridge, Midlothian.
H. P. DONALD, Ph.D., D.Sc., F.R.S.E., Animal Breeding Research Organisation, King's Buildings, West Mains Road, Edinburgh 9.
J. F. FALGATE, Pinkerton, Dunbar.
G. A. STORRAR, M.C., B.Sc., J.P., Rossie, Auchtermuchty.
D. THOMSON, Cessford, Kelso.

1967

ROBERT ALLISON, Turnhouse, Corstorphine, Edinburgh 12.
W. LOGAN FORREST, B.Sc., Wester Hall, Greenlaw, Berwickshire.
G. B. R. GRAY, Smeaton, East Linton.
JOHN MARSHALL, C.B.E., Dalreoch, Dunning.
P. P. WADE, Whitegates, Bardon Mill, Hexham, Northumberland.
JOHN WATSON (McGill & Smith Ltd.), 67 Kyle Street, Ayr.

1968

H. F. D. ELDER (William Dods & Son), Haddington.
W. H. M. GILL, Rosskeen, Invergordon, Ross-shire.
A. HOWIE, B.Sc.(Agric.), N.D.A., N.D.D. (North of Scotland College of Agriculture), 581 King Street, Aberdeen.
Sir DAVID LOWE, C.B.E., D.Sc., Elvingston, Gladsmuir, East Lothian.
A. GORDON PORTER, C.D.A., East Scryne, Carnoustie, Angus.
R. H. WATHERSTON, C.B.E. Crichton Mains, Ford.

Directors Co-opted

JOHN ARBUCKLE, Logie, Newburgh.
GEORGE CLAPPERTON, Sheriffhall Mains, Dalkeith.
A. K. M. MEIKLEJOHN, B.Sc., Edinburgh School of Agriculture, West Mains Road, Edinburgh 9.

Directors nominated by the Secretary of State for Scotland

Professor ROBERT BROWN, D.Sc., F.R.S., 15a Corrennie Drive, Edinburgh 10.
M. A. H. TINCKER, M.A., D.Sc., F.L.S., F.R.S.E., Arbeadie House, 44 Station Road, Banchory.
D. W. WILLIAMS, M.Sc., Ph.D., Scientific Services, East Craigs, Corstorphine, Edinburgh.
Sir MAURICE YONGE, C.B.E., D.Sc., F.R.S., 13 Cumin Place, Edinburgh 9.

Standing Committee—Finance

Sir JAMES DENBY ROBERTS, Bt., *Convener.*
R. ALLISON.
JOHN ARBUCKLE.
ROBERT BROWN.
H. F. D. ELDER.
G. B. R. GRAY.
JAMES GRAY.
ROBERT L. SCARLETT.
D. THOMSON.
M. A. H. TINCKER.
W. A. BIGGAR (*ex officio*).

Research Committees

Forage Crops

H. F. D. ELDER, *Convener.*
G. CLAPPERTON.
J. L. DAWSON.
H. P. DONALD.
W. L. FORREST.
G. B. R. GRAY.
JAMES GRAY.
A. HOWIE.
Sir DAVID LOWE.
A. K. M. MEIKLEJOHN.
D. THOMSON.
P. P. WADE.
R. H. WATHERSTON.
J. WATSON.
W. A. BIGGAR (*ex officio*).
Sir JAMES DENBY ROBERTS, Bt. (*ex officio*).

Potatoes

J. ARBUCKLE, *Convener.*
R. ALLISON.
A. MANTON BAXTER.
H. P. DONALD.
J. F. FALGATE.
W. H. M. GILL.
Sir DAVID LOWE.
J. MARSHALL.
A. GORDON PORTER.
G. A. STORRAR.
D. THOMSON.
J. WATSON.
D. W. WILLIAMS.
W. A. BIGGAR (*ex officio*).
Sir JAMES DENBY ROBERTS, Bt. (*ex officio*).

Election of Directors

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

A. Manton Baxter (Baxter & Guion Ltd.), Museum Buildings, Priestgate, Peterborough.

J. Leslie Dawson, M.Sc. (S.A.I. Ltd.), West Mains of Ingliston, Newbridge, Midlothian.

H. P. Donald, Ph.D., D.Sc., F.R.S.E., Animal Breeding Research Organisation, West Mains Road, Edinburgh 9 (co-opted).

J. F. Falgate, Pinkerton, Dunbar.

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

D. Thomson, Cessford, Kelso.

To fill these vacancies the Board of Directors recommends election of the following:—

John Arbuckle, Logie, Newburgh.

George Clapperton, Sheriffhall Mains, Dalkeith.

H. P. Donald, Ph.D., D.Sc., F.R.S.E., Animal Breeding Research Organisation, King's Buildings, West Mains Road, Edinburgh 9.

J. W. Grant, B.Sc., North of Scotland College of Agriculture, Drummondhill, Stratherrick Road, Inverness.

A. K. M. Meiklejohn, B.Sc., Edinburgh School of Agriculture, West Mains Road, Edinburgh 9.

E. F. Sherriff (Sherriff & Sons Ltd.), Burleigh Mead, Great North Road, Hatfield, Herts.

Meetings

The Board of Directors met four times: on 25th July 1968; 14th November 1968; 3rd April 1969; and 5th June 1969.

The Finance Committee met on 5th June 1969.

Research Committee Meetings were held as follows: Potatoes on 22nd August and 24th October 1968 and on 9th January 1969; Forage Crops on 29th July 1968.

8. ADMINISTRATION

Finance

The abstract of audited accounts set out on pages 58-64 reveals the Society's financial position at 31st March 1969. The Department of Agriculture and Fisheries for Scotland provided a grant to cover maintenance of the research programme amounting to £132,650. Income from other sources was £1,097, 9s. 5d.

A small barley breeding project was started under a grant from the Home-Grown Cereals Authority. In the year, expenditure was £1,114, 13s. 11d., against which an instalment of grant amounting to £449, 4s. 11d. was received.

It was decided to erect two workers' cottages at Bilston at a cost of £11,908, 8s. 11d. from funds held in the General Account together with a supplementary grant from the D.A.F.S. This means that the whole of the fund, raised at the inception of the Society for establishing the Scottish Plant Breeding Station, will have been invested in heritable property and capital equipment.

Unspent balances of grants have been carried forward. These amount to £9,185, 10s. 5d., of which a portion has been reserved, with D.A.F.S. approval, for alterations to property.

During the year the Department provided £9,654, 18s. to meet the cost of capital works and equipment.

Membership

At 31st March 1969 the total membership was 356, comprising 189 life members and 170 annual members. Eleven new members were elected during the year and 16 members died or resigned.

Distribution of Membership as at 31st March 1969

Aberdeen	11	Fife	23	Renfrew	1
Angus	25	Inverness	6	Ross and Cromarty	10
Argyll	2	Kincardine	2	Roxburgh	11
Ayr	11	Kinross	1	Selkirk	3
Banff	2	Kirkcudbright	2	Stirling	6
Berwick	19	Lanark	18	Sutherland	..
Bute	..	Midlothian	62	West Lothian	7
Caithness	4	Moray	6	Wigtown	3
Clackmannan	2	Nairn	1	England	25
Dumfries	6	Orkney	3	Ireland	1
Dunbarton	4	Peebles	..	Wales	..
East Lothian	49	Perth	22	Abroad	8

Board of Directors

The Board of Directors heard with regret of the death of Mr David Bell, a Trustee of the Society for many years. Mr W. Andrew Biggar and Mr James Gray were elected Trustees. Dr H. P. Donald and Mr A. K. M. Meiklejohn were welcomed to the Board, on cooption.

Staff

The following new appointments were made during the year:—

Scientific	M. J. Allison, Ph.D. (Forages—Home-Grown Cereals Authority project). A. M. Hayter, B.Sc. (Forages). T. J. Riggs, B.Sc. (Forages),
Experimental	G. N. Price, B.Sc. (Field and Works).
Assistants	T. G. Archibald. Miss M. J. Blackhall. Miss E. A. R. Bogle. Miss R. A. Llewellyn. Miss S. P. McLean. Miss M. Orr. Mrs E. J. C. Pearce. Miss M. Thomson. R. B. W. Williamson (Home-Grown Cereals Authority project).
Administration	Mrs C. M. Leith.

The following resignations were received:—

Miss J. M. Hartridge, B.Sc.
Mrs K. I. Campbell.
Z. P. E. B. Kozlowski.
N. Miller.
D. McCall.
D. S. McDonald.
B. P. E. Thomson.
Mrs M. Smith.

The following retirements took place:—

Dr W. Black.
Dr G. Cockerham.

Dr Black and Dr Cockerham both retired after many years of distinguished service to the Station, the one noted for his contributions to potato breeding, the other for his work on the potato viruses. They were presented with retirement gifts, with the best wishes and thanks of the Society, at the 1968 Annual General Meeting. Appreciations of their work appear elsewhere in this Report.

The following interclass promotions took effect during the year to 31st March 1969:—

Dr F. J. W. England from EO to SSO.
I. A. Cowe, O.N.C. from SA to AEO.

Two visits abroad by staff was made with the aid of travel grants from the Agricultural Research Council. Mr Cameron attended the Conference of the International Association on Mechanisation of Field Experiments held at Braunschweig, July 1-6, 1968. He gave a paper on the Scottish Plot Seeder and, *en route*, visited cereal workers in Germany, Holland and Belgium. Dr J. T. Walker visited cereal research workers in Sweden and Denmark for a week in March 1969.

Members of staff attended sundry scientific meetings in the United Kingdom and gave seven lectures or seminars to various audiences in meetings or at Universities. Among these lectures was a review by Dr Black of potato blight resistance breeding at the First International Congress of Plant Pathology, London, July 1968, entitled: " Major and minor gene resistance to *Phytophthora infestans* in potatoes."

The Director again gave a course of lectures to the fourth year Botany Class in the University of Edinburgh. He also served as External Examiner to the Birmingham University M.Sc. course in Applied Genetics. Mr Fyfe was appointed an Honorary Fellow of the University of Edinburgh and gave a course of lectures on plant breeding in the Department of Genetics.

The Director also gave ten lectures in various universities and research stations during the year. He attended (25th August to 15th September, 1968) the Natural Rubber Conference in Kuala Lumpur, followed by meetings of the Coordinating Advisory Committee for rubber research. At the Conference he delivered a review lecture entitled " Genetical bases of plant breeding." Later in the year (27th November to 16th December) he visited Guyana and Barbados in connexion with sugarcane breeding research. He continued to serve on several committees within or directly connected with the work of the Agricultural Research Service. In August 1968 he discussed the work of the Station on the Scottish BBC radio.

The Station received many visitors during the year and we were pleased to see them all. There were several parties of students and farmers as well as many individual scientists from home and abroad. Two visitors, Mr K. Swiezynski from Poland and Mr B. Costelloe from Northern Ireland, both interested in potatoes, made more prolonged visits.

Awards

We are pleased to record that Mr James Gray, M.B.E., T.D., Trustee of the Society, was honoured with an O.B.E.

Acknowledgements

Acknowledgement of financial assistance from the Department of Agriculture and Fisheries for Scotland and of practical help in various forms from Universities, Colleges, Institutes, Companies and individuals has been made elsewhere in this Report. To all, whether named individually or not, who have thus supported the work of the Station, we offer our warmest thanks.

9. PUBLICATIONS, 1966-9

CAMERON, D. (1968). The development of a self-propelled plot seeder. *Proc. II Int. Conf. I.A.M.F.E., Braunschweig* 12/68.

CAMERON, D., MILNER, J. B., and CARRUTHERS, J. (1967). An automatic self-propelled seed drill for cereal plots. *J. agric. Eng. Res.*, **12**, 142-146.

ENGLAND, F. J. W. (1967). Non-sward densities for the assessment of yield in Italian ryegrass, I. Comparison between sward and non-sward densities. *J. agri. Sci.*, **68**, 235-41.

ENGLAND, F. J. W. (1968). Non-sward densities for the assessment of yield in Italian ryegrass, II. Convenient plot and block size and shape. *J. agric. Sci.*, **70**, 105-8.

ENGLAND, F. J. W. (1968). Competition in mixtures of herbage grasses. *J. appl. Ecol.*, **5**, 227-42.

ENGLAND, F. J. W. (1969). Make this polythene house for 1s. 10d. a square foot. *Grower*, **71**, 314-7.

FELL, B. F., KAY, M., and WALKER, J. T. (1967). Ruminal lesions in cattle fed on barley. *Vet. Record*, **81**, 715-6.

GLENDINNING, D. R. (1968). Regional variation in leaf form and other characters of *Solanum tuberosum* Group Andigena. *Eur. Potato J.*, **11**, 277-280.

GLENDINNING, D. R. (1969). The performance of progenies obtained by crossing Groups Andigena and Tuberosum of *Solanum tuberosum*. *Eur. Potato J.*, **12**, 13-19.

GRAY, ELIZABETH G., and MALCOLMSON, JEAN F. (1967). Some problems in chemical control of diseases of seed potato tubers. *Proc. 4th Br. Insect. Fung. Conf. Brighton* **I**, 285-293.

MALCOLMSON, JEAN F., and BLACK, W. (1966). New R genes in *Solanum demissum* Lindl. and their complementary races of *Phytophthora infestans* (Mont.) de Bary. *Euphytica*, **15**, 199-203.

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MALCOLMSON, JEAN F., and GRAY, ELIZABETH G. (1968). The incidence of gangrene of potatoes caused by *Phoma exigua* in relation to handling and storage. *Ann. appl. Biol.*, **62**, 89-101.

MALCOLMSON, JEAN F., and GRAY, ELIZABETH G. (1968). Fungi assigned to *Phoma exigua*, with special reference to those causing gangrene of potato. *Trans. Br. mycol. Soc.*, **51**, 618-620.

MERRITT, N. R., and WALKER, J. T. (1969). The development of starch and other components in normal and high amylose barley. *J. Inst. Brewing*, **75**, 156-164.

Simmonds, N. W., and Malcolmson, J. F. (1967). Resistance to late blight in Andigena potatoes. *Eur. Potato J.*, **10**, 161–6.

Simmonds, N. W. (1968). The Scottish Plant Breeding Station. *Scott. Agric.*, **47**, 79–83.

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Simmonds, N. W. (1968). Change of leaf size in the evolution of the Tuberosum potatoes. *Euphytica*, **17**, 504–6.

Walker, J. T. (1969). Selection and quantitative characters in field crops. *Biol. Rev.*, **44**, 207–43.

Walker, J. T., and Merritt, N. R. (1969). Genetic control of abnormal starch granules and high amylose content in a mutant of Glacier barley. *Nature, Lond.*, **221**, 482–3.

10. ABSTRACT OF ACCOUNTS

ABSTRACT OF ACCOUNTS

For year ended 31st March, 1969

INCOME

1968		
£407	Dividends and Interest	£436 19 0
821	Sales of Produce and Stock on Hand	469 11 5
—	Sale of Van	67 4 0
85	Subscriptions—Annual	78 15 0
	Note.—Annual Subscriptions amounting to £16 10 0 are in arrear.	
28	Rent of Cottage	45 0 0
£1,341	*Total Ordinary Income* . .	£1,097 9 5
	Grant received from the Department of Agriculture and Fisheries for Scotland:—	
111,000	Maintenance for year 1968-69	132,650 0 0
£112,341	*Total Income*	£133,747 9 5
	Balance at 1st April 1968:—	
6,456	Department of Agriculture and Fisheries for Scotland—Maintenance Grant	6,020 18 0
£118,797		£139,768 7 5

EXPENDITURE

1968			
	Salaries:—		
£56,720	Scientific and Technical Staff	£66,579 0 9	
6,459	Administrative and Clerical Staff	7,439 4 1	
1,259	Pension Supplementation	1,417 7 9	
£64,438			£75,435 12 7
5,662	Superannuation Contribution		6,117 4 3
12,391	Wages		12,779 17 8
3,050	National Insurance and Graduated Contributions		3,639 11 6
4,597	Apparatus and Equipment		4,101 15 7
2,847	Chemicals and Materials		3,063 4 10
1,972	Travelling and Subsistence		1,768 12 5
1,534	Rates, Taxes and Insurance		2,112 17 8
4,332	Power, Heat and Light		5,807 2 6
543	Library Books and Periodicals		523 1 2
590	Printing and Binding		842 14 11
1,152	Stationery, Postages, Telephones and Office Expenses		1,413 13 0
364	New Vehicles	£2,316 6 0	
1,076	Maintenance of Vehicles	1,325 6 1	
			3,641 12 1
168	Audit and Legal Expenses		178 10 0
1,160	Property Repairs		923 13 10
60	Trial Centres		221 0 0
1,035	Edinburgh Centre of Rural Economy—Contribution towards upkeep		1,053 10 0
571	Repairs and Servicing		422 5 4
645	Seed Testing, Plant Variety Trial Fees		675 0 0
26	Transport		234 9 7
1,459	Land Improvement		1,438 11 11
1,118	Advertising		651 15 6
868	Furniture		287 0 4
400	Miscellaneous		513 0 9
718	Security Patrols		—
—	Property Alterations		2,236 5 7
—	I. B. M. Computer Rentals		500 14 0
£112,776	*Total Ordinary Expenditure*		£130,582 17 0
	Balance at 31st March 1969:—		
6,021	Department of Agriculture and Fisheries for Fisheries—Maintenance Grant		9,185 10 5
£118.797			£139,768 7 5

BALANCE SHEET

as at 31st March 1969

I Funds:—		
Balance as at 31st March 1968	£223,784 15 6	
Grants received from DAFS Capital . . .	2,053 1 0	
" " " " " Equipment .	7,601 17 0	
	£233,439 13 6	
Loss on realisation of Investments . . .	137 2 1	£233,302 11 5
II Current Liabilities:—		
Accounts outstanding due by Society . .	£850 18 0	
Subscriptions paid in advance	4 0 0	
Dept. of Agriculture and Fisheries for Scotland Balance of Maintenance Grant . . .	9,185 10 5	10,040 8 5
		£243,342 19 10

	Cost	*Amounts charged to Revenue*	*Net*
I Fixed Assets:—			
Heritable Property . .	£217,119 2 2	}	£225,930 11 0
Capital Equipment . .	8,811 8 10	}	
Implements and Tools . .	14,221 8 0	£14,221 8 0	...
Vehicles	4,784 13 3	4,784 13 3	...
Laboratory Apparatus . .	14,669 14 4	14,669 14 4	...
Furniture and Fittings . .	6,585 1 4	6,585 1 4	...
Library Books . . .	5,196 0 0	5,196 0 0	...
	£271,387 7 11	£45,456 16 11	£225,930 11 0

II Current Assets:—		
Stocks on Hand as valued by Directors . .	£27 0 0	
Accounts Outstanding, due to Society . .	4,569 1 6	
Income Tax Recoverable	163 19 10	
Investments (see Appendix), at cost . .	4,086 0 1	
Cash and Bank Balances.	8,566 7 5	17,412 8 10
		£243,342 19 10

Edinburgh, *12th May, 1969*.—The undersigned, having had access to all the Books of the Society, and having examined the foregoing Statement of Accounts and verified the same with the Accounts and Vouchers relating thereto, now sign th[illegible]nd to be correct, duly vouched, and in accordance with law.

16 Alva Street.

R. L. MACDONALD, C.A., F.C.W.A., *Auditor.*

J. D. ROBERTS, *Convener, Finance Committee.*

LIFE MEMBERSHIP SUBSCRIPTIONS AND DONATIONS ACCOUNT

Dividends and Interest .	£402 8 3
Donations	110 0 0
Life Subscriptions .	110 0 0
Fee (D.A.F.S.)	11 1 0
Malayan Rubber	625 0 0
Balance at 1st April 1968	8,176 6 2
	£9,434 15 5

W. J. REID AND JAMES MUNRO BEQUESTS

Dividends and Interest .	£103 18 11
Gain on realisation of 5% Defence Bonds	4 10 0
Balance at 1st April 1968	1,812 5 10
	£1,920 14 9

DR. WILSON MEMORIAL FUND

Dividends and Interest .	£22 15 0
Balance at 1st April 1968	484 6 7
	£507 1 7

Linnean Society			£100 0 0
Restoration of Pictures			3 16 0
Loss on Sale of Guardian Royal £1 pref. shares			3 9 9
Staff Retiral Gifts			205 0 0
Flowers			5 0 0
Balance at 31st March 1969, consisting of:—			
	Investments (see Appendix), at cost	£7,583 2 3	
	Recoverable Income Tax	122 19 2	
	Cash in Bank of Scotland Current Account	710 14 2	
	Cash in Bank of Scotland Savings Account	700 14 1	
			9,117 9 8
			£9,434 15 5

Grant for hospitality			£76 5 0
Gifts (Mr Angus, Mr Burnett)			9 10 0
Balance at 31st March 1969, consisting of:—			
	Investments (see Appendix), at cost	£1,699 2 10	
	Recoverable Income Tax	37 16 6	
	Cash in Bank of Scotland Current Account	36 6 6	
	Cash in Bank of Scotland Savings Account	61 13 11	
			1,834 19 9
			£1,920 14 9

Loss on Sale of Guardian Royal £1 pref. shares			£1 3 3
Balance at 31st March 1969, consisting of:—			
	Investments (see Appendix), at cost	£464 0 1	
	Recoverable Income Tax	8 8 7	
	Cash in Bank of Scotland Current Account	8 7 0	
	Cash in Bank of Scotland Savings Account	25 2 8	
			505 18 4
			£507 1 7

APPENDIX

LIST OF INVESTMENTS

General Account

Nominal Value				*Market Value at 31/3/69*
£375	0	0	Courage, Barclay & Simonds 750 Ordinary 10s. Shares	£1,031
325	0	0	Electrical & Musical Industries Ordinary 10s. Stock Units	1,666
146	5	0	Guardian Royal Exchange Assurance Co. 425 Ordinary 5s. Shares	680
			40 7 per cent Cumulative Redeemed Preference £1 Shares	32
525	0	0	Imperial Chemical Industries Ordinary £1 Stock Units	1,614
225	0	0	National Commercial Banking Group Ltd. 900 Ordinary 5s. shares	765
				£5,788

Life Membership Subscriptions and Donations Funds

£360	0	0	City of Birmingham 6¼ per cent Redeemable Stock 1972-1973	£313
240	0	0	Courage, Barclay & Simonds Ordinary 10s. Shares	660
220	0	0	Electrical & Musical Industries 440 Ordinary 10s. Stock Units	1,127
1,983	10	6	6¾ per cent Exchequer Stock 1971	1,894
416	8	1	6½ per cent Funding Stock 1985-1987	321
82	15	0	Guardian Royal Assurance 331 Ordinary 5s. Shares	530
345	0	0	Imperial Chemical Industries Ordinary £1 Stock Units	1,061
247	10	0	National Commercial Banking Group Ltd. 990 Ordinary 5s. Shares	841
32	10	0	" Shell " Transport & Trading Co. 130 Ordinary 5s. Shares	587
1,153	0	0	Stirling County Council 7¾ per cent Loan 1977/1979.	1,038
				£8,372

W. J. Reid and James Munro Bequests

£1,359	5	9	6½ per cent Funding Stock 1985-1987	£1,047
80	0	0	Imperial Chemical Industries 80 Ordinary £1 Stock Units	246
208	0	0	Stirling County Council 7¾ per cent Loan 1977/1979.	187
				£1,480

Dr Wilson Memorial Fund

£276	12	0	6½ per cent Funding Stock 1985-1987	£213
26	15	0	Guardian Royal Exchange Assurance 107 Ordinary 5s. Shares	171
				£384

SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING

APPLICATION FOR MEMBERSHIP

The subscription is ten shillings for the year 1st April to 31st March or part of the year. Advance subscriptions will be accepted. Donors of £10 or over become life members without further payment. Applications should be addressed to:

The Secretary,

Scottish Plant Breeding Station,

Pentlandfield,

Roslin, Midlothian.

I desire to be enrolled a member of the Society and enclose the sum of

....

Name: ....

(*including Honours, Degrees, etc.*)

Address: ....

....

....

Signature: .... *Date:* ....

A note on the Scottish Plant Breeding Station

The Scottish Society for Research in Plant Breeding was founded in 1921 with the aims of conducting scientific investigations into plant breeding and of breeding plants for Scottish agriculture. Membership of the Society is open to any interested person whether farmer, merchant, scientist or other, in or out of Scotland. Management of the Society is vested in a Board of Directors which is elected partly by the members and partly nominated by the Secretary of State for Scotland. The principal activity of the Society is to look after the affairs of the S.P.B.S. The Station was for thirty-three years at Craigs House, Corstorphine, and moved to new premises on the Bush Estate of the Edinburgh Centre of Rural Economy in 1954. The Society met a third of the cost of the new laboratories but the recurrent expenses of running the Station were, from an early stage, greater than the Society could bear and nowadays nearly the whole cost is met from public funds granted by the Department of Agriculture and Fisheries for Scotland under scientific advice from the Agricultural Research Council.

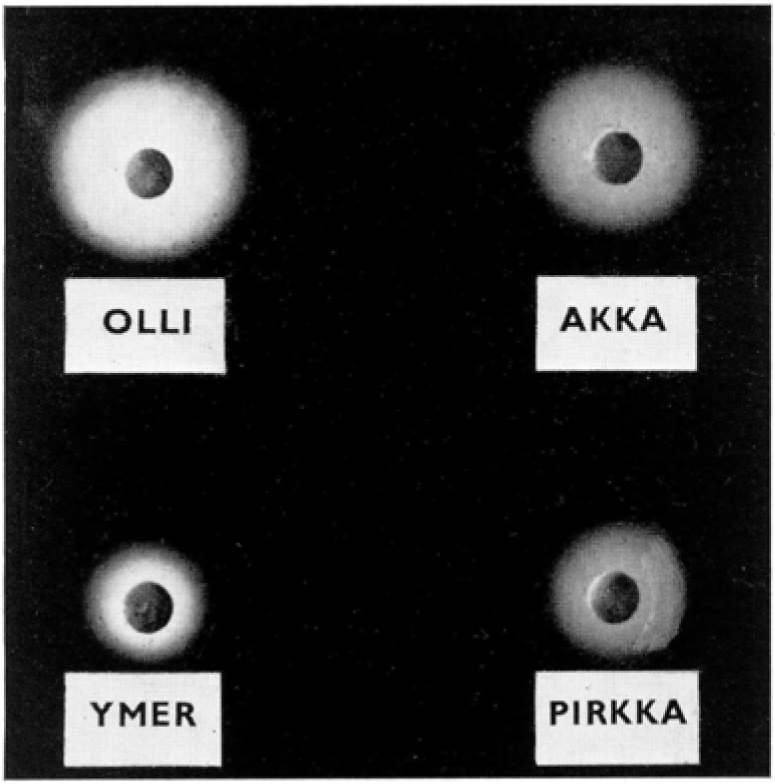
Interested persons are invited to submit the adjacent membership form. Members receive the Annual Report and any other publications and are eligible to participate in the affairs of the Society.

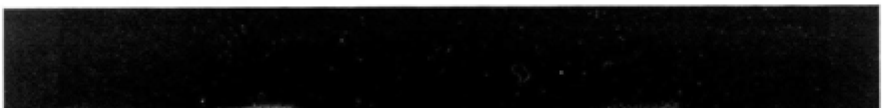
Address: Scottish Plant Breeding Station, Pentlandfield, ROSLIN, Midlothian, Scotland.

Telephone: 031-445 2171.

Location: See map on back cover.

Printed by William Blackwood & Sons Ltd., Edinburgh





HIGH DIASTASE BARLEYS. The top photograph shows the quick diastase assay method based on clearing of a starch-iodine gel; Olli has the greatest activity, Ymer the least. The bottom picture shows an electrophoretic zymogram in which the individual diastatic enzymes are separated; all four varieties have both alpha- and beta-enzymes but the first two differ from the last two in beta-amylase constitution.