SCOTTISH PLANT BREEDING STATION
PENTLANDFIELD, ROSLIN, MIDLOTHIAN
EH25 9RF

REPORT

TO THE

ANNUAL GENERAL MEETING

OF

THE SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING

26th JULY 1973

BY THE

BOARD OF DIRECTORS

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1. REPORT BY THE DIRECTOR

General

The year has been dominated—for the Director, at least—by the toings and froings generated by the Green Paper of November 1971, the subsequent White Paper and the gradual emergence, which is still in progress, of a new organization for agricultural research in Britain. The outlines of the new system now seem clear enough to justify an attempt to describe it, and this is done in a later section of this report. It is much to be hoped that a period of tranquillity will now follow. The disturbance and uncertainty generated by Rothschild and Fulton—themselves only the most conspicuous among many other concurrent changes—have not been good for the spirits of staff, even though many of the changes will, in themselves and in the longer run, probably prove beneficial. Among Directors, jokes about early retirement are only half-jokes.

Building made progress during the year, though more slowly than could have been wished. The cottages and steading at The Murrays and the three glasshouses at Pentlandfield mentioned in the last report were completed, all much behind schedule. Plans to reconstruct the blight laboratory were halted when deeper study of our needs revealed that an altogether more sophisticated potato storage facility was what was needed. At present we are planning an eastwards extension of the main building to include facilities for potato pathology (mainly blight and latent tuber diseases) together with a seminar-meeting room and staff common-room.

From April 1972 we have been systematically costing the work of the Station under guidance from ARC. Our work is divided into 22 projects and staff fill in forms monthly with estimates of time spent in various activities. The results are sent to ARC, computerized and returned in the form of quarterly statements of project costs. Costs are based upon direct staff time, overheads and allocation of expensive equipment. Since direct staff time accounts for over half the cost and is quite well estimated, a relatively simple system gives acceptably accurate results; the concept of absolute accuracy, sometimes invoked as justification of complex costing procedures (sometimes also, perhaps, as a delaying device, an excuse to do nothing), is meaningless. We hope to include project costs for 1972/73, the first full year of operation, in this report if final figures are available in time.

In response to suggestions from the Board of Directors we are introducing a new feature into this report: a Summary (section 2). The object is to try to describe briefly and in language as simple as possible the year's work for the benefit of those readers who find the report proper heavy going. We have to acknowledge that previous efforts to make the report more readable have failed: scientific results must be reported but can effectively be set out only in scientific terms. Both for the main report and the summary we use as a basis, for the first time, the ARC project list as defined for the year 1972/73. The list will, inevitably, change in future years as projects are initiated, dropped or reorientated.

The second SSRPB lecture was given on 13th April 1972 by Dr K. L. Blaxter, F.R.S., under the title " Plants for Animals ". The audience was a full one and the lecture a resounding success. The third lecture will be given by Prof. K. Mather, F.R.S., on 12th April 1973, with the title " Genetics and Plant Breeding ". A summary is included later in this report.

Reference was made earlier in this section to the many administrative and structural changes that have been initiated in the past two or three years. Committees proliferate and paper multiplies and both will yet get worse; there is no hope that either will just go away, nor that they can be conscientiously evaded. In short, the administrative load is inexorably increasing. In recognition of this and of the, in some ways, peculiar position of the Director of the SPBS, the DAFS and ARC have agreed that we shall appoint a full-time Deputy Director. The plan is that Mr Fyfe shall take on the job, and that we shall fill the vacancy so created as Head of the Forage Crops Department by a suitable appointment. We hope to be able to make the appointment before the end of the summer of this year, 1973.

The use of the computer has grown rapidly in the Station, from nil, five or six years ago, to substantial and still increasing at the present time. There are now nine registered users on the staff. All our work is done on the machines of the Edinburgh Regional Computing Centre to the operation of which three Research Councils (ARC, MRC, NERC) make a substantial contribution. Work is transmitted either by teleprinter and line or by daily van service, usually in the form of stacks of cards. Results return either as teleprinter output in the Station or, more generally, as line printer output, by van, from the Centre. The system works well and has resulted in an enormous increase in range, sophistication and accuracy of calculation. However, users generally feel the need for the faster turn-round which would be offered by easy access to a " remote job entry terminal "; this, in effect, is a small computer, with all the necessary peripheral equipment, which is linked to the big distant machine and serves as a high speed means of both putting in work and getting back results. In 1972, a joint venture between the National Institute of Agricultural Engineering (Scottish Station), Hill Farming Research Organisaton and ourselves was directed to providing such a facility. With the aid of an ARC grant, a small computer (PDP 11), *plus* ancillary equipment, was installed at NIAE for the joint use of the three institutes. At the time of writing (February

1973) the installation has just become fully operational. It will be greatly appreciated.

Forage Crops Investigations

ARC Project 1: Barley genetics

Genetical and systematic studies in support of barley breeding programmes, including breeding methods and classification of collection.

(Workers: A. M. Hayter, T. J. Riggs)

In the "halo" test a rough estimate of diastatic power (DP) is given by the diameter of the circle of starch gel digested by a measured drop of extract from a germinated grain. The test was used in a selection experiment on material from a composite cross. Selection for high (H), mid (M) and low DP (L) was practised for two generations. After one generation the means of the three groups showed $H > M \sim L$. After two generations the position became $H > M > L$. There was a correlated response in respect of dormancy, L being the most dormant, though none of the material was free of dormancy. Although the method has the disadvantage that successive increments in enzyme concentration produce smaller increments in diameter, it does provide a simple and cheap method of selection. Our need for it is reduced because we have developed a partly automated method of estimating DP using an auto-analyser. Lines selected for agronomic features and with high DP, confirmed on the auto-analyser, were transferred to the high-DP breeding project. The experiment was discontinued.

Another selection experiment, with a different composite cross, approached completion in 1972. Its object was to test the utility of canonical analysis as a method of selecting towards a generally acceptable type of feeding barley. In a lattice square trial, 42 selections were compared with standard varieties. The highest yielding standards were Universe and Maris Mink; the highest yielding selection gave 98 per cent of their mean yield, the difference being non-significant. The best five selections were kept for more extensive testing. Only two generations of selection were involved and it is encouraging that such useful material can be quickly extracted from a composite cross; canonical analysis is clearly capable of extracting it, but whether it is the best method remains an open question. It has the disadvantage that it implies gathering a vast body of data, much of it from lines that are obviously due to be scrapped. On the other hand the skill needed to gather the data is minimal and the processing of the data by computer is automatic.

Rachilla-hair length was used as a marker to establish natural crossing in yet another composite cross. Taking account of the recessive (short) and dominant (long hairs) phenotypes, of the frequency of heterozygotes among the dominants and of the frequency with which dominant plants were obtained in progeny of recessives, an estimate of 2 per cent crossing was obtained. This is rather higher than had been expected and, if confirmed, would imply a useful degree of recombination within the composite cross. The plants known to be crossbred can be used as the start of a second cycle of composite crossing.

The barley collection has grown to about 1,100 accessions; ear and grain characters have been measured on 20 ears of each of 800 accessions. Field characters of 650 accessions have been recorded. The computer program which calculates canonical variates has been extended to produce a dendrogram, using Rothamsted algorithms. In a preliminary run with over 400 accessions, using grain and ear characters, the dendrogram produced showed broad geographical groupings of land varieties. Modern varieties also showed discernible groupings, though less clearcut. The conventional taxonomic characters were not used in the analysis but it could be shown by analysis of variance that the cells into which they divide the collection differed significantly in respect of several canonical variates. A classification based on conventional taxonomic characters is less arbitrary than it might appear. Striking variants, like hooded or naked grain, show marked separation from the rest; this may be due to single gene differences, of large effect, disguising natural affinities. A start has been made on typing accessions in respect of α- and β-amylase variation, displayed by agar-gel electrophoresis; so far, 120 accessions have been examined.

A variant which occurred in our accession of Glacier has lax ears and five stamens. Crossed with normal barley it was recessive and segregated in F_2 into 63 normal: 1 variant, indicating three duplicate loci. F_3 segregations in 1972 were consistent with this hypothesis.

Work continued on the large diallel cross experiment grown in 1970 and 1971. Statistical analysis of the data on time to heading, ears per plant, grains per ear and weight per grain has been completed and two papers are in the press. Nitrogen determinations on grain have been completed but there has been a delay in completing DP and α-amylase determinations, because of a failure of the supply of Lintner starch. Progenies from the diallel have been incorporated in the breeding work on feeding barley and high-diastase barley.

ARC Project 2: Barley biochemistry

Biochemical genetics of diastatic enzymes in relation to barley breeding; mutagenesis.

(Worker: M. J. Allison)

The β-amylases of malted barley, on electrophoretic separation, are seen to be of two types, called by us Sd1 and Sd2. The latter, which is about twice as common as Sd1, shows its strongest starch-digesting activity in the last, or most cathodic, band; in Sd1 the last band is very weak and the strongest band is the last but one. On crossing, the F_1 grains produce strong bands at both positions; minor differences between reciprocal crosses suggest dosage effects in the triploid endosperm. F_2 grains segregate in the ratio 1 Sd1 : 2 heterozygote : 1 Sd2. Work at Aberystwyth showed that, in developing (pre-harvest) grain of Deba Abed, three zones of β-amylase activity appear, zone I in the youngest grain, then zone I + zone II and finally all three. We have found the same to be true of Golden Promise, Himalaya, Mochimugi, Maris Baldric and Plumage Archer. Each zone has three bands. Bands II.2 and II.3 are strong, with maximum activity in II.2. We propose to call this type Sd^f. A second type, called Sd^d, develops only bands I.1, I.2, I.3 and II.1; bands I.3 and II.1 are strong, with maximum activity in I.3. Pirkka and Zephyr are of this type. A third type, called Sd^e, is represented by Glacier (both the original variety and the high-amylose variant). Here bands I.1, I.2, I.3, II.1 and II.2 develop; II.1 and II.2 are strong, with maximum activity at II.1. Crosses between Pirkka and Golden Promise produced F_1 grains showing co-dominance, with four strong bands, and a 1:2:1 segregation in F_2 grains. The six Sd^f varieties are all of type Sd2 in their malts, the others being Sd1. It is suspected that this is a case of multiple alleles, with only one locus involved, but this needs further genetical work to confirm.

Canadian workers found that by comparing the β-amylase activity in aqueous extracts of mature, ungerminated grain (free β-amylase) with that achieved after 20 hours treatment with papain (total, or free + bound, β-amylase), they could divide varieties into two groups, high and low, according to the fraction of the total which is free. We have confirmed and extended these results. If the dividing line is taken at 50 per cent, 35 varieties studied divide into 13 high and 22 low; without exception the lows are all Sd1 and the highs all Sd2. We find, however, that the division is not as clear cut as reported from Canada and also that varieties exist with a lower proportion of free β-amylase than any they reported. The results suggest that aspects of β-amylase in the immature grain, the mature grain and the malt may be under control of a rather simple genetical system—perhaps only one locus.

Close correlations between the total β-amylase of resting, mature grain and malt DP have often been reported. They are of interest to the breeder because determinations which do not require controlled germination are more repeatable than those which do. We have confirmed the correlation, using the standard, manual method of determining DP and two different methods for total β-amylase. In both cases the correlation was 0·97. The correlation between total β-amylase and auto-analyser estimate of DP is lower (about 0·72), though still useful. One of the methods can be used with single grains, leaving the embryo available, if needed, to produce a plant.

Some attention has been given to the sequence of α-amylase production in the pericarp, the aleurone and the rest of the endosperm in developing grains. The young pericarp has high activity, reaching a maximum 13 days after awn exsertion; the electrophoretic pattern does not change with development. The aleurone and the rest of the endosperm both start with a different electrophoretic pattern from the pericarp and both reach a maximum activity 25 days after awn exsertion; their electrophoretic pattern changes with development, passing through a stage similar to the pericarp's pattern. The level of phosphorylase activity in each tissue runs parallel with α-amylase activity; perhaps the same enzyme is responsible for both activities.

DP determinations were made on 17 of the 23 lines selected by abscisic acid screening from Ymer treated with ethyl methane sulphonate (see *Ann. Rep.* **51**, 1972). The nitrogen contents of this grain in the 1971 season were very high and the Ymer control gave 250° Lintner in green malt. One mutant line gave a DP of 320°L and another had high α-amylase, though with rather low grain set. The lines were increased in 1972 and the low fertility of the high α-amylase line was confirmed. Maris Mink and Universe were treated with EMS and M2 grain has been harvested for screening.

ARC Project 3: Barley breeding

Breeding spring barley varieties for Scotland, with specific objectives: feed; high diastase and high amylose types for whisky.

(Workers: R. P. Ellis, A. M. Hayter, T. J. Riggs)

Variety-nitrogen trials were conducted at three sites, in Fife, East Lothian and Midlothian. There were 15 varieties grown at three levels of applied nitrogen, with and without repeated spraying with Calixin to control mildew. The spray treatment was very intense by commercial standards and Universe, showing little mildew in any case, was somewhat reduced in yield by spraying. The best average yields were given by Maris Mink and Universe; Golden Promise yielded well when sprayed. The response to nitrogen, averaged over varieties, was improved by spraying, which reduced mildew attack. In 1971 the improved response was obtained with Golden Promise only; averaged over varieties, the response to nitrogen was not significantly affected by spraying in 1971. The mean response to spray in 1972 was only 4 g/m^2, but for Golden Promise it was 45 g/m^2 (about 3 cwt/acre).

Pedigree breeding aimed at a high yielding barley for feed involved some 17,500 F_2 plants and 1,500 F_3 selections, some 200 of which were carried on to F_4. A further 56 crosses were made, using varieties tested in our own trials. Reference has already been made to selection by canonical analysis of feeding barley from composite crosses; in addition, 1,200 ear-rows were grown at F_7 for their first season of selection and 275 at F_8 for their second season.

The breeding work on high-diastase barley was on a similar scale, with 24,000 F_2 plants and 1,000 F_3 rows. Selection on field characters reduced these to 2,000 F_2 plants and 200 F_3 rows; further reduction will follow laboratory tests. The most promising material derives from Midas × Akka; the best F_3 rows combined the short erect habit of Midas with DP approaching the very high level of Akka. Maris Mink and Universe have been crossed both to high DP varieties and to selections from the halo-screening experiment; F_2 seed was raised in the greenhouse for 1973 field sowings.

In the back-cross programme to transfer the gene for high amylose from our Glacier mutant to acceptable two-row varieties, it had been found that the starch-grain phenotype of the high-amylose mutant was not recovered on self-fertilizing the sixth back-cross generation (cf. *Ann. Rep.* **51**, 1972). It was feared that this meant that the high amylose content had not been recovered. Chemical determinations of total starch and of amylose confirmed that this was indeed the case. The highest amylose content of any derivative of sixth back-crosses was 38 per cent; this was disappointingly low, compared with 46 per cent in the original mutant, and doubly so because the recurrent parent was Proctor, a variety of little interest in Scotland. Attention was therefore turned to inbred derivatives of third and fourth back-crosses, which had been carried for a different purpose. A virtually continuous range of amylose contents was found. High-amylose derivatives have been found with Midas, Zephyr, Akka and Proctor as recurrent parents and the best of these have been increased in the greenhouse for field sowing in 1973. The work continues to be hampered by the lack of a quick and reliable method for chemical estimation of amylose. In the course of the work, some variation in amylose content in existing varieties has been found and the correlation between maximum starch grain size and amylose content was confirmed to be negative, though much looser than in crosses between Glacier and its mutant.

ARC Project 4: Oat breeding

Breeding spring oats for Scotland, including eelworm resistance and varieties for marginal areas (uplands, islands and machair).

(Worker: D. Cameron)

The oat programme was described at some length in the 1971–72 Report and so a briefer account will be given here. In the most advanced material there are six candidates for varietal status. Work on evaluating these and producing pure stocks continued. The evaluation was hampered by the loss of a trial because of damage by sheep. The oldest composite crosses are going successively through the selection procedure. These were set up in 1965, 1966 and 1967. More recent composites have been designed to meet specific requirements. A naked-oat composite was set up in 1971, a short-strawed one in 1972 and also one resistant to stem eelworm (Ditylenchus). In the pedigree breeding for eelworm resistance, promising yields from short-strawed types were obtained in preliminary trials. An attempt is being made to obtain early mutants from Aa725, a Station selection with good yield and very strong straw but maturity rather too late for Scotland. From an M2 generation following treatment with ethyl methane sulphonate, 30 early selections have been taken; a further M1 generation has been raised. The breeding work on grey speck resistance is nearing completion. Since the work was started, control by spraying manganese has become a common routine on the machair soils in the West. The need for a resistant variety is thus less urgent, though it would still be useful.

The whole oat collection of some 500 accessions has now been grown and about half has been described.

ARC Project 5: Hybrid swedes

Methods of exploitation of known intervarietal heterosis.

(Worker: S. Gowers)

Production of F_1 hybrid seed by natural pollination was examined in six inbred lines from the self-incompatible swede APZ. These lines were placed in isolation plots with the marker variety Parkside to test the degree of outcrossing. Whilst Parkside produced only 7·2–26·8 per cent outcrossing, the APZ lines produced 97·4–99·6 per cent hybrid seed. A yield trial of the hybrids showed an increase in dry matter yield of 11·5 to 28·8 per cent over the higher parent. This is probably the first time self-incompatibility has been used to produce hybrid swedes in bulk.

The proposed scheme for commercial production of F_1 hybrid swede seed involves the breeding of three isogenic lines with different *S* alleles for each of the varieties to be used as parents. It is intended that seed of the parents will be multiplied in the three-way crosses between the isogenic lines and then sown together to produce F_1 hybrid seed. Towards this end, isolation of several *S* alleles in *B. napus* and their introgression into the parent varieties of swedes has started.

Although the APZ line has the only known naturally occurring *S* allele in swede, they appear to be slightly more common in rape and three alleles have been obtained from Matador rape. Although uncommon in natural *B. napus*, many artificially produced *B. napus* lines show incompatibility. Two lines produced at the Station appear to have two *S* alleles each; three, possibly four, *S* alleles have been isolated from Panter rape; and several lines of artificial *B. napus* produced in collaboration with Dr D. Harberd of Leeds University also show self-incompatibility. The most promising of these lines are now being backcrossed to swedes.

Before the range of *S* alleles described above was obtained, we had thought that the easiest way to obtain self-incompatibility in swedes would be to introgress *S* alleles from turnips. Over 200 swede-turnip hybrids were placed in an isolation plot with swedes, in an attempt to obtain *B. napus* plants directly from the backcross. Although only a small amount of seed set is obtained when this cross is performed in the glasshouse, hybrid plants flowering in coincidence with the swedes produced quite large quantities of seed. Some plants produced over 50 gm of seed, which is as much as is usually obtained from swedes. Only a small number of plants have been examined cytologically and no 38-chromosome plants have been found so far. However, this is not surprising as, assuming random distribution of the c genome at metaphase I in the sesquidiploids, only one plant in 512 would be expected to have 38 chromosomes.

Although this line of work is now not needed for the introgression of *S* alleles into swede, it is to be continued so as to examine any resulting *B. napus* plants for cytoplasmic male sterility. In order to examine a wider range of cytoplasms, crosses have been made of oriental varieties of *B. campestris* with swedes.

Examination of seven lines of swede showing male sterility showed that six of these lines, when crossed with normal swedes, produced only male-fertile offspring. It is assumed, therefore, that these male steriles are due to recessive genes. An eighth line, when crossed with normal swede, showed segregation of male-fertile and male-sterile offspring. This may be due to a dominant gene, but the parent plant of this line showed univalents at meiosis and the two phenomena may be related. Further examination of this line is planned.

ARC Project 6: Swede breeding

New swede varieties to replace Pentland Harvester for mechanised cultivation.

(Worker: Miss I. K. Munro)

A trial of 134 F_4 lines from crosses involving Pentland Harvester was grown in four replications at The Murrays. The Pentland Harvester control gave poor establishment; the other control, Bangholm, was better. More than half the lines yielded more dry matter than the better control. There was obviously plenty of material in which to select for resistance to raan, had the condition occurred. In fact, it did not, even in Pentland Harvester.

F_4 seed was produced from lines of crosses not involving Pentland Harvester, for field trial in 1973. An élite line of Pentland Harvester, with less than average incidence of raan, was increased for further testing.

ARC Project 7: Tetraploid turnips

To test alleged superiority of tetraploid turnips and, if superior, produce varieties.

(Worker: S. Gowers)

A trial was made to examine five lines of tetraploid turnips and their respective diploid progenitors. Diallel crosses at both levels of ploidy were also included to examine the prospects of producing a synthetic variety from these lines. Heterosis for yield was shown at the tetraploid level, but not at the diploid level. In all cases, however, the tetraploid lines were inferior to their respective diploid lines. It was concluded that no advantage could be gained from breeding at the tetraploid level and the project has been terminated.

ARC Project 8: Kale improvement

Study of kale breeding systems with object of developing genetically widely based grazing types.

(Worker: G. R. Mackay)

Progenies from polycross progenies were grown and harvested at The Murrays, as were bi-parental progenies in a biometric experiment. No analyses of the data are so far available. In the final stages of the investigation of matromorphs, produced by pollinating *Brassica oleracea* by *B. campestris*, it was established that there was response, within progenies derived by selfing matromorphs, to selection for early flowering. A comparison of the variability of young plants failed to show that matromorphs give more uniform progeny on selfing than do inbred plants from the same individual. It is now regarded as thoroughly established that the matromorphs are not completely homozygous, as had been claimed in the literature.

ARC Project 9: Brassica wide crosses

Exploitation of polyploid interspecific crosses as possible rape-substitutes or as new forage species, including: *napocampestris* (5x and 6x) artificial *napus* (4x) and triploid (aac) hybrids.

(Workers: G. R. Mackay, I. H. McNaughton)

Derivatives of back-crosses of *B. napocampestris* to rape showed some improvement in dry matter content. Yield assessment was prevented by poor establishment. Work on *napocampestris* is now terminated.

Artificial *B. napus*, produced by crossing *B. campestris* and *B. oleracea* at the tetraploid level, is valuable both as a source of *S* alleles (see project 5, above) and as a means of extending the range of variability in rape. Those produced in collaboration with Dr D. Harberd have low seed fertility which, however, can be greatly improved by crossing with rape. The F_1 hybrids show heterosis to a useful degree. The F_1s with Nevin rape plants gave yields of dry matter up to 30 per cent better than Nevin. F_2 segregants have been selected for leafiness, vigour and tillering capacity.

The greatest difficulty in work with artificial *B. napus* is in making the initial interspecific cross. From thousands of pollinations, we have obtained by embryo culture only one certain hybrid and one which is almost certainly hybrid. Both had tetraploid *B. campestris* as female parent, although far more pollinations, and ovules cultured, had *B. oleracea* as female parent. From over 2,000 pollinations on *B. campestris* as female, over 1,000 ovules were cultured, of which 9·4 per cent started embryo growth; losses occurred at all stages up to establishment in soil. More studies on technique are obviously needed; meantime, intraspecific tetraploid hybrids are being developed as potential parents.

The triploid hybrids of turnip and rape (see *Ann. Rep.* **51**, 1972) were analysed for digestible organic dry matter. On average they yielded 15 per cent more than the rape controls. The next step is to produce *S*-allele homozygotes in turnip. This will allow hybrid seed production on a larger scale. Diallel matings were made within progenies produced by selfing; the compatibility relations were studied by the ultra-violet fluorescence technique and 13 putative homozygous lines were established.

ARC Project 10: Raphanobrassica

Intergeneric allopolyploids as new forage species, with clubroot resistance, to substitute for or supplement rape.

(Worker: I. H. McNaughton)

A small greenhouse has been adapted for testing resistance to clubroot (*Plasmodiophora brassicae*) and 15 collections of Plasmodiophora from southern Scotland have been typed, using differential hosts obtained from the Welsh Plant Breeding Station. Nevin rape was attacked by eight of the collections, five of which attacked all the differential hosts. Two of these virulent collections were tested against five F_4 families of Raphanobrassica. All five families were wholly resistant to one culture. With the other culture, one family was completely resistant and the others between 70 and 90 per cent resistant. One of the expected advantages of Raphanobrassica over rape has thus been confirmed.

A transplanted field trial of 24 F_4 families of Raphanobrassica against Nevin rape was grown. Severe stunting of many Raphanobrassica plants occurred and only 11 per cent were as vigorous as rape. By late September 20 per cent had flowered; this was from a late June sowing, giving only a few bolters in the rape. There were differences between families in respect of both vigour and bolting, as there were also in other F_4 families in observation plots. One F_4 family in the latter showed only vigorous plants.

Low seed fertility continues to hamper the work, though it is slowly improving in the later generations. Some 10,000 new pollinations were made, using a selected, late-flowering tetraploid radish and tetraploid *B. oleracea* (mainly marrow-stem kale). Radish proved easy to cross with *Raphanus maritima* ($2n = 18$) and the hybrids have been treated with colchicine. It may be possible to reduce bolting in Raphanobrassica by using derivatives of this cross as the Raphanus parent.

ARC Project 11: Grass breeding methods

Biometrical genetics and population studies aimed at advancing breeding techniques; using Dactylis and Lolium.

(Worker: F. J. W. England)

In a large experiment with Italian ryegrass, planted in 1971, 59 reciprocal pairs of progenies, produced according to the North Carolina I design, are grown as wide-spaced plants, as spaced plants in narrow rows and as swards.

Yields were measured and other attributes scored in 1972 and a cold period in February 1973 allowed scoring for frost damage. Analyses of the frost damage scores showed large and significant differences associated with average effects of parents. A rough estimate of narrow-sense heritability on a single-plant basis was 27 per cent. Heavy statistical analyses on this experiment remain to be done.

Each of seven first inbred lines of Italian ryegrass was crossed with each of seven perennial ryegrass inbred lines to form a North Carolina II design for planting in 1973. The ventilated isolation tents designed at the Station were used, pairs of seedlings being isolated together.

In theory, pooling two unrelated first inbred lines of ryegrass, well matched in flowering date, should lead to 78 per cent crossing. To test this, four isolations in different greenhouses were set up; in each case one line was Italian and the other perennial ryegrass. Seed was harvested for 1973 sowing.

Measurements on a large inter-population diallel experiment in cocksfoot were completed with determinations of *in vitro* digestibility. The design of the crosses was not fulfilled in practice, which makes the accurate analysis difficult. A rough estimate of heritability of yield, on a single-plant basis, for a total of two cuts in 1970 is 32 per cent and a similar estimate for 1971 is 27 per cent; for the sum of the four cuts the estimate is 35 per cent. The populations crossed in this experiment are a sample of a much greater number which entered a cocksfoot composite cross. The implication of these estimates is that the composite population would respond to mass selection for yield, at least in the early generations of selection.

The cocksfoot composite cross population has been sown in its third cycle on three different sites, one being at about 1,000 feet (300 m), to be grazed by sheep.

ARC Project 12: Winter kill in ryegrass

Nature of winter kill and selection techniques, including collaboration with WPBS.

(Workers: F. J. W. England, Miss C. J. Williamson)

Recovery cuts were harvested from the experiment with perennial ryegrass and all the data were sent to the Welsh Plant Breeding Station (see *Ann. Rep.* **51,** 1972); none has come back. The experiment has been ploughed out. The response to selection for winter hardiness practised on wide-spaced plants of Italian ryegrass was assessed in a spaced-plant trial of 190 polycross progenies and controls. No analyses are yet available.

ARC Project 13: Cocksfoot breeding

Selection of nutritious and high yielding derivatives of Scotia cocksfoot.

(Worker: Miss C. J. Williamson)

Better progress was made with assessment of digestible organic dry matter (DOMD), although assessment of field characters was hampered by illness. A backlog of DOMD determinations on F_2 plants was worked through and showed that 26 per cent of some 400 plants had DOMD of 70 per cent or over; 80 progenies from these have been raised for field planting in 1973. F_3 progenies planted in 1972 were assessed for DOMD from an autumn cut on a progeny basis. Nearly half of them had 68 per cent or more DOMD. As this project is the largest "customer" for DOMD *in vitro* determinations it may be appropriate here to thank the Moredun Institute for their past help with fistulated sheep and also to thank the Hill Farming Research Organisation for the help they are now giving, closer at hand.

ARC Project 14: Poa breeding

Interspecific hybrids of *Poa pratensis* as perennial, rhizomatous grasses for hill land.

(Worker: Miss C. J. Williamson)

Multivariate analysis of 81 possible hybrids, obtained by pollinating *P. ampla* by *P. pratensis* in 1969, showed that 47 were hybrid; the remainder were classed as *P. ampla*. F_2 progenies from 40 hybrids are involved in three trials at The Murrays (spaced plants and micro-swards) and in one micro-sward trial on Turnhouse Hill, by courtesy of the Hill Farming Research Organisation. F_2 progenies from the crosses made in 1968 have been assessed in 1972 as spaced plants. The overall impression is that about a tenth of the *P. ampla* derivatives and nearly half of those from *P. iberica* and *P. longifolia* are worth further study.

ARC Project 15: Breeding systems

Theoretical (including computer) models of breeding systems; biological models and trials systems.

(Workers: D. A. Couzin, J. L. Fyfe)

A computer program has been developed, for use from an interactive terminal, to simulate plant breeding procedures. The object is to test and compare different breeding plans. The system simulated is an organism with two chromosomes (n = 2), with arbitrary numbers of loci, arbitrary recombination frequencies, interference according to Kosambi's rules and arbitrary gene effects (*d* and *h* in Mather's sense). The environmental variance has an expectation of unity. The player of this " game " can produce " progenies " by single matings (self or cross) or by batch matings and can select from the top, middle or bottom or at random.

A start has been made on work with Arabidopsis in growth chambers but no breeding operations have started yet. The installation of the growth chambers has given a great deal of trouble.

Potato Investigations

ARC Project 16: Potato breeding

New varieties (early and maincrop) for ware and processing (crisps, chips, dehydration, canning).

(Workers: T. M. W. Davidson, J. M. Dunnett, A. W. Macarthur)

Two promising new early-maincrop clones were entered for Plant Variety Rights and Statutory Performance Trials following regional trials at three centres in England and one at The Murrays, East Lothian. Their identities and a brief description are given below:—

Clone 6456 ab(50), derived from the cross 3059(2) × 3071(1) is a possible dual-purpose variety suitable for processing or for direct consumption. The dry matter content is high, but below that of Record, while the tuber yield is below that of P. Crown but distinctly higher than Record. Tuber size is uniformly medium-large with good keeping characteristics. The high dry matter content, which is of interest in relation to processing, gives a floury potato on boiling, bright and attractive in appearance but liable to disintegration. The clone is notable for extreme field-resistance in foliage and tubers to blight, for resistance to viruses X, A and C and probably to virus Y also.

Clone 6371 abc(23), derived from the cross 3033(5) × 3071(1) is another potential dual-purpose variety which approaches the yield of Pentland Crown and the dry matter content of Record. Cooking quality assessments are variable from the regional trials but usually superior to P. Crown. It yields a floury potato on boiling and should preferably be steamed to avoid disintegration. It has been classed as very resistant to gangrene, resistant to common scab and has very high field-resistance to blight in foliage and tubers.

The breeding methods for first-early varieties were changed during the year, to take into account two features of first-early production which influence the efficiency of selection. The first is the geographical localisation of first-early production in Cornwall, west Wales and the Ayrshire coast. Climatic conditions in these regions differ so much from those in East Lothian that selections made at Pentlandfield or The Murrays cannot be expected to show any particular adaptation to early production in the west and south-west. Furthermore, in order to promote tubering at the earliest possible date, specialist growers are accustomed to planting so-called "physiologically-old" seed tubers. Both factors are of considerable importance in first-early potato production and a selection programme must take them into account.

The earlier system of testing fairly advanced selections in Cornwall and Ayrshire was extended last year to Pembrokeshire and this year to the Gower peninsula as well. We intend, in future, to screen material at an earlier stage in the selection process at these four centres, to multiply seed of the most promising at one of them, to chit it in accordance with local practice so as to plant fully replicated trials with suitably prepared tubers. In this way we expect to make more realistic assessments of new clones against established varieties.

The main breeding programme utilizes parents derived from related programmes producing virus resistant, eelworm resistant and, more recently, Neo-tuberosum material, together with well tried Tuberosum parents. Some 40 per cent of the clones which, in 1972, were in their second year at Blythbank, were derived from crosses between Neo-tuberosum and Tuberosum. A full assessment of this material will be made during the next four years under lowland conditions at The Murrays, but present indications are that the Neo-tuberosum derivatives are at least as promising as the more conventional material derived from Tuberosum parents.

The high specific gravity programme designed to produce processing varieties was begun in 1970 with a crossing programme. The first material to reach the field was planted as single plants at The Murrays in 1972 using small tubers from glasshouse grown seedlings, planted alternately with single plants of Arran Victory. The 14,000 plants were successfully harvested by the single-plant potato harvester. The purple tubers of Arran Victory provided a check on the efficiency of the machine in keeping separate the tubers from each plant. Rapid retain-reject decisions based on tuber appearance were made on the machine during the harvesting process. Five-tuber samples from selected plants were subsequently scored for specific gravity and 960 with values equal to or greater than the Record control were retained. To continue this programme, some 25,000 single-tuber selections from glasshouse grown seedlings in 1972, are available for field planting in 1973 while 70 diverse parents with moderate to high specific gravity were crossed with Pentland Ivory to maintain the flow of progenies.

A start was made during the year towards improving tests for cooking quality. It is intended to assess this character in future on material grown at The Murrays rather than on that from Blythbank, as was necessary in the past. Material from The Murrays will be more mature and the dry matter and texture scores more realistic. Initial assessments are made in the fourth year of selection on small tuber samples cooked at atmospheric pressure in an industrial steamer. More detailed investigations are made on those clones surviving to the Regional Trials stage. Samples of each clone from each of the trial centres are peeled and steamed individually for their own optimum cooking time.

The Department of Agriculture of Malawi have released a new blight resistant potato variety under the name Roslin Bembeke. This variety was selected in Malawi from breeding material sent from Pentlandfield in 1967. Excellent results from earlier Roslin varieties in Malawi in 1968/69 were reported in 1972 (*Ann. Rep. Dep. Agric. Malawi*). Roslin Bvumbwe, Tsangano, Castle and Eburu, all field resistant to blight, gave roughly four times the yield of older susceptible varieties and have been widely distributed to farmers. Irrigated crops of Roslin Tsangano and Eburu gave yields in the 11–16 t/a range, which is exceptionally high for the tropics.

We agreed this year to supply annually to potato breeders in Pakistan surplus tubers from unselected glasshouse grown seedlings. It is hoped that this material will yield varieties for use in Pakistan.

ARC Project 17: Potato disease resistances

Resistance to virus, eelworms and various fungi (causing blight, scab, storage diseases) in above breeding programme.

(Workers: T. M. W. Davidson, Miss J. F. Malcolmson, W. G. Rogers, Miss H. E. Stewart)

Routine screening for blight reaction of material in the general breeding programme, again revealed resistance in several families. In leaflet tests, resistance of the upper surfaces to infection was particularly evident in families derived from *S. vernei*, a parent used primarily as a source of quantitative resistance to potato cyst eelworm. Resistance to sporulation was also recorded in detached leaflet tests on some of the élite diploid clones. However, many of these clones, when subjected to whole-plant tests, showed extensive infection with necrosis and tissue collapse.

The poor correlation between foliage and tuber resistance was again apparent (*Ann. Rep.* **51**, 13, 1972).

Samples of 50 plants from each of 22 families, selected on the basis of small lesion size and reduced sporulation in detached leaflet tests, reacted in the same way when tested as whole plants. This correlation between the results from the two types of test is encouraging and supports the continued use of the detached leaflet test for large scale screening. However, the need remains for whole-plant tests on material classed as resistant by detached leaflet test because, in some families with resistant leaves, the stems have been shown to be susceptible.

Arising from this routine screening work on blight resistance is an increasing body of evidence on the different manifestations of resistance in the host (*e.g.*, restriction of lesion size or limitation of sporulation) and also on the possibilities for different response to the pathogen by leaflet, petiole, stem and tuber. These aspects of host-parasite relations are the subject of a separate research project which, it is hoped, will lead to a fuller understanding and more efficient exploitation of " field-resistance " to blight.

In the organisation of the breeding process it is always desirable to conduct tests for resistance to important diseases as early as possible, so as to avoid multiplying clones which are to be rejected later because of disease susceptibility. This is particularly so in the case of gangrene resistance in the breeding of processing varieties, which are liable to have to withstand prolonged storage. Early testing therefore would be advantageous, providing it could be done on a few tubers since the large bulks currently used (20 to 30 tubers) are not available during the first few years of selection.

Four methods of inoculation have been tried in the gangrene work:—

(i) dipping whole undamaged tubers into inoculum,
(ii) rubbing tubers in a sand/cornmeal inoculum, using non-riddled tubers,
(iii) as in (ii) but using riddle-damaged tubers, and
(iv) point inoculation into undamaged tubers.

The first method is similar to that used in the past in the Scottish Merit Trials. The second method differs from the first only in that a dry inoculum is used and that the sand causes some abrasion of the tubers. The third, using riddle-damaged tubers, is closest to farm conditions where gangrene is usually associated with tuber damage. However, the randomness of the number and distribution of infection sites mitigate against interpretation of data except on large samples. The fourth method, point inoculation, has the great advantage that, if successful, few tubers would be required for the test. Tests of the point inoculation method (iv) have been found to give results which are in close agreement with those from the less precise methods requiring larger numbers of tubers. Accordingly, it has been decided to use this method for the routine screening work in future, while keeping the question of methods under constant review.

Routine testing for tuber reaction to common scab is made on fifth-year material from the general programme by planting tubers in sandy land at Archerfield, East Lothian, known to be heavily infected. Although susceptible varieties usually show severe scab symptoms, the pathogen is not uniformly distributed and escapes from infection are not uncommon. To supplement the field test, therefore, a start has been made on developing a glasshouse test for scab reaction, though we are aware that little success has attended similar ventures in the past.

The most advanced material in the eelworm resistance programme based on *S. vernei* reached the fourth year of selection and was grown at The Murrays. Of over 14,000 seedlings derived from (*S. vernei* × *S. tuberosum*)^2, 59 clones remain, a survival rate of 0·4 per cent. On the other hand, 1 per cent or 67 clones survive from the 6,500 seedlings derived from (*S. vernei* × *S. tuberosum*) × Maris Piper. In each case, selection was for general agronomic characters.

When tested for reaction to pathotype E of the eelworm, the mean level of susceptibility of *ex-vernei* × *ex-vernei* progenies was about 20 per cent of the Pentland Crown control, and half the plants showed less than 10 per cent of full susceptibility. The progenies from the outcrosses to Maris Piper had a mean susceptibility of 54 per cent of that of Pentland Crown while 20 per cent of plants showed less than 10 per cent of full susceptibility. Thus the higher retention rates of the outcrossed material with the greater Tuberosum component is offset by its lower but still useful level of eelworm resistance. In addition to the *vernei* resistance, much of this material contains race-specific resistance genes H_1 and H_3 derived from Andigena and *S. multidissectum* respectively.

The relationship between resistance genes in the potato host and various strains of virus Y has been under investigation for some time. The present understanding may be summarised as follows. Four genes in the host interact with five strains of the virus in the manner outlined in the table.

	Host genes			
Strains of virus Y	*Recess-ive*	Na_{tbr}	Nc_{tbr}	Ny
Primitive strain	H	H	H	H
A	+	H	+	+
Y^c	+	+	H	+
Y^o	+	+	+	H
Y^n	+	+	+	+

H = hypersensitive reaction; + = susceptible.

The two major genes Na_{tbr} and Nc_{tbr} induce a hypersensitive reaction with viruses A and Y^c respectively. The third gene, provisionally symbolised Ny and derived from Katahdin, confers (with occasional aberrant behaviour) hypersensitive resistance to the British field strains (Y^o) of the virus. These Y^o strains may be sub-divided into two groups differing marginally in aggressive ability. The primitive strain is non-indigenous but can be recognised by its ability to interact hypersensitively with host genotypes which do not carry any specific major resistance gene, as well as with those which do. Thus, since all Tuberosum varieties react hypersensitively to it, it is most unlikely to become established in the field. It may be maintained systemically in *S. stoloniferum* and in certain Andigena clones susceptible to the common Y^o strains of the virus.

The fifth group of strains, designated Y^n (the tobacco veinal necrosis strains), which was introduced into Europe in the recent past, is the most aggressive in overcoming all the specific resistance genes.

In contrast to viruses X and Y, resistance to leaf roll virus is polygenically controlled, segregating progenies showing quantitative variation. Attempts to transfer resistance from a range of parental types to acceptable Tuberosum cultivars have been hindered by its association with poor commercial attributes. However, it is now possible to report some progress in the appearance of progeny with improving tuber quality and superior leaf roll resistance. In the table below, 66 clones are classified according to leaf roll resistance and agronomic worth. All 66 are also highly resistant to viruses X and Y.

	Resistance				
Tuber grading	More 1	2	3	4	Less 5
Very good	–	–	1	2	1*
Good	–	1	2	4	8
Fair	6	5	6	9	8
Poor	2	5	4	1	1

Pentland Crown would fall in the cell marked * above. This variety has good, though not extreme, leaf roll resistance so it should be noted that the scale is truncated; all 66 clones are markedly more resistant than ordinary varieties.

Probably the best clone to emerge from this part of the programme so far is one selected for inclusion in the Regional Trials in 1973 which has excellent resistance to leaf roll, comprehensive resistance to all strains of virus Y and immunity to virus X.

ARC Project 18: Potato economic genetics

Biometrical genetics of economic characters in potatoes with objective of defining improved breeding plans.

(Worker: R. J. Killick)

The problem of how best to estimate the reaction of a clone to gangrene from the characters of the lesions was investigated during the year. Analyses made on existing data from the screening of breeding material showed significant variation in the size of lesions. The highest degree of genetical determination (clonal repeatability) (40 per cent) was for lesion length. Combining measurements, such that the lesions were approximated to the shapes of either circles or ellipses or cones gave somewhat lower heritabilities. The standard method of scoring gangrene resistance by estimating the proportion of tuber surface affected was also assessed. Here the heritability was nearer 60 per cent, confirming this to be not only a more rapid but also a more reliable method of selection. Using the same data, random samples of varying sizes were drawn repeatedly by computer and the means, ranges, and variances of the means of the sub-samples were calculated. Results indicated that scores from 10-15 tubers would give a sufficiently accurate estimate of clonal reaction when the sand/cornmeal method of inoculation was used.

In order to investigate combining abilities for a range of characters in the potato, tubers from glasshouse-raised seedlings from a six-parent half-diallel have been saved for multiplication in 1973. Results should be available in 1974 and provide unbiased estimates of general and specific combining abilities of, and correlations between, several characters of economic importance.

ARC Project 19: Potato blight

Mechanisms of field resistance and variability of the pathogen.

(Worker: Miss J. F. Malcolmson)

The first part of this project overlaps Project 17, reported above, and results appear there. No work has been done during the year on the curious somatic hybridization in the fungus reported previously but we hope to take this up again.

ARC Project 20: Commonwealth Potato Collection

Introduction, quarantine, maintenance and distribution of the Collection.

(Worker: D. R. Glendinning)

The systematic screening of the Commonwealth Potato Collection for the presence of spindle tuber virus was continued (see *Ann. Rep.* **51**, 9, 1972). In an attempt to complete the testing in 1972, all previously untested lines were grown at Pentlandfield and screened by the Department of Agriculture and Fisheries for Scotland, Scientific Services, East Craigs. Infection was detected in two further seed lines which had been in store in the Collection for many years. They bore a strain of the virus which differed from that previously identified in the intensity of symptom expression on the tomato test plants. This new strain requires a modified testing procedure for reliable detection and lines screened before this modification was introduced are therefore being retested. Distribution of seed within the United Kingdom has been restricted to persons able to maintain satisfactory quarantine precautions while warnings have accompanied seed sent abroad.

ARC Project 21: South American tetraploids

Studies and exploitation of Andigena Group (Neotuberosum) and Chilean potates as material for potato breeding.

(Worker: D. R. Glendinning)

Various modifications are being introduced in the Neotuberosum project. These arise from the heavy losses of selected clones at Pentlandfield caused by infection with leaf roll virus and virus Y. The clonal plantings are therefore being transferred to The Murrays. Old clones are being indexed for virus infection before transfer and many which fail are being discarded. Facilities for exposing material to blight infection have become available at Blythbank and the use of plots at the Rosewarne Experimental Horticulture Station in Cornwall for this purpose has therefore been discontinued. We are most grateful to the Rosewarne staff for their prolonged and generous assistance with this work since 1961. When the new system is stabilised, the Neotuberosum work will be confined to The Murrays, with the exception of the tuber-planted blight plot at Blythbank and some glasshouse grown seedlings.

It is hoped that these arrangements will permit the second major development in this programme, the purposive inter-breeding of selected clones. Hitherto, these clones have been regarded as a sample for the assessment of the population. While samples will continue to be taken for this purpose, the interbreeding of rigorously selected élite clones will be practised in order to achieve desired combinations of characters and so improve the value of Neo-tuberosum clones used as parents in the commercial breeding programme.

The third change results from the evidence of inbreeding in this population (*Ann. Rep.*, **51**, 10, 1972) and the erosion of the genetic base of the population which this implies. In order to restore genetic diversity, crossing with many Andigena lines in the Commonwealth Potato Collection is planned.

ARC Project 22: Dihaploids and diploids

Studies of the potential of South American diploids and Tuberosum-diploids for potato breeding.

(Worker: C. P. Carroll)

A field experiment designed to estimate progress in the diploid mass-selection programme was begun. Comparisons were made between three groups of seedlings representing advanced generation material, unimproved Phureja-Stenotomum baseline material and progenies of tetraploid cultivars. The improved material showed superior adaptation: 99 per cent of plants tubered as against only 47 per cent in the " baseline ". Total tuber yields of improved diploids were similar to those of tetraploid Tuberosum seedlings but tubers were smaller and more numerous. In the course of improvement under mass-selection leaf-length has fallen, although this was not the subject of selection. Both baseline and improved diploids showed blight resistance superior to that of Tuberosum in standard leaflet tests, having smaller lesions and less sporulation.

An attempt to correlate blight resistance (as measured by standard detached leaflet tests) with that from whole plants grown in the field, was unsuccessful. As an alternative, whole plant inoculations of 105 Phureja-type clones were carried out in the glasshouse. Susceptibility of a range of plant organs was scored, the greatest variability being found in stem resistance. However, no relationship was found between the performance of the same clone in the two tests and the assumption that tests which are suitable for tetraploids are also suitable for diploids is to be investigated. It may be necessary to devise new methods of screening this material to take into account some unusual aspects of its behaviour. For example, some clones showed sporulating *Phytophthora* without necrotic lesions.

The Phureja-Stenotomum diploids are self-incompatible and, in effect, exclusively out-breeding; for the success of a mass-selection improvement scheme it is necessary that the vast majority of successful pollinations occur between clones. A small field experiment was conducted to test the effectiveness of the self-sterility mechanism in two clones known to be self-sterile in the glasshouse. Nylon mesh cages were used to exclude natural pollinators (bumble-bees). The results suggested that, under natural conditions, about 3 per cent of the berry-set could be due to self-pollination in clones normally considered to be self-sterile.

A survey of specific gravity in hybrid material derived from dihaploids × diploids showed that high values, comparable with those previously found in "pure" diploids, can be achieved. The tuber yields of high S.G. clones are on average below those of the best hybrids but can reach over 90 per cent of the yield of Pentland Crown controls. There would thus appear to be good potential for high dry matter breeding in this material. A survey of cooking quality showed that the only respect in which these hybrids fell below Pentland Crown was in the higher incidence of yellow flesh colours, presumably derived from yellow-fleshed Phureja-type parents.

The Murrays

In spite of the dry year (rainfall 448 mm (17·65 ins)) and the cold spring, cereal crops yielded well. Seed bed preparation, however, was difficult as a result of the mild winter and the heavier ground had too many clods to provide ideal growing conditions for potatoes and Brassica crops.

A total of 60 a (24·3 ha) was "rotosprayed" with T.C.A. for couch control and the treatment was very effective. In addition, Eptam was applied immediately before ridging up the potato ground. Annual weeds presented a problem in the Brassicas and it is planned to use, next year, a weedkiller such as Treflan.

The cereals acreage was 146 (59·1 ha). It included 20 a (8·1 ha) of winter wheat (Cappelle Desprez and Joss Cambier), 112 a (45·4 ha) of barley (Ymer, Golden Promise and Midas) and 14 a (5·7 ha) of barley and oat trials and oat multiplication plots. All cereals received 2·75 cwt/acre (345 kg/ha) of 20-10-10 fertilizer. This was applied as a top dressing to the wheat and in the seed bed for barley and oats. There was little lodging in the barley and wheat, but the oat plots were badly affected.

Harvesting started on 29th August and finished on 29th September. The new drier system worked very well though the need for drying was limited. Yields varied from 31 cwt to 40 cwt/a (3,890–5,020 kg/ha) for Ymer, 32 cwt to 41·5 cwt/a (4,020–5,210 kg/ha) for Golden Promise and 40 cwt/a (5,020 kg/ha) for Midas. Yields for Cappelle Desprez wheat were 48 cwt/a (6,020 kg/ha) but for Joss Cambier, which was badly affected by yellow rust, only 30 cwt/a (3,770 kg/ha). The barley was sold at harvest time and realised £5,122; wheat realised £1,200.

Four acres (1·6 ha) of winter beans (Throw's M.S.) and one acre (0·4 ha) of spring beans (Maris Bead) were grown. These were not harvested until 2nd and 3rd January 1973. In spite of the late harvest, the winter beans yielded 37 cwt/a (4,640 kg/ha), the spring beans 17 cwt/a (2,130 kg/ha) and they jointly realised £450.

About 35 a (14·2 ha) of winter wheat were sown in the autumn of 1972, 10 a (4·1 ha) of Maris Ranger and the rest Cappelle Desprez. Winter beans (3·5 a (1·4 ha)) were also sown.

There were 16 a (6·5 ha) of potatoes in 1972. Pentland Crown and Red Craig's Royal were planted to form sprayways between the plot areas. The cold spring made for slow growth and estimated yields were not high. Three sprayings, using a mixture of fungicide and aphicide, were made on most of the area. The treatment was effective, though blight was not severe on the untreated part. Fertilizer (15-15-19) was applied at the rate of 8·5 cwt/a (1,067 kg/ha).

About eight acres (3·2 ha) were sown as trial and selection plots of kale, rape, swedes, stubble turnips, Raphanobrassica and *napocampestris* and an area of 16 a (6·5 ha) in the same field sown with stubble turnips for grazing. Brairding was very irregular and several trials could be used for observation and limited selection only. Fertilizer (15-15-19) was applied at the rate of 8·5 cwt/a (1,067 kg/ha).

Ninety-six acres (38·9 ha) of grass were let for grazing and a further 12 a (4·9 ha) were undersown. Of the grass area, 27 a (10·9 ha) were ploughed in the autumn and will be treated with T.C.A. followed by sowing with a catch crop.

A programme of chisel ploughing has been carried out, prior to conventional ploughing of the stubble ground.

As a matter of policy, we wish to use the land at The Murrays as far as possible for purposes of agricultural R. and D. Accordingly we made enquiries of sister institutes and the Edinburgh School of Agriculture as to their needs for additional grazing. In the event, we have agreed to let the grass to the ESA, a very satisfactory outcome. To protect both their stock and our experiments, fencing needs to be greatly improved. A programme to renew march fences is already in hand; a scheme for improvement of internal fences has been worked out with the ESA and we hope to complete the work this spring.

2. SUMMARY OF REPORT

1. *Barley genetics*

Objective: to provide essential background information on barley breeding methods and systematics for subsequent use in breeding programmes.

Experiments designed to try to answer the questions: what parents to use? and how to select the best progeny lines? have continued successfully. The methods used are essentially statistical and depend upon so-called diallel crosses and canonical analysis. A simple method devised for selecting high diastase barley grains by means of the " halo test " has worked well but is being superseded by a streamlined version of a more exact method. Natural crossing in the field has been estimated as 2 per cent, a surprisingly high figure that encourages our use of composite crosses. The classification of the barley collection (about 1,000 entries) is nearly complete.

2. *Barley biochemistry*

Objective: to gain essential understanding of starch-breaking enzymes in barley grains in support of programme to breed barleys for whisky manufacture.

This project is concerned with the biological catalysts (enzymes) that break barley starch down to sugars which yeast can ultimately ferment. Results bear on the analysis of what is meant in biochemical terms by the maltster's " diastatic power "; they are so complex as to defy any exposition that is both simple and brief. Good progress is being made. One " high diastatic power " mutant (the first on record) has been induced and others are being sought.

3. *Barley breeding*

Objective: to breed spring barley varieties for Scotland with specific objectives: feed, and barleys chemically specialized for whisky manufacture.

Some 1,500 advanced lines are being screened for potential feeding barleys; these came from composite crosses and it is very encouraging that the best so far identified are equal to leading varieties in yield. The question is, though: are there any that are better? The composite crosses in general appear promising and experiments on how best to use them are in progress. Nearly 20,000 pedigree F_2 plants and 1,500 F_3 selections were also grown and selected. Of the specialized barleys, the high diastase material is being handled on a similar scale. The work is going well and efficient selection methods are now available. Varieties having this characteristic are designed to replace imported American grain for grain whisky manufacture. Work on high amylose barleys has run into some trouble, which we don't really understand. However, several high amylose lines are available, though not so many as we had hoped. The aim is to improve the malting characteristics for malt whisky manufacture of barley grain by altering the molecular structure of the starch.

4. *Oat breeding*

Objective: to breed spring oats for Scotland, including, as secondary objectives, resistance to oat-stem eelworm and tolerance of marginal environments.

Ten advanced lines, of which four are eelworm resistant, are going into extended trials. Potential varieties are beginning to emerge from composite cross populations and, collectively, selected lines appear promising. Here, as in barley, composite crosses look good, so studies of how best to use them (*e.g.*, by establishing sub-populations with short straw and naked grain) are in progress. An attempt to induce early mutants in an otherwise promising line, Aa 725, is being made. No new eelworm resistant stocks are being handled; existing material is being worked through the pipeline and a resistant composite cross is being set up. Several lines resistant to grey speck (caused by manganese deficiency on alkaline soils) are being investigated; this work is now nearly finished.

5. *Hybrid swedes*

Objective: to take practical advantage of known hybrid vigour in the crop by breeding hybrid swede varieties.

There is good evidence that "hybrid" swedes (*i.e.*, crosses between two different inbred lines or varieties) have very high yield potential, maybe 30 per cent over standard varieties. The practical question is: how to make commercial seed? Both male sterility and self-incompatibility (a genetically controlled pollen tube growth inhibition) are being studied. The latter appears the more promising but there are many and severe difficulties to be overcome. However, several incompatibilities are in hand, others are being developed, and an attempt to construct cytoplasmic male sterility is being made.

6. *Swede breeding*

Objective: to breed new swede varieties by conventional methods which shall replace Pentland Harvester for mechanized cultivation.

Pentland Harvester, an otherwise excellent swede, failed because of " raan " (boron deficiency that causes brown staining of the flesh) to which the variety is genetically susceptible. Good progress is being made, though " raan " is difficult to induce at the precise level necessary for efficient selection. Over 100 lines derived from Pentland Harvester and selected for high yield and dry matter content, good shape and freedom from raan are being screened. If successful, the programme should yield a variety well before hybrid swedes could become available (see 5).

7. *Tetraploid turnips*

Objective: to test published reports that tetraploid turnips (with twice the usual chromosome number) are superior to the usual diploids.

Experiments in 1972 gave no support to the idea that tetraploids are superior; if anything, they are the reverse. The project has been terminated.

8. *Kale improvement*

Objective: to test theoretical ideas that kale improvement should be expedited by using unconventional parents and/or crossing patterns.

Kales are diploids and intolerant of inbreeding. One way to achieve marked improvement is by means of " hybrids " (*e.g.*, Maris Kestrel). Another possibility is to widen the genetic base and minimize inbreeding in later generations. This work is therefore based on complex hybrids using kales, sprouts, cabbages etc., and seeks to answer the questions: is improvement of yield of digestible matter possible by these simple means and, if so, how much and by which combination? Kale is a minor crop in Scotland and prolonged breeding would be justified only if very striking gains were in prospect. An attempt to make " instant inbred lines " by means of so-called matromorphs was written off; promising results published elsewhere were refuted.

9. *Brassica wide crosses*

Objective: to test the idea that nutritious and high yielding substitutes for rape can be made from crosses between different Brassica species.

This work has three components, all founded on the belief that really substantial improvements in the leafy Brassica fodders will have to be based on new materials. First, there are polypoid combinations of rape and turnip relatives, the *napocampestris* stocks referred to in earlier reports. Briefly, they now seem to be generally inferior to rape (especially in dry matter content) and work on them has come to an end. Second, we are trying to make artificial rapes and swedes on quite a big scale by crossing cabbage relatives with turnip relatives. The cross is difficult but worth considerable effort (using embryo culture methods) because it bears both on this project and on hybrid swedes (5). And, third, there is a very attractive prospect of making rape substitutes out of F_1 hybrids between rapes and turnips; the cross is surprisingly easy and the hybrids very productive. The trick will be to make hybrid seed on a big scale and, for this, an incompatibility method (see 5) is being investigated.

10. *Raphanobrassica*

Objective: to test the idea that polyploid (many-chromosome) hybrids between the two different genera Raphanus (radish) and Brassica can be made into a new forage species having the field characteristics of rape but with clubroot resistance.

A considerable volume of material is on hand and earlier difficulties with fertility are being slowly, but apparently steadily, overcome. The plants are hardy and have, this year, been shown to have inherited good clubroot resistance from the radish parent. As a by-product, a parental radish stock intensely selected for non-bolting has been turned over to NSDO for possible exploitation in continental Europe.

11. *Grass breeding methods*

Objective: to test unconventional breeding plans in cocksfoot and Italian ryegrass.

In cocksfoot the work has been directed towards enquiring how best to utilize a very wide range of variability. Part of the work, based on a large diallel cross, has just ended with clear indications that substantial response to selection is to be expected. The other part, which consists of exposing a bulk hybrid population to grazing pressure, continues. In the Italians, the purpose is to enquire whether a suggestion made some years ago, that F_1 hybrids (possibly including PRG) could be made utilizing the incompatibility system, is feasible or not. A suitable trial is being set up. Related work concerns efficiency and methods of selection of IRG for yield and digestibility.

12. *Winter kill in ryegrass*

Objective: to develop techniques for selection against winter-kill susceptibility in ryegrasses.

This work is in two parts, one to develop lines of IRG with winter kill resistance, the other a collaborative study of PRG with WPBS and PBI. In the former, 190 families have been exposed for selection. Earlier experience had been that it was surprisingly difficult to get enough winter kill in the plots. In winter 1972/73, however, weather was favourable and results from a parallel experiment showed that susceptibility to damage had a high heritability. This means that selection for resistance should be relatively effective. In the latter, the PRG work, two years of trials at four sites have given rather inconclusive results. The order of varietal response to cold was more or less as expected but there were complex interactions and no clear guidance as to how to produce the desired level of winter damage to order.

13. *Cocksfoot breeding*

Objective: to breed a nutritious and high yielding derivative of Scotia cocksfoot.

Scotia's digestibility is in the ryegrass range but it has defects. A substantial body of breeding material is now in hand having digestibilities in the range 60-70, with some even higher. This finding, that cocksfoot responds well to selection for digestibility, confirms results from the WPBS, Aberystwyth.

14. *Poa breeding*

Objective: to breed interspecific hybrids of the native grass, *Poa pratensis*, as hardy, perennial, rhizomatous grasses for the hills.

Three groups of hybrids are on hand: native *Poa pratensis* crossed by *P. ampla* (from the USA), *P. iberica* and *P. longifolia* (from Europe). Cytological complexity in some of them is predicted and has been found. Several small field trials to test establishment and growth have been laid out. At present, the indications are that establishment and constancy of breeding will be the principal obstacles to success.

15. *Breeding systems*

Objective: to test theoretical ideas on unconventional breeding systems by using computer models and the experimentally convenient plant, Arabidopsis.

There is reason to doubt that conventional breeding plans for inbreeders (such as cereals) are the most efficient available. Possible alternatives are being tested by computer simulation, for which a programme has been developed and is working well. In parallel, the small inbred ephemeral weedy plant, Arabidopsis, is being adopted as a biological simulator; about six generations a year can be grown in a growth chamber. After much trouble and delay, three growth chambers are now working and experiments on Arabidopsis are about to start.

16. *Potato breeding*

Objective: to breed new potato varieties (early and maincrop) for ware and processing (crisps, chips, dehydration, canning).

Two clones were submitted for Rights during the year. They are both of fairly high dry matter and hold promise both for processing and for quality ware (they must be steamed rather than boiled). Both have good field resistance to blight in tops and tubers, the first varieties in Britain, and among the first few in the world, to have this character; both also have several other useful disease resistance. For further details see p. 19. The programme, which started in 1970, to develop large populations with high specific gravity for processing went well and plots were successfully lifted with our new single-plant harvester. There is now a substantial body of Neotuberosum crosses in the pipeline (see *Ann. Rep.*, **48**, 18-38, 1969). The procedure for selecting earlies was strengthened during the year by the inclusion of plots in Wales Methods of assessing cooking quality were also improved.

17. *Potato disease resistance*

Objective: to monitor the disease resistance component in the above breeding programme in respect of viruses, eelworms, blight, scab and storage diseases.

Continuing work on field resistance to blight emphasises the remarkable diversity of kinds of resistance involved; the situation is very much more complex than had been supposed even a few years ago but the practical outlook for resistant varieties seems very good (see 16). Techniques for screening for gangrene and scab resistance are being improved with the object of early testing and economy of material. Clones having field resistance (derived from *Solanum vernei*) to all known races of potato cyst eelworm are well through the pipeline. Under viruses, some new understanding of the Y group is recorded and a substantial body of clones having high field resistance to leafroll is on hand; there is a potential variety having resistances to three viruses (X, Y and leafroll) in this material.

18. *Potato economic genetics*

Objective: to define improved breeding plans by study of genetic control of economic characters.

This work is now well established with the publication during the year of an important paper on the genetic control of blight resistance; a high degree of "specific combining ability" means that the resistance is there and can be bred but is poorly predictable. Work during the year has included a biometrical study of gangrene resistance and the setting up of material for extensive field trials of agronomic characters in 1974.

19. *Potato blight*

Objective: to gain improved understandings of the inter-relations of potatoes and the blight fungus, including study of the mechanisms of field resistance and variability in the fungus.

The dividing line between this project and project 17 (*q.v.*) is ill-defined. The extreme complexity of the potato's reaction to blight is apparent. No further work has been done on the fungus itself.

20. *Commonwealth Potato Collection*

Objective: to augment, maintain, classify and distribute the Commonwealth Potato Collection for the use of potato breeders.

The year has been dominated by the need to rid the Collection, with much help from DAFS Scientific Services and under very strict quarantine restraint, of spindle tuber virus. We believe the CPC to be the only potato collection in the world which is rigorously screened for this virus, which is borne in true seed and is very difficult to detect.

21. *South American tetraploid potatoes*

Objective: to develop populations of South American tetraploid potatoes for use in potato breeding.

The Neotuberosum programme, which started at the John Innes Institute 13 years ago, is now providing a major flow of parents into the breeding pipeline (see 16, above). Several substantial modifications of it are planned or begun, including a re-widening of the genetic base and a new crossing and selection pattern.

22. *Dihaploid and diploid potatoes*

Objective: to develop diploid potatoes (having half the normal chromosome number) for use in potato breeding.

The diploid potatoes are primitive South American types having $2 \times 12=24$ chromosomes. Andigena and our European (Tuberosum) potatoes have $4 \times 12 = 48$ chromosomes. Dihaploids have $2 \times 12 = 24$ and are derived from tetraploids with 48 chromosomes. Diploid populations have been greatly improved by a selection programme analogous to that which produced Neotuberosum from Andigena; last year, trials showed that in yield and blight resistance they were roughly equal to Tuberosum and that high specific gravity and attractive cooking characteristics are present. The dihaploids are generally rather a poor lot and suffer much (rather complex) sterility but diploid × dihaploid crosses have some attractive features. How best to use this material for potato improvement is yet unclear.

3. THE OLD ORDER CHANGETH

N. W. Simmonds

The Old Order

Organized agricultural research began in Britain in 1843 with the foundation of Rothamsted Experimental Station. Several more institutes were founded during the first three decades of this century, the Scottish Plant Breeding Station among them (in 1921). At first, all these institutes were self-supporting or nearly so, running on a mixture of bequests and subscriptions. As time went on the needs grew but the funds did not; so, increasingly, Government support was sought. The Agricultural Research Council (ARC) * was founded in 1931 to guide public expenditure in this field. Its budget in the early years was miniscule since funds for the institutes came from the agricultural departments and other government sources, notably the Development Commission. In 1946 the agricultural departments assumed total financial responsibility and in 1956, the ARC itself took over funding and administration of the grant-aided institutes in England and Wales. The late forties, fifties and sixties was a period of rapid growth and it saw the foundation of several new institutes. In sum, there were grant-aided institutes in England and Wales (such as Rothamsted and East Malling), wholly ARC institutes (such as Animal Breeding Research Organisation) and eight Scottish institutes (still funded by the Department of Agriculture and Fisheries for Scotland (DAFS) but guided scientifically by the ARC). In the 15 years, 1956/57 to 1971/72, annual public spending on the institutes rose from about £4m to £23m, a threefold increase at constant prices. Nearly all institutes grew in size and the scope of the work widened. Latterly, ARC funds came from the Department of Education and Science (DES). The system could broadly be described as a confederation of institutes whose scientific programmes were guided by ARC policy; on the principle that the able working scientist knows best what's worth doing, it gave wide scope to Directors to develop their own programmes. Thus there was a big element of *laissez faire* in the system and many informed observers thought it worked well. Certainly there were numerous excellent R and D achievements. Whether the superb economic record of British farming during the fifties and sixties was directly related to immediately antecedent agricultural research is a much disputed question; at any rate, excellent research coincided with excellent farming.

The generous Government support for increased agricultural research during

* For a full account see the pamphlet *The Agricultural Research Service* (ARC, London (HMSO), 1969, pp. 71).

the past two decades was founded firmly on the belief—subject of many official pronouncements from nearly everyone from the Prime Minister downwards—that Science was the key to Success. A measure of disillusion has since set in. High technology is in some current disrepute. Few believe any longer that good science automatically results in successful technology and there are even some who argue that technology is self-sustaining. To them, science is a luxury or, at the least, ought to be visibly directed towards economic ends. Some of this general disillusion with science rubbed off on agricultural research. The result has been a fairly profound modification of the Old Order. *Laissez faire* is on the way out. Since October 1972, important structural changes have been in progress and are not yet complete. The shape of the New Order, however, is becoming clear, or at least clear enough to be worth trying to describe here.

Rothschild and After

There are three key documents upon which the following paragraphs are virtually entirely founded. First, there is the Government Green Paper (Cmd. 4814, November 1971) *A Framework for Government Research and Development* which contained two reports, one by Sir Frederick Dainton and the other by Lord Rothschild, Head of the Central Policy Review Staff, the Prime Minister's "Think Tank". Second, there is the Government White Paper bearing the same title as the Green Paper (Cmd. 5046, July 1972). And third, there is the joint announcement by the Agricultural Research Council (ARC), the Ministry of Agriculture, Fisheries and Food (MAFF), and the Department of Agriculture and Fisheries for Scotland (DAFS), dated 23rd October 1972, about the proposed new arrangements.

The Green Paper became commonly known as "the Rothschild Report" and it evoked considerable discussion. From the first it was generally guessed—correctly as it later turned out—that the Government was going to take no notice of Sir Frederick Dainton but a lot of notice of Lord Rothschild; a writer in *Nature* remarked that the Green Paper was very pale green. Despite the inclusive-sounding title, Lord Rothschild's report was largely concerned with spending by the Research Councils and he proposed some radical changes. In 1971 virtually all Research Council funds came from the Department of Education and Science (DES); Lord Rothschild proposed that a varying proportion of the budget of each of three Research Councils should be diverted to the relevant executive departments, in the case of ARC to the MAFF.

The underlying argument ran as follows. Public expenditure must be for the public good and should be seen to be so; this is the Accountability Principle. Government must assure itself of this and the best way of doing so is to place responsibility for expenditure on the Ministry most closely concerned, in this instance the MAFF; the Ministry, Lord Rothschild said, was to pay only for the R and D that it wanted. This, the Customer-Contractor Principle, was stated as follows: " The customer says what he wants; the contractor does it (if he can); and the customer pays". In practical terms, Lord Rothschild recommended the progressive transfer of about three-quarters of ARC funds from the Department of Education and Science (DES) to the MAFF. He also said that the transfer should be conditional upon the appointment by the Ministry of a Chief Scientist, a senior man weighty enough to guide its research expenditure effectively.

" The Rothschild report " aroused much discussion and not a little antagonism. Some felt that it cast an unjustified slur on the performance of the Research Councils. Others questioned the argument that Ministries were the appropriate arbiters of public expenditure on research as distinct from practical administrative matters; were not farmers and the food industries the true customers? Yet others foresaw creeping bureaucracy and disastrous slippage of research standards. Contrary arguments were also heard: the Research Councils were thought by some to be over-academic, by others to be insufficiently " accountable " and to be unresponsive to economic needs.

The White Paper emerged when everyone had become rather tired of the " wide public debate " called for by the Green Paper. In practice, the debate had been prolonged and vociferous but rather more of an affirmation of taken positions than a debate. The White Paper, in effect, accepted Lord Rothschild's arguments and stated the Government's practical intentions as to action. The only significant deviation from Lord Rothschild's proposals was that about 50 per cent of ARC funds should be progressively transferred from DES to MAFF over the three years 1973/74 to 1975/76; Lord Rothschild had proposed about 75 per cent. For the rest, the MAFF was to appoint a Chief Scientist and the ARC and Departments were to set up a Joint Consultative Organisation to advise on R and D needs and priorities. In respect of the funds transferred the ARC was generally to be Contractor to the MAFF Customer, though no obligation was placed on MAFF to spend all the money in ARC-controlled institutes; it could spend it anywhere, including, presumably, its own establishments. The DAFS was to join into the new system, so that the work it supported in the Scottish Agricultural Research Institutes (SARI) should be effectively integrated into the total UK effort. (This was nothing new; it long had been.)

The New Order

The beginnings of the New Order, firmly founded on the White Paper, were outlined in the joint announcement of October 1972. Since this announcement was made, Dr H. C. Pereira, lately Director of East Malling Research Station, has been appointed Chief Scientist to the MAFF and, with a small team of senior scientific colleagues in post, the function can now be considered well established. There has been, as may be imagined, a considerable flurry of activity since the joint announcement; rather than describe the proposals and then subsequent developments separately, it seems better to summarize the way in which the New Order seems to be developing in general. The following paragraphs are therefore based on the joint announcement but with a certain element of extrapolation and interpretation (for which I alone am responsible) of likely future trends.

The essence of the New Order is a joint enterprise by ARC-MAFF-DAFS to develop a nationally integrated agricultural research and development service under advice as to programmes and priorities from a newly constituted Joint Consultative Organisation (JCO). The underlying scheme is essentially a closed loop (Fig. 1). However, all schemes of research management are of this

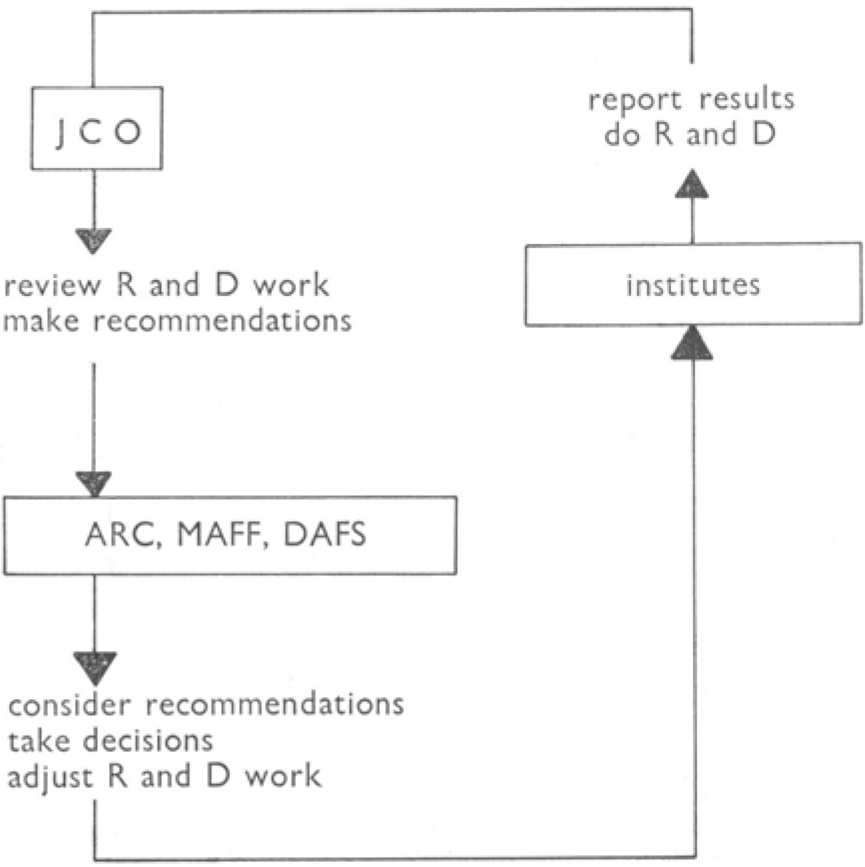

FIG 1. The cyclical nature of the New Order.

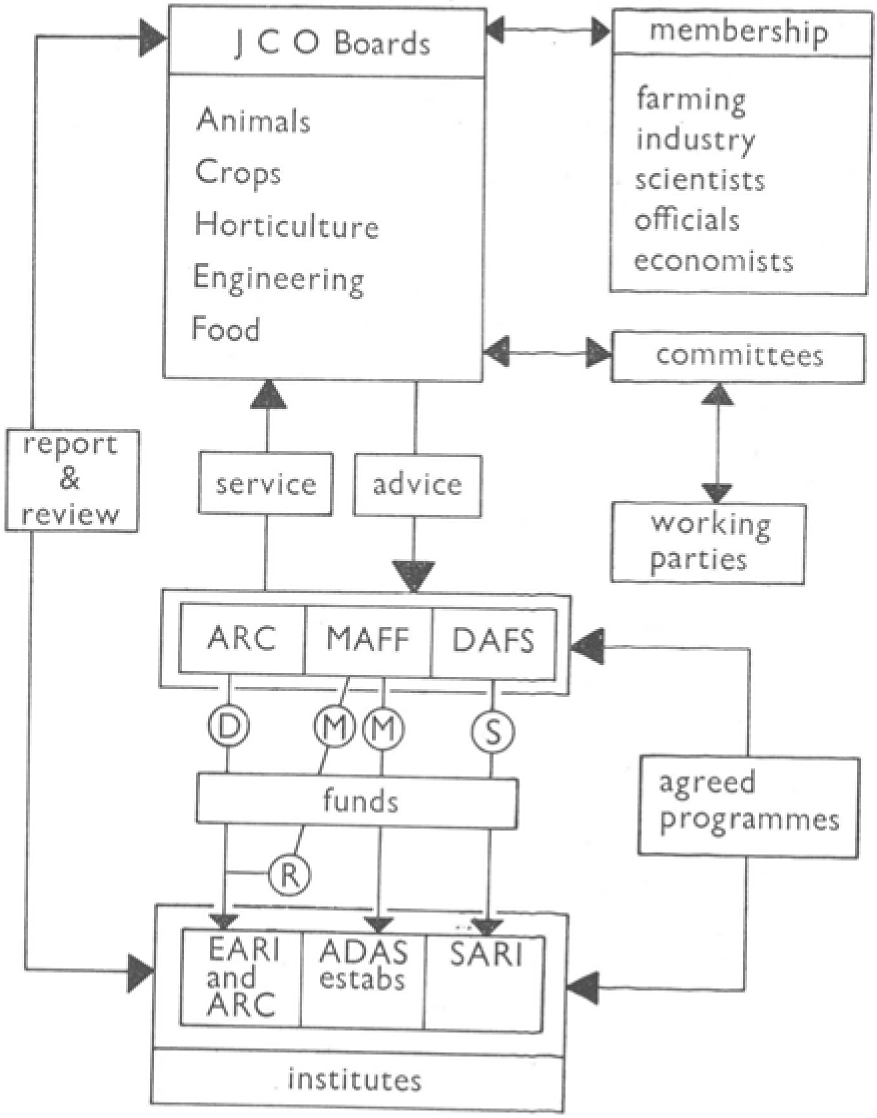

FIG. 2. The working structure of the New Order. (*Notes*: the symbols D, M, S indicate funds derived respectively from DES, MAFF and Scottish Office (DAFS). R indicates funds diverted, on Rothschild principles, from DES to MAFF. EARI (by analogy with SARI) signifies grant-aided institutes in England and Wales.

nature (so was that of the Old Order). The practical question is: can the New Order identify the needs and respond quickly, flexibly and economically to them and do all this better than the Old Order?

The working structure is summarized in Fig. 2. There are to be five R and D Boards each with an independent Chairman and about 15 members. Members will be jointly appointed as individuals, *not* as representatives of any other bodies. The Boards' functions will be to review research, assess priorities and make recommendations; much of their work will be done by committees and *ad hoc* working parties. "These Boards will advise direct the Council and the Departments." There is no provision for a top policy-making body which shall adjudicate between the potentially competing claims of the Boards; many would say that this is a serious weakness. Somehow, the ARC and Departments will have to decide among themselves how to weight the claims on their resources but it is by no means clear how this will be done.

At the time of writing (late February 1973) the names of the five Board Chairmen have just been announced. It is good to be able to record both that Mr W. A. Biggar, a Trustee of the SSRPB and member of ARC, is to be Chairman of the Animals Board and that this Board is to be based in Edinburgh.

The ARC and Departments, then, will receive considered advice on what to do, will take essential decisions, agree on work to be done and spend their money (Fig. 2). When significant changes in programmes are necessary—as they often will be—decisions as to how best to stop research, initiate new work and generally reallocate resources will be taken with the aid of *ad hoc* Ways and Means Panels of officials and working scientists set up for the purpose. It will be noted that the New Order will take in, besides the work of the institutes, also the work of departmental establishments, other than those having certain statutory functions.

That the New Order could be made to work well is certain; any system could be made to work, given goodwill and commonsense. That it will work well now seems more than likely, since the goodwill and commonsense are clearly there. But the system has its deficiencies (notably, lack of an authoritative policy body) and it is undoubtedly cumbrous, as many critics have pointed out; some calculations have suggested that years might elapse before a proposal filtered through the system from Working Party to Committee to Board to Officialdom to Institute, finally to emerge on the ground as a new project. On the other hand, no system that has the responsibility of spending over £20m of public money annually could conceivably be simple; the means must inevitably match the complexity of the task. It has also been pointed out that the old ARC committee system itself was by no means simple; indeed, with its hierarchy of working parties, technical committees and standing committees, it bore a strong resemblance to the JCO; or perhaps the JCO resembles it?

At this point it may be helpful to summarize the principal points of difference between the Old and the New Orders:

(1) The Board-Committee structure will be more powerful and less academic in composition.
(2) The ARC's policy-making function will be reduced and its composition will be altered.
(3) MAFF will be deeply involved in the system and some of its own establishments will be subject to it.
(4) MAFF will be spending (through the ARC Contractor) "Rothschild money" as Customer in institutes over which it has no managerial control; and most ARC and EARI institutes (Fig. 2, see legend) will have two distinct ultimate sources of funds, though spending will be canalized through ARC.

The joint announcement by ARC and Departments was made in October 1972. The White Paper said that the first transfer of ARC funds to MAFF was to take place in 1973/74, to be completed with the transfer of about £10m in 1975/76. Clearly, the New Order cannot be in full working shape by April 1973. One might guess (no official forecast has yet been made) that it will be fully operational in 1975/76. One factor that will undoubtedly ease the transition is the fact that the work of the institutes is now all on a costed project basis. In 1971/72 the ARC Planning Section devised a rather sophisticated project classification system which, having been suitably computerized, provides rapid information on all aspects of work in progress; it also counts the costs, a relatively simple but adequate costing system having been introduced in April 1972. It should thus be fairly easy for the MAFF-Customer to buy the bits of the ARC-Contractor's programmes that he wants, as an immediate step to get the New Order rolling. In Scotland, where we have a direct relationship between the Department and the institutes (Fig. 2) the move is to define costed groups of projects in direct relation to the annual grant; thus, for the SPBS, our letter of grant for 1973/74 will specify, with costs, the eight groups of projects (sometimes called "parcels" or "packages") which the DAFS-Customer will pay for during the year.

To conclude this section I think it may be useful to list several uncertainties or anomalies in the New Order which have yet to be resolved. First, to repeat a point made above, how are the recommendations of the Boards to be collated and overall policy formulated? Second, the Old Order was a federal institute-orientated system in which the progress of work and plans for the subsequent sexennium in individual institutes were reviewed at six-year intervals by Visiting Groups, appointed by ARC. The New Order implies a much more centralized control of programmes and a decline of the quasi-autonomy of institutes. So what is the future of the Visiting Group? Third, the White Paper said that

MAFF should have a Requirements Board under the chairmanship of the Chief Scientist. The joint announcement was silent upon this subject. It is not evident where such a Board fits into the New Order. And, fourth, the joint announcement said that the Scottish Agricultural Development Council should have a " firm organisational link " with the JCO; the nature of this link is yet unclear.

Conclusions

Lord Rothschild said that the organization of R and D should be " logical, flexible, humane and decentralized, the prerequisites of an efficient system ". The New Order will at least be somewhat more logical than the Old; its flexibility will probably be as good as an essentially complex situation allows; its humanity will depend on extrinsic factors; and it is far from being decentralised. On the last point, however, one may suspect that Lord Rothschild was just wrong. In a time (such as we are clearly entering) of more or less static budgets, an ever more centralized control of programmes seems to be inevitable. The day of the quasi-autonomous institute has gone; at the end of the day and after all the arguments have been heard, directors will have to do what they're told. After Rothschild, nothing will ever be the same again; it may be that this will be no bad thing.

Acknowledgement

I am grateful to several colleagues both within and outwith the Station for helpful criticisms. I have not, however, taken all their advice. The facts stated here are as accurate as careful checking can make them; the opinions and interpretations are mine alone.

4. GENETICS AND PLANT BREEDING

K. Mather

The following is a summary of the third SSRPB lecture planned, at the time of writing, to be held at the Bush at 16.00 hrs on Thursday, 12th April 1973.

There has recently been a great deal of discussion about basic research, strategic research and applied research, their differences, their inter-relations and even, in the case of strategic research, its very existence. As geneticists and plant breeders this touches us all, since between us we cover the whole spectrum. It is therefore of interest to examine the relations of genetics and plant breeding to see how much they interact, what form or forms the interaction takes, how important it has been and at what we should be aiming in the future. As will no doubt be obvious, in talking of this interaction I shall be doing so essentially as a geneticist.

I use the term plant breeding to mean the production and maintenance of varieties or forms superior to their predecessors in meeting, or in the way they meet, the needs of our society. As such there is a lot more than genetics in plant breeding. The aims of the breeder may in some measure reflect genetical considerations, but they will commonly be set by social, industrial, nutritional, commercial, economic or even political needs. Equally they may require the attention of, for example, the physiologist or the pathologist as well as the geneticist for their achievement. Plant breeding is applied genetics, however, in its essential component of assembling and manipulating an appropriate pool of hereditary materials. By the same token, genetics transcends plant breeding. It is a major scientific discipline, essential to our understanding of the evolution development and functioning of living things, and has outlets in, for example, industry, medicine and psychology as well as in plant and animal breeding.

There were of course successful plant breeders (Shirreff, Hjälmar Nilsson, the Vilmorins for example) before the so-called rediscovery of Mendelism in 1900. Their methods were perhaps simple but they unquestionably worked, and on the face of it the early years of genetics did not add a great deal. True, we learned how to handle, economically and precisely, major genic differences in a breeding programme; but, although there has been a continuing need for this, especially perhaps in relation to genes for disease resistance, it does not touch the nub of most breeding—the manipulation of continuous variation. Indeed in the early years it may be held that genetics got at least as much from the breeder as it gave, for Johannsen can hardly have been unaware of the single-ear selection practised by Hjälmar Nilsson when he devised his experiments with beans and formulated his pure-line theory. At the same time we must not underestimate the importance of this early genetics for it was shown that at any rate some practically important traits could be handled by the new methods, and Mendelism must have given great encouragement to the developing use of hybridisation in breeding. Also it saw the coming of the understanding that continuous variation was mediated by nuclear genes, albeit acting in polygenic systems, and R. A. Fisher's demonstration of how to analyse this type of variation. This interest was, however, submerged under the rising tide of linkage and organisational studies.

The analysis of continuous variation, however, began to be taken up again in the '30s and '40s and methods are now available for recognising and measuring dominance, interactive effects, and linkage. Animal breeders, particularly, have also studied methods of selection and its consequences. At the same time, polygenic systems have been looked at and their genetical properties examined. Perhaps the most striking of these has been the immense store of variability that they can carry in a concealed or latent condition—a store which Dr Simmonds and his colleagues at the Scottish Plant Breeding Station are putting to use in a dramatic way in their selection of Neotuberosum from Andigena potatoes. We have come to see the key significance of crossing and recombination in promoting response of polygenic variation to selection. And we have come to recognise the relation between polygenic balance and the natural breeding system of the species, of correlated responses and inertia under selection, of genetic architecture in relation to selection, and in the light of all these, of dependence of response to future selection on the adjustment of the genetic system by the action of selection in the past. All this affects the way we look at breeding programmes. For example, our knowledge of inbreeding and outbreeding species strongly suggests that, in the long term, the attempt to apply to inbreeders the methods of hybrid breeding, so successful in crossbreeding species, is likely to be no more advantageous than was De Vries's proposal of 70 years ago to apply pure-line selection, so successful in oats, barley, etc., to maize. The real value of male sterile forms in our cereals is more likely to lie in their use for producing high levels of heterozygosity to give recombination the chance to release hidden variability and so promote change under selection. A similar attack on the genetic systems of fungi and other pathogens might not wholly solve the problem of coping with new races which destroy the disease resistance we have so laboriously built up, but by showing us what to expect might well help us in devising measures for their control.

Chromosome studies have played their part in the development of our understanding of population structure. They also gave us, in the early years of genetics, the concept of polyploidy with all that that has come to mean for the breeder in the understanding of his species, their origins, the transfer of desirable genes from their relatives and even direct breeding by the induction of polyploidy.

Finally we come to the induction of new variation. It was shown nearly 50 years ago that ionising radiation stimulated mutations of all kinds and we now know that many chemicals do so also. Such induced mutations were at one time regarded almost as the panacea for all the breeder's ills. They are, however, mostly destructive in their effects and, while they have occasionally produced prospectively useful changes, further experience of these in domestic species has largely confirmed the scepticism with which some of us have always viewed the more extravagant claims. We really need means of inducing directed changes, such as are given by Durrant's " conditioning " in the few strains of the few species where it has been shown to work. A new possibility now under discussion is the transfer of DNA from one species to another, but we have a long way to go before this is a practicable approach and we would do well to be cautious about it—while not neglecting the basic investigations which such an enticing possibility clearly justify.

I hope I have shown that genetics and plant breeding are interlinked. Genetics' contribution lies in the understanding it gives of the system of variation that the breeder must manipulate and in the provision of means for their manipulation. Breeding makes its positive contributions too, not only in putting genetical conclusions to the practical test, but also and even more importantly in throwing up and emphasising the problems, of inbreeder versus outbreeder, of measuring and manipulating continuous variation, of chromosome management, and so on. The relationship is symbiotic: as has been observed before, a vast amount of good science has stemmed from the requirement to satisfy practical needs.

5. VARIETIES BRED BY THE STATION

The following varieties are on the market:—

Oats	ALBYN EMPRESS BELL	SHEARER PENTLAND PROVENDER*
Swede	PENTLAND HARVESTER	
Grasses	SCOTIA COCKSFOOT SCOTIA PERENNIAL RYEGRASS	
Potatoes	CRAIGS ALLIANCE PENTLAND BEAUTY PENTLAND DELL PENTLAND GLORY* PENTLAND IVORY* PENTLAND LUSTRE* PENTLAND METEOR* PENTLAND MARBLE*	CRAIGS ROYAL PENTLAND CROWN PENTLAND HAWK* PENTLAND JAVELIN* PENTLAND SQUIRE* PENTLAND RAVEN* 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., Newton Hall, Newton, Cambridge.

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

6. 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:*

Agricultural Development and Advisory Service (Gleadthorpe, Terrington and Ely E.H.F.; Rosewarne E.H.S.; Shardlow Hall, Woodthorne, Ormskirk, Swansea, Haverfordwest).
Animal Breeding Research Organisation, Edinburgh.
Animal Diseases Research Association, Edinburgh.
Canada Department of Agriculture, St John's West, Newfoundland.
Department of Agriculture and Fisheries for Scotland, Scientific Services, Edinburgh.
Food Research Institute, Norwich.
Forestry Commission, Research Branch, Edinburgh.
Grassland Research Institute, Hurley.
Hill Farming Research Organisation, Edinburgh.
John Innes Institute, Norwich.
MRC Clinical and Population Cytogenetics Unit, Edinburgh.
National Institute of Agricultural Botany, Cambridge.
National Institute of Agricultural Engineering (Scottish Station), Edinburgh.
National Seed Development Organisation, Cambridge.
National Vegetable Research Station, Warwick.
Nature Conservancy, Hope Terrace, Edinburgh.
Plant Breeding Institute, Cambridge.
Potato Marketing Board, London.
Rowett Research Institute, Aberdeen.
Scottish Horticultural Research Institute, Dundee.
Welsh Plant Breeding Station, Aberystwyth.

(*b*) *Universities and Colleges:*

A.R.C. Unit of Statistics, University of Edinburgh.
Edinburgh Regional Computing Centre.
Edinburgh School of Agriculture.
Edinburgh University, Departments of Botany and Chemistry.
Heriot-Watt University, Department of Brewing and Biochemistry.

North of Scotland College of Agriculture, Aberdeen.
School of Agricultural Sciences, University of Leeds.
West of Scotland Agricultural College, Glasgow.

(*c*) *Industrial Collaborators:*

Brewing Industry Research Foundation, Redhill, Surrey.
Distillers Co. Ltd., Menstrie, Clackmannan.
Dornay Foods Ltd., King's Lynn, Norfolk.
Gordon-Innes Ltd., Huntly, Aberdeenshire.
Hoffman-la Roche Co., Basel, Switzerland.
Imperial Foods Ltd., Imperial House, London.
Plant Protection Ltd., Fernhurst, Surrey.
Rothwell Plant Breeders Ltd., Caistor, Lincs.
Scottish Agricultural Industries Ltd., Edinburgh.

(*d*) *Individual:*

H. Stephen Burtt, Barn Farm, Bourne, Lincs.
G. Clapperton, Sheriffhall Mains, Dalkeith, Midlothian.
T. Dale, Auldhame, North Berwick, East Lothian.
J. Donald, West Powburn, Laurencekirk, Kincardine.
R. Dykes, Myles Farm, Tranent, East Lothian.
J. S. Graham, Queenston Bank, North Berwick, East Lothian.
M. J. Hamilton, Muirhouse, Edinburgh.
T. Hill, Currie Vale, Currie, Edinburgh.
Kinnordy Estates, Kirriemuir, Angus.
Sir David Lowe, Elvingstone, East Lothian.
A. Macintyre, South Ledaig, Argyll.
R. Miller, Tullochgorum, Inverness-shire.
A. Gordon Porter, East Scryne, Carnoustie, Angus.
T. Rowe & Sons, Over Ardoch, Braco, Perthshire.
W. J. Simpson & Son, Castlemains, Dirleton, East Lothian.
J. Small, Vicarsford, Leuchars, Fife.
G. A. Storrar, Rossie, Auchtermuchty, Fife.
Strathallan Growers, Ruthenvale Mills, Auchterarder.
J. C. Trainer, Byretown Farm, Lanark.
R. M. Williams, Penfeidir, Castlemorris, Haverfordwest.
A. R. Wilson, Brightmony, Auldearn, Nairn.

7. STAFF LIST

(in post at 31st March 1973)

Director: N. W. Simmonds, Sc.D., A.I.C.T.A., F.R.S.E., F.I.Biol.
Deputy Director: J. L. Fyfe, M.Sc.

Forage Department

Head: J. L. Fyfe, M.Sc.

PSO: D. Cameron, B.Sc.
I. H. McNaughton, M.A., D.Phil.

SSO: M. J. Allison, B.Sc., Ph.D.
F. J. W. England, B.Sc., Ph.D.

HSO: D. A. Couzin, B.Sc., Ph.D.
R. P. Ellis, B.Sc., Ph.D.
S. Gowers, B.Sc., Ph.D.
A. M. Hayter, B.Sc., Ph.D.
Miss A. R. Hutchison, B.Sc.
G. R. Mackay, M.Sc.
Miss I. K. Munro, B.Sc.
T. J. Riggs, B.Sc.
Miss C. J. Williamson, B.Sc.

SO: I. M. Chapman, B.Sc.
I. A. Cowe, H.N.C.
R. J. Giles, B.Sc.
M. S. Phillips, B.Sc.
Miss C. L. Snell, M.Sc.
R. B. W. Williamson, H.N.C.
A. Young

ASO: T. G. Archibald
R. J. Begbie
R. Borzucki, O.N.C.
R. W. Hutchison
Mrs K. E. Mann
D. D. Mathieson
J. McGregor, S.D.A.
P. Nairn
L. G. Newman
Miss E. A. Purves
A. Shaw
Miss C. Stuart
J. S. Swanston, B.Sc.
Miss D. Watt
G. R. Young

LA: Mrs I. Davidson
Mrs I. Macanulty
Miss L. Macpherson
Mrs J. Speirs
Mrs M. Stewart
Miss E. Vallery

Potato Department

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

PSO: J. M. Dunnett, B.Sc., Ph.D.
D. R. Glendinning, B.Sc.
Miss J. F. Malcolmson, B.Sc., Ph.D.

SSO: C. P. Carroll, M.Sc.
T. M. W. Davidson, B.Sc., Ph.D., N.D.A.
R. J. Killick, B.Sc., Ph.D.
A. W. Macarthur, B.Sc.

HSO: W. G. Rogers, B.Sc., Ph.D.
Miss H. E. Stewart, H.N.C., M.I.Biol.

SO: M. J. De Maine, B.Sc.
Miss R. M. Ford, B.Sc.
Mrs R. J. Low, B.Sc.
A. A. McFarlane
Miss S. C. Tribble, M.Sc.

ASO: G. J. Bleazard
D. Fleming
Miss K. M. Howe
I. L. Howie, B.Sc.
J. D. Hanratty, O.N.C.
D. J. Millar
Mrs L. E. Scott
Mrs J. Spence
G. E. L. Swan

LA: Mrs E. Gray
Mrs E. Wann

Field and Works

D. W. Speed, B.Sc. (Head)
W. Dick (Grieve)
A. E. Hamilton (Technical Officer)
G. Stevens (Craftsman)

The Murrays

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

Administration

R. J. L. Gallie, F.C.I.S. (Secretary)
H. C. M. McLeod (Assistant Secretary)
Miss S. McLeod (Clerical Officer)
Mrs D. M. Smith (Clerical Officer)
Mrs E. McNeill (Clerical Assistant)
Mrs C. M. Leith (Shorthand Typist)
Mrs J. B. P. Stevenson (Typist)
Miss I. M. Hayes (Director's Personal Secretary)

8. BOARD OF DIRECTORS, 1972-73

Trustees

H.M. SECRETARY OF STATE FOR SCOTLAND, Scottish Office, St Andrew's House, Edinburgh.
W. ANDREW BIGGAR, O.B.E., M.C., B.Sc., F.R.Ag.S., Magdalene Hall, St Boswells.
JAMES GRAY, O.B.E., T.D. (James Gray & Co. (Stirling) Ltd.), Stirling.
Sir JAMES DENBY ROBERTS, Bt., O.B.E., M.A., J.P., Strathallan Castle, Auchterarder.
ROBERT L. SCARLETT, C.B.E., C.D.A., S.H.M., V.M.H., Sweethope, Musselburgh.

Chairman of Directors

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

Vice-Chairman

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

Ordinary Directors

1970

A. MANTON BAXTER (Baxter & Guion Ltd.), Crescent House, Midland Road, Peterborough.
J. G. M. BREMNER, O.St.J., M.A., D.Phil., D.Sc., M.I.Chem.E., F.R.I.C., 13 Wyncote Court, Jesmond Park East, Newcastle-upon-Tyne NE7 7EG.
J. LESLIE DAWSON, B.Sc. (S.A.I. Ltd.), West Mains of Ingliston, Newbridge, Midlothian.
J. E. RENNIE, C.B.E., Greendykes, Macmerry, East Lothian.
J. STEWART, 63 The Avenue, Girvan, Ayrshire.
G. A. STORRAR, M.C., B.Sc., J.P., Rossie, Auchtermuchty.

1971

ROBERT ALLISON, Turnhouse, Corstorphine, Edinburgh 12.
JAMES D. G. DAVIDSON, M.V.O., M.I.Ex., Royal Highland and Agricultural Society, Ingliston, Newbridge, Midlothian.
G. B. R. GRAY, Smeaton, East Linton, East Lothian.
Mrs B. A. GORDON, B.Sc.(Agric.), Rosefarm, Cromarty.
M. JOUGHIN, C.B.E., J.P., Wester Manbeen, Elgin, Morayshire.
J. WATSON (Sinclair, McGill (Scotland) Ltd.), 67 Kyle Street, Ayr KA7 1RY.

1972

HUGH C. DRUMMOND, The Curragh, Girvan, Ayrshire.
H. F. D. ELDER (Wm. Dods & Son), Haddington.
W. H. M. GILL, Rosskeen, Invergordon, Ross-shire.
J. B. D. HERRIOTT, B.Sc., Ph.D., Edinburgh School of Agriculture, West Mains Road, Edinburgh EH9 3JG.
Sir DAVID LOWE, C.B.E., D.Sc., F.R.S.E., F.R.Ag.S., Elvingston, Gladsmuir, East Lothian.
DOUGLAS MORRISON, B.Sc.(Agric.), Dip.Agric., M.S., School of Agriculture, 581 King Street, Aberdeen AB9 1UD.

Directors Co-opted

JOHN ARBUCKLE, O.B.E., Logie, Newburgh, Fife KY14 6HL.
GEORGE CLAPPERTON, Sheriffhall Mains, Dalkeith EH22 1RX.
E. F. SHERRIFF (Sherriff & Sons Ltd.), The Mill, Great North Road, Hatfield, Herts.

Directors nominated by the Secretary of State for Scotland

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

Professor H. P. DONALD, Ph.D., D.Sc., F.R.S.E., Animal Breeding Research Organisation, King's Buildings, West Mains Road, Edinburgh EH9 3JQ.

D. W. WILLIAMS, M.Sc., Ph.D., Scientific Services, East Craigs, Corstorphine, Edinburgh EH12 8NJ.

Sir MAURICE YONGE, C.B.E., D.Sc., F.R.S., P.R.S.E., 13 Cumin Place, Edinburgh EH9 2JX.

Standing Committee—Finance

JOHN ARBUCKLE, *Convener.*
R. ALLISON.
W. A. BIGGAR.
J. G. M. BREMNER.
ROBERT BROWN.
G. CLAPPERTON
J. D. G. DAVIDSON.
H. F. D. ELDER.
W. H. M. GILL
G. B. R. GRAY.
Sir DAVID LOWE.
ROBERT L. SCARLETT.
VICE-CHAIRMAN (*ex officio*).

Research Committees

Forage Crops

H. F. D. ELDER, *Convener.*
J. G. M. BREMNER.
G. CLAPPERTON.
J. L. DAWSON.
G. B. R. GRAY.
J. B. D. HERRIOTT.
M. JOUGHIN.
Sir DAVID LOWE.
D. MORRISON.
J. STEWART.
J. WATSON.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

Potatoes

W. H. M. GILL, *Convener.*
R. ALLISON.
A. MANTON BAXTER.
H. DRUMMOND.
Mrs B. A. GORDON.
Sir DAVID LOWE.
J. E. RENNIE.
E. F. SHERRIFF.
G. A. STORRAR.
D. W. WILLIAMS.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

Farm Advisory

G. CLAPPERTON, *Convener.*
R. ALLISON.
G. B. R. GRAY.
J. E. RENNIE.
G. A. STORRAR.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

9. ADMINISTRATION

Finance

The abstract of audited accounts on pages 64 to 70 reveals the Society's financial position at 31st March 1973. The cost of the research programme at the Scottish Plant Breeding Station was met by a maintenance grant of £326,000 from the Department of Agriculture and Fisheries for Scotland. Included in the cost of operating the Murrays Farm is £24,300 in respect of rental for the period 28th November 1970 to 28th November 1972. The annual rental for the farm, £12,150, is based on 9% of the purchase price paid in 1970. Sundry items of income at Pentlandfield amounted to £964·67. The unspent balance of maintenance grant for the year amounted to £1,493·79. This sum has been added to unspent balances of grants from previous years, increasing them to £8,252·70.

Capital expenditure at Pentlandfield amounted to £31,226·03 on buildings and £1,891·16 on equipment for which DAFS grants were received. At the Murrays Farm, DAFS spent £37,124·36 on erecting a new steading, two workers' cottages and improvements to existing buildings and fences. As the farm is let to the Society by the Secretary of State for Scotland, capital expenditure at the Murrays Farm is not included in the Fixed Assets of the Society.

Membership

At 31st March 1973 the total membership was 332, comprising 197 life members and 135 annual members. Seventeen new members were elected during the year and seven died or resigned.

Board of Directors

The Board welcomed on election for the first time: Mr Hugh C. Drummond, Dr J. B. D. Herriott and Mr Douglas Morrison. Dr M. A. H. Tincker retired after many years of service as member nominated by the Secretary of State for Scotland and was replaced by Prof. H. P. Donald.

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.), Crescent House, Midland Road, Peterborough PE3 6DQ.

J. G. M. Bremner, O.St.J., M.A., D.Phil., D.Sc., M.I.Chem.E., F.R.I.C., 13 Wyncote Court, Jesmond Park East, Newcastle-upon-Tyne NE7 7EG.

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

J. E. Rennie, C.B.E., Greendykes, Macmerry, East Lothian.

J. Stewart, 63 The Avenue, Girvan, Ayrshire.

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

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

John Arbuckle, O.B.E., Logie, Newburgh, Fife KY14 6HL.

George Clapperton, Sheriffhall Mains, Dalkeith EH22 1RX.

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

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

E. F. Sherriff (Sherriff & Sons Ltd.), The Mill, Great North Road, Hatfield, Herts.

W. Steven, The Brax Farm, By Arbroath, Angus.

Meetings

The Board met four times: on 13th April 1972; 2nd June 1972; 20th July 1972; 9th November 1972.

Research Committee meetings were held as follows: Potatoes on 12th October 1972, Forages on 19th October 1972.

The Finance Committee met on 2nd June 1972 and the Farm Advisory Committee on 4th May 1972, 6th July 1972 and 14th December 1972.

Fifty-First Annual General Meeting

Minute of Proceedings at the Fifty-First Annual General Meeting of Members of the Scottish Society for Research in Plant Breeding, held at the Scottish Plant Breeding Station, Pentlandfield, Roslin, Midlothian, on Thursday, 20th July 1972.

Mr John Arbuckle, O.B.E.,
Logie, Newburgh, Fife, presided.

Minute. The Minute of the 50th Annual General Meeting, held at the Scottish Plant Breeding Station on Thursday, 22nd July 1971, having been circulated prior to the meeting, was taken as read and was approved and signed.

Apologies. Apologies for absence were intimated by the Secretary.

Annual Report and Accounts. The 50th Annual Report of the Directors embodying the audited accounts for the year ended 31st March 1971, which had been distributed to members before the meeting, was submitted by the Chairman.

After a brief speech, the Chairman moved and Mr James Gray, O.B.E., T.D., Stirling, seconded the adoption of the Report and Accounts and the motion was carried unanimously.

Elections to the Board of Directors. Moved by Mr George Clapperton, Sherriffhall Mains, Dalkeith and seconded by Mr G. B. R. Gray, Smeaton, East Linton, a motion was unanimously adopted to elect to the Board of Directors the following members:—

Hugh C. Drummond, The Curragh, Girvan, Ayrshire.
H. F. D. Elder (Wm. Dods & Son), Haddington, East Lothian.
W. H. M. Gill, Rosskeen, Invergordon, Ross-shire.
J. B. D. Herriott, B.Sc., Ph.D., Edinburgh School of Agriculture, West Mains Road, Edinburgh EH9 3JG.
Sir David Lowe, C.B.E., D.Sc., F.R.S.E., F.R.Ag.S., Elvingston, Gladsmuir, East Lothian.
Douglas Morrison, B.Sc.(Agr.), Dip.Agric., M.S., School of Agriculture, 581 King Street, Aberdeen.

Appointment of Auditors. On the motion of the Chairman and seconded by Mr W. H. M. Gill, Rosskeen, Invergordon, Messrs Brown, MacDonald & Fleming, Chartered Accountants, were appointed Auditors of the Society.

This concluded the formal business of the meeting.

In the informal business which followed, the Chairman, in the course of his address to the meeting, referred to the retirement of Sir James Denby Roberts, during the preceding year, from the office of Chairman. Expressing the thanks of the Board and members for Sir James's long and valuable service to the Society, Mr Arbuckle paid tribute also to him for the keen and knowledgeable interest he took in the work of the Station. Sir James's interest in seed potatoes had brought him quickly into contact with the work at the SPBS and he became a member of the Society in 1942. In 1945, he joined the Board and was appointed to its Research and Finance Committees. He became Vice-Chairman in 1951 and Chairman in 1957, when Sir John Milne Home retired.

Virus diseases of potatoes were of special interest to Sir James; so much so, indeed, that he became one of the first growers in Scotland to engage in virus testing in his own laboratory. But, while the high health standard of his crops were of prime importance to him he realised that the potato seed industry must expand trade beyond the confines of the UK market. For this reason, new varieties to compete with continental ones for the early (Mediterranean) trade were of special interest to him. Nor was his interest in research confined to potatoes. His article in the 1961 Report testified to the need for research into hill grasses. He was, indeed, a very widely experienced agriculturalist to whom the Society was deeply indebted for much help, encouragement and good counsel.

Though retired from the Chairmanship of the Society, Sir James remained a Trustee and would thus still be in touch with its affairs.

Staff

The following appointments were made during the year:—

HSO	D. A. Couzin, B.Sc., Ph.D.
	Miss H. E. Stewart, H.N.C., M.I.Biol.
SO	Miss R. M. Ford, B.Sc.
	M. J. De Maine, B.Sc.
	Miss S. C. Tribble, M.Sc.
ASO	R. Begbie
	J. D. Hanratty, O.N.C.
	Miss K. M. Howe
	I. L. Howie, B.Sc.

	J. McGregor, S.D.A.
	Mrs L. E. Scott
	A. Shaw
LA	Miss L. S. Macpherson
	Mrs E. Wann
Administration	H. C. M. McLeod
	Miss S. McLeod

The following staff left employment:—

SO	Miss M. A. Turner
	A. S. Peddie, S.D.A., D.C.P.
ASO	J. M. Chalmers
	Mrs A. Clark, O.N.C.
	T. R. Crawford
	B. H. Gordon (temporary)
	Miss B. C. Graham, B.Sc.
	D. A. Hamilton
	Miss D. Hanning, O.N.C.
	A. Nicholson
	Mrs E. J. C. Pearce
Administration	Miss E. A. Piggott
	Mrs I. M. Walley
Retirement	Miss A. G. Dunnett (Admin.)

Members of staff made two visits abroad during the year, with the aid of travelling grants from ARC. Dr Allison attended a meeting in Amsterdam of the European Federation of Biochemists, 20th-25th August 1972. Mr Cameron attended the third international conference of the International Association for Mechanization of Field Experiments, at Brno, 10th-15th July 1972.

Staff also attended management courses as follows: Dr England a Management of Personnel Course run by the Civil Service College, Edinburgh, 13th-30th November 1972; and Dr Hayter and Mr Riggs a course jointly organized by ARC/SRC in London, 13th-16th February 1973.

Members of staff presented several papers or seminars to scientific meetings and university audiences during the year. Dr Holden gave a course of lectures on Economic Genetics to the fourth year Botany Class, Edinburgh University, early in 1973. This course was in succession to one the Director had given for the previous six years. Mr Fyfe again acted as external examiner for the honours B.Sc. and M.Sc. degrees in agricultural botany at the University College of Wales, Aberystwyth.

The Director gave six lectures to various audiences during the year. They included one entitled "Plant Genetics and Crop Improvement" which was given in connection with the exhibition "Search" put on by the Department of Education and Science in the summer of 1972 in the Science Museum, London. The intention was to illustrate the work of the Research Councils in the exhibition itself and to elaborate on chosen fields in the accompanying lectures. In March 1973 he contributed a paper on plant breeding to a discussion meeting of the Royal Society of London entitled "Agricultural Productivity in the 1980s". The Director visited Barbados in connection with sugar cane breeding in December 1972 and continued to serve on SADC, on several ARC committees, on local committees in Edinburgh concerned with Research Councils' computing affairs and on certain outside bodies such as the BBC Scottish Agricultural Advisory Committee and the Forestry Commission Advisory Committee on Forest Research.

The Station received many visitors during the year. Among them were parties of farmers, advisers and students as well as individual scientists from home and abroad. We were pleased to see them all.

10. PUBLICATIONS

ALLISON, M. J. (1973). Genetic studies on the β-amylase isozymes of barley malt. *Genetica*, **44**, 1-15.

CAMERON, D. (1972). The rationalisation of cereal plot mechanisation at the Scottish Plant Breeding Station. *Proc. 3rd Int. Conf. Mechanization of Field Experiments.* Brno, 131-137.

CAMERON, D., HAMILTON, A. E. and STEVENS, G. C. (1973). A single plant potato harvester. *J. intn. Ass. Mechaniz. Field Exp.*, **1**.

ENGLAND, F. J. W. (1972). Isolation chambers for controlled pollination in grasses. *Euphytica*, **21**, 523-526.

HAYTER, A. M. and ALLISON, M. J. (1972). A gel diffusion assay for diastatic power and its use in plant breeding. *J. Inst. Brew.*, **78**, 310-313.

HOLDEN, J. H. W. (1973). New processing potatoes—Pentland Marble, Squire and Raven. *Scott. Agric.*, **51**, 471-473.

KILLICK, R. J. (1972). The analysis of penetrometer data from a potato breeding programme *Potato Res.*, **15**, 91-105.

KILLICK, R. J. and MALCOLMSON, J. F. (1973). Inheritance in potatoes of field resistance to late blight (*Phytophthora infestans*). *Physiol. Plant Path.*, **3**, 121-131.

MCNAUGHTON, I. H. and MUNRO, I. K. (1972). Heterosis and its possible exploitation in swedes (*Brassica napus* L. ssp. *rapifera*). *Euphytica*, **21**, 518-522.

MCNAUGHTON, I. H. (1973). Synthesis and sterility of *Raphanobrassica*. *Euphytica*, **22**, 70-88.

RIGGS, T. J. and HAYTER, A. M. (1972). Diallel analysis of the time to heading in spring barley. *Heredity*. **29**, 341-357.

SIMMONDS, N. W. (1972). Food for man and beast. *Scott. Agric.* **51**, 408-412.

Other papers by staff:

ALLISON, M. J. (1972). The effect of phosphate buffer on the differential response of two genes in *Neurospora crassa* to UV. *Mutation Res.*, **16**, 243-248.

ELLIS, R. P. (1971). The identification of wheat varieties by the electrophoresis of grain proteins. *J. natn. Inst. agric. Bot.*, **12**, 223-235.

ELLIS, R. P. (1971). Electrophoresis of grain proteins: detection of rye proteins in wheat × rye hybrids. *J. natn. Inst. agric. Bot.*, **12**, 136-241.

GLENDINNING, D. R. (1972). Natural pollination of cocoa. *New Phytol.*, **71**, 719-729.

KILLICK, R. J. (1972). The genetical architecture of sternopleural chaeta number in *Drosophila melanogaster*. *Heredity*, **28**, 95-100.

KILLICK, R. J. (1973). Sex-linkage and sex-limitation in quantitative inheritance. II. Diallel crosses. *Heredity*, **30**, 41-51.

11. ABSTRACT OF ACCOUNTS

ABSTRACT OF ACCOUNTS

For Year ended 31st March 1973

INCOME

1972		
£142	Sales of Produce and Stock on Hand	£190·95
..	Sale of Vehicle	432·00
136	Subscriptions—Annual	134·00
	Note.—Annual Subscriptions amounting to £16·50 are in arrear	
153	Rent of Cottages	207·72
£431	*Total Ordinary Income*	£964·67
	Grant received from the Department of Agriculture and Fisheries for Scotland—	
244,600	Maintenance	326,000·00
£245,031	*Total Income*	£326,964·67
10,876	Capital—The Murrays	37,124·36
	Balance at 1st April 1972—	
	Department of Agriculture and Fisheries for Scotland—	
5,008	Maintenance Grant	6,758·91
£260,915		£370,847·94

EXPENDITURE

1972			
	Salaries:—		
£118,577	Scientific and Technical Staff	£138,229·25	
11,662	Administrative and Clerical Staff	13,906·73	
2,855	Pension Supplementation	4,173·67	
£133,094			£156,309·65
9,442	Superannuation Contribution		13,108·25
27,648	Wages		32,894·31
7,457	National Insurance and Graduated Contributions		9,654·18
11,250	Apparatus and Equipment		18,696·35
10,176	Chemicals and Materials		16,381·66
3,436	Travelling and Subsistence		4,151·22
4,253	Rates and Rents		4,364·67
8,774	Power, Heat and Light		12,094·99
724	Library Books and Periodicals		689·83
1,232	Printing and Binding		784·10
2,735	Stationery, Postages and Telephone		4,137·68
1,099	Vehicles—Purchased £2,583·05		5,466·17
2,551	Maintenance 2,883·12		
250	Audit and Legal Expenses		350·00
5,014	Property Repairs		2,061·72
—	Property Alterations		689·72
153	Trial Centres		538·00
1,963	Edinburgh Centre of Rural Economy		2,544·00
1,449	Repairs, Servicing		2,522·88
712	Seed Testing Fees		609·85
108	Transport		297·50
270	Staff Training		852·55
1,053	Advertising		1,641·79
2,081	Furniture and Fittings		1,671·15
831	Miscellaneous—Hosp. £154·21 Misc. 717·60		871·81
742	Rentals		706·38
4,783	The Murrays—Net Cost		31,327·73
—	Land Improvements		52·74
£243,280			£325,470·88
10,876	The Murrays: Improvements		37,124·36
6,759	Balance DAFS Maintenance		8,252·70
£260,915			£370,847·94

BALANCE SHEET

as at 31st March 1973

I. Funds:—

Balance at 31st March 1972	£410,328·78	
Grant received from DAFS Capital—Works	31,226·03	
Equipment	1,891·16	£443,445·97

II. Current Liabilities:—

Subscriptions paid in advance	£5·00	
Balance of DAFS Maintenance Grant	8,252·70	
		8,257·70
		£451,703·67

I. Fixed Assets:—

	Cost	*Amounts charged to Revenue*	*Nett*
Heritable Property	£398,498·23		£442,954·27
Capital Equipment	44,456·04		
Implements and Tools	30,215·12	£30,215·12	..
Vehicles	8,748·88	8,748·88	..
Laboratory Apparatus	48,807·39	48,807·39	..
Furniture and Fittings	12,791·76	12,791·76	..
Library Books	8,079·00	8,079·00	..
	£551,596·42	£108,642·15	£442,954·27

II. Current Assets:—

Stocks	£14·00	
Due to Society	1,697·40	
Cash and Bank Balance	7,038·00	8,749·40
		£451,703·67

Edinburgh, *28th May, 1973*.—The undersigned, having had access to all the Books and Accounts of the Society, and having examined the foregoing Statement of Accounts and verified the same with the Accounts and Vouchers relating thereto, now sign the sa[illegible] found to be correct, duly vouched, and in accordance with law.

16 Alva Street.

Messrs BROWN, MACDONALD & FLEMING, *Auditors*.

JOHN ARBUCKLE, *Convener, Finance Committee*.

LIFE MEMBERSHIP SUBSCRIPTIONS AND DONATIONS ACCOUNT

Dividends and Interest	£765·92	SSRPB Lecture	£50·00
Donations	50·00	Gift to Miss Dunnet	10·00
Refund Andes Travel Grant	10·00	Insurance	9·25
Life Subscriptions	120·00	Hospitality	1·70
Balance at 1st April 1972	12,163·42	Friendly Society Fee	2·50
		Balance at 31st March 1973	
		Investments (see Appendix), at Cost £11,564·95	
		Recoverable Income Tax 278·02	
		Cash in Bank—Current Account 1,068·51	
		Savings Account 124·41	13,035·89
	£13,109·34		£13,109·34

W. J. REID AND JAMES MUNRO BEQUESTS

Dividends and Interest	£120·30	Balance at 31st March 1973	
Balance at 1st April 1972	2,146·79	Investments (see Appendix), at Cost £1,990·24	
		Recoverable Income Tax 42·09	
		Cash in Bank—Current Account 234·76	£2,267·09
	£2,267·09		£2,267·09

DR. WILSON MEMORIAL FUND

Dividends and Interest	£28·05	Balance at 31st March 1973	
Balance at 1st April 1972	589·88	Investments (see Appendix), at Cost £566·41	
		Recoverable Income Tax 11·64	
		Cash in Bank—Current Account 39·88	£617·93
	£617·93		£617·93

APPENDIX

LIST OF INVESTMENTS

Life Membership Subscriptions and Donations Funds

Nominal Value		*Market Value at 31/3/73*
£710·00	Claverhouse Investment Trust Ltd. 1,420 Ordinary 50p shares	£1,065·00
1,581·40	6½% Funding Stock 1985-87	1,217·68
82·75	Guardian Royal Exchange Association 331 Ordinary 25p shares	777·85
345·00	Imperial Chemical Industries Ordinary £1 Stock Units	966·00
290·25	Imperial Tobacco Group 1,161 Ordinary 25p shares	1,126·17
638·00	Imperial Tobacco Group 10·5% U.L.S. 1990/95	641·19
580·00	Imperial Tobacco Group 8% U.L.S. 1985/1990	556·80
28·50	London and Manchester Assurance Co. Ltd. 570 Ordinary 5p shares	954·75
247·50	National Commercial Banking Group Ltd. 990 Ordinary 25p shares	1,702·80
86·25	Shell Transport & Trading Co. Ltd. 345 Ordinary 25p shares	1,166·10
1,153·00	Stirling County Council 7¾% Loan 1977-79	1,014·64
2,359·35	Treasury 8¾% Loan 1997	2,088·02
760·00	Treasury 8½% Loan 1980-82	729·60
		£14,006·60

W. J. Reid and James Munro Bequests

£200·00	English & International Trust Ltd. 7% Loan Stock 1986	£225·00
1,359·29	6½% Funding Stock 1985-87	1046·65
80·00	Imperial Chemical Industries 80 Ordinary £1 Stock Units	224·00
208·00	Stirling County Council 7¾% Loan 1977-79	183·04
		£1,678·69

Dr Wilson Memorial Fund

£70·00	English & International Trust Ltd. 7% Loan Stock 1986	£78·75
276·60	6½% Funding Stock 1985-87	212·98
26·75	Guardian Royal Exchange Assurance 107 Ordinary 25p shares	251·45
		£543·18

12. LIST OF MEMBERS

The following information is the latest known to the Society. It would be appreciated if alterations requiring to be made could be intimated to the Secretary.

ABERDEEN

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ANGUS

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Adam, Andrew, Newhouse of Glamis, Glamis, Forfar.
Archie, Alex. R., South Leckaway, Forfar.
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Galloway, George L., East Balmirmer, Arbroath.
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Milne, Alex. S. Timaru, Trinity, Brechin.
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Pattullo, A., M.C., J.P., Littleton of Airlie, Kirriemuir.
Rankin, G. M., Westdrums, Brechin.
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Robertson, G. Kenneth, Heatherstock, Forfar.
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Hamilton, James, Hoprigg, Cockburnspath.
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Mather, James, Printonan, Duns.
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Thurso, Lord Robin McDonald, East Mains, Thurso.

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DUMBARTON

Findlay, John S., Easter Cadder, Kirkintilloch.

EAST LOTHIAN

Blakebell, John R., Bowmont, Dunbar.
Cochran, John M., Knowes, Dunbar.
Crawford, Lieut.-Commander W. H., Ugston, Haddington.
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Fullerton, A. W., Tranent Mains, Tranent.
Gardner, J., Stonelaws, East Linton.
Gibson, Frank P., New Blyth Stables, East Linton.
Graham, John, Queenstonbank, North Berwick.
Gray, G. B. R., Smeaton, East Linton.
Hamilton, Thomas Shearer, Phantassie, East Linton.
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MacKintosh, H. J., Bughtknowe, Humbie.
McLaren, John, Ballencrieff, Longniddry.
Miller, Hugh, West Fortune, North Berwick.
Miller, James B., Ferrygate, North Berwick.
Miller, J., Prora, North Berwick.
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Rennie, Douglas V., South Belton, Dunbar.
Rennie, James E., C.B.E., Greendykes, Macmerry.
Russell, Jack T., West Mains, Haddington.
Simpson, Thomas, Highfield, North Berwick.
Spence, C. G., Biel, Dunbar.
Steven, John, Under Bolton, Haddington.
Stoddart, J. A., M.P., Lorrimers, North Berwick.
Tweedie, A. J., Parkend, East Linton.
Watson, Rupert, Fenton Barns, North Berwick.
Wemyss and March, The Earl of, Discretionary Trust Estates Office, Longniddry.
Wright, W. J., C.B.E., Heugh, North Berwick.

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Dunlop, Wm. L., Ormiston, Newburgh.
Ferguson, Wm. Crawford, Grange of Lindores, Newburgh.
Gibb, John, Fliskmillan, Newburgh.
Howie, John, Newton, Wormit.
Howie, John C., Ballinbreich, Newburgh.
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ORKNEY

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Murray, William, Rossdene, Glenfarg.
Niven, John A., Gloagburn, Tibbermore.
Pattullo, I. N., Langlogie, Meigle.
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ROSS AND CROMARTY

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Gill, W. H. M., Rosskeen, Invergordon.

Gill, Wm. L., Rosskeen, Invergordon.
Gill, John D. Wilkhaven, Portmahomack IV20 1RD.
Gordon, Mrs B. A., B.Sc.(Agric.), Rosefarm, Cromarty IV11 8XU.
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Paterson, W. F., Tomich, Invergordon.
Paul, Harold D., Munlochy Mains, Munlochy.
Robertson, John C., Castlecraig, Nigg.
Stirling, Captain Sir J., Fairburn, Muir of Ord.
Sutherland, D., Tullich Farm, Fearn.

ROXBURGH

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Cadzow, James N., Kilpunt, Broxburn.
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WALES

Nil

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13. INSTITUTES FOR AGRICULTURAL RESEARCH IN GREAT BRITAIN

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

ARC Institutes:

Animal Breeding Research Organisation	King's Buildings, West Mains Road Edinburgh EH9 3JQ
Institute of Animal Physiology	Babraham, Cambridge CB2 4AT
Institute for Research on Animal Diseases	Compton, Newbury, Berks.
Food Research Institute	Colney Lane, Norwich NOR 70F
Letcombe Laboratory	Letcombe Regis, Wantage, Berks. OX12 9JT.
Meat Research Institute	Langford, Bristol BS18 7DY
Poultry Research Centre	King's Buildings, West Mains Road, Edinburgh EH9 3JS
Weed Research Organisation	Begbroke Hill, Sandy Lane, Yarnton, Oxford OX5 1PF

State-aided Institutes in England and Wales:

Animal Virus Research Institute	Pirbright, Woking, Surrey
East Malling Research Station	East Malling, Maidstone, Kent
Glasshouse Crops Research Institute	Worthing Road, Rustington, Little-hampton, Sussex
Grassland Research Institute	Hurley, Maidenhead, Berks. SL6 5LR
Houghton Poultry Research Station	Houghton, Huntingdon PE17 2DA
John Innes Institute	Colney Lane, Norwich NOR 70F
Long Ashton Research Station	Long Ashton, Bristol BS18 9AF
National Institute of Agricultural Engineering	Wrest Park, Silsoe, Beds. MK45 4HS
National Institute for Research in Dairying	Shinfield, Reading, Berks. RG2 9AT
National Vegetable Research Station	Wellesbourne, Warwick
Plant Breeding Institute	Maris Lane, Trumpington, Cambridge CB2 2LQ
Rothamsted Experimental Station	Harpenden, Herts. AL5 2JQ
Welsh Plant Breeding Station	Plas Gogerddan, Aberystwyth, Cardiganshire SY23 3EB
Wye College, Department of Hop Research	Ashford, Kent TN25 5AH

State-aided Institutes in Scotland:

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

SIR JAMES DENBY ROBERTS, 1904–1973