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

REPORT

TO THE

ANNUAL GENERAL MEETING

OF

THE SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING

18th JULY 1974

BY THE

BOARD OF DIRECTORS

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1. REPORT BY THE DIRECTOR

General

The year has been dominated by uncertainty as to how the New Order will work in practice, as to funding and as to staff pay. The first main round of meetings of committees set up under the various JCO Boards is now (March 1974) nearly complete and the Boards should soon be assembling their first reports. How the proposals emerging will be translated into action remains to be seen. On funding, provision for 1974-75, though somewhat cut from estimates, appears likely to be adequate. But much will depend upon whether nominal provision for the year can be adjusted for inflation. A Director has freedom of choice of expenditure only for, perhaps, 5 per cent of the budget; the remainder is made up of committed expenditure such as salaries, heat, light and power, and basic supplies. It follows that no economies within a fixed budget can possibly meet inflation such as we are now experiencing. On staff pay, the public will now be generally aware that there is serious discontent in the Scientific Civil Service over pay. One result has been an ever increasing wastage rate, especially in the more junior grades. Another has been the unprecedented strike of 6th March 1974; "unprecedented" because it was the first time scientists actually took an action that, a few years ago, would have been inconceivable. This is not the place to rehearse details of the scientists' case; one simply notes that, starting from being not-very-well paid in 1971, pay increased to 1973 by about 20-24 per cent while the cost-of-living index increased 27 per cent in the same period and the wage index by 40 per cent.

The uncertainties outlined in the preceding paragraph notwithstanding, some confidence in the future seems to be reflected in the fact that we have been encouraged to proceed with planning the laboratory extension mentioned in the last Annual Report. Building should start in September 1974 and, to make space, a new car park was constructed in March. At The Murrays, the new steading, effectively completed 1972-73, was in use and the surrounds were tarmacced in 1973-74. Fences were largely renewed during the year and the appearance and working of the farm much improved. There is still some way to go, however, and we are still wondering what to do with the picturesque but ruinate old steading.

Mr Fyfe became full-time Deputy Director in August 1973 when he was succeeded by Mr R. N. H. Whitehouse as Head of Forage Department. Mr Whitehouse, noted for his work on barley, came from the PBI, Cambridge, where he was for 25 years.

The third SSRPB lecture was given by Prof. K. Mather, F.R.S., to a large and receptive audience at Bush on 12th April 1973. His lecture was summarised in the last report; that of the fourth lecturer, Prof. A. H. Bunting, is summarised elsewhere in this report.

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, R. J. Giles)

Although barley is regarded as a self-pollinating plant, some cross pollination does occur. Breeders often disregard this until it is brought to their attention by the irregular behaviour of some progenies. In pedigree and pure stock work, cross-pollination has only nuisance value but in composite crosses it could provide a useful level of recombination. In either situation it is desirable to know the frequency of cross-pollination. To obtain estimates, two populations, each containing a wide range of genotypes and segregating for rachilla hair length, were analysed by recording the occurrence of long-haired dominant plants appearing in progenies of short-haired plants. The frequencies of the recessive allele were 14 and 20 per cent in the two populations and the crossing frequencies were 2·6 and 4·6 per cent respectively. If these figures were applicable generally to composite crosses they would suggest that useful amounts of recombination could be obtained without recourse to male sterility. On the other hand selection for increased cross-pollination could cause problems during the multiplication of pure lines subsequently selected from such composites.

Further additions to the barley genotype collection included a group of Canadian varieties required for the study of their amylases. Data on field characters were recorded on part of the collection and the taxonomic description of over eight hundred varieties was completed. No attempt will be made to describe all new varieties and more emphasis will be given in future to performance characters. The data obtained so far has been collated and is being prepared for computer handling, probably using the programme TAXIR which is now being mounted on an IBM 370 computer at the Edinburgh Regional Computing Centre.

Biochemical information on the large diallel cross experiment previously reported is now complete and the results for α-amylase activity and diastatic power are being analysed. While the experiment has contributed useful material to the breeding programme its main value lies in the experience gained through handling large numbers of crosses using a uni-variate approach. Unlike geneticists, who frequently study one character at a time, plant breeders must take all the relevant characters into account in reaching a balanced judgment. The diallel experiment has shown the need to apply multi-variate methods in plant breeding. In order to encourage their use, a short course on these methods was given by Mr J. L. Fyfe.

One multi-variate method, canonical analysis, has previously been used both to examine the varietal collection and to aid selection from a composite cross. Two selections from the composite cross performed well in trial again. A modification to the method has been devised in an attempt to estimate the genotypic economic values of the original variates making use of all the information provided by correlations with the other variates measured. Preliminary tests showed that the method has merit but a fuller evaluation is planned.

ARC Project 2: Barley biochemistry

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

(Worker: M. J. Allison)

The amylase enzymes of barley, under the general title of diastase, form a complex which is being studied in developing, resting and germinating (or malted) grain. The two main groups (α- and β-amylase) each exist as a number of morphs which can be detected either electrophoretically or as a result of their starch breakdown. For β-amylase the current position may be summarised as follows, where the strength of electrophoretic bands is shown by the number of + signs.

Developing Grain Type:—	Sd^d	Sd^e	Sd^f
Electrophoretic band I 3	+++	+	+
II 1	++	+++	+
II 2		++	+++
II 3			++
Resting grain Free vs. bound β-amylase	Bound > Free		Free > Bound
Malted grain Electrophoretic band β 5	+++		+
β 6	+		+++
Type:—	Sd1		Sd2

These β-amylase morphs are probably under the control of an allelic series at the Sd locus. The division into two groups based on the proportions of free and bound β-amylase (see *Ann. Rep.* **52,** p. 9, 1973) may be an over simplification as some aberrant types are still being investigated. The relationship between α-amylase morphs in developing and germinating grain is also being examined and their value in starch degradation is being assessed. This work provides an opportunity to develop genotypes with enhanced amylolytic properties of value to maltsters.

In addition to studying the amylases of barley varieties, the possibility exists of creating new, or at least changed, enzyme patterns by mutation. Such a procedure presents a problem because favourable mutations are rare events and if the population studied is small it may contain none of the mutants required; on the other hand, if the population is large the task of isolating the mutants is a formidable one. To overcome this difficulty it is desirable to incorporate a mass screening technique into a mutation breeding programme. This has been attempted by using an α-amylase inhibitor, abscisic acid, at a concentration which prevents the germination of genotypes with low diastatic power (DP) but permits those exceeding an acceptable minimum. The populations screened in this way were the M_2 generations of three varieties treated with the mutagen ethyl methane sulphonate.

The first variety treated, Ymer, yielded a number of lines with confirmed high diastatic powers. These are now being tested for their performance with regard to agricultural and other characters and are also being introduced as parents into the breeding programme. Crosses between these lines and naturally occurring high DP varieties are being made in order to determine their genetic relationships. The lines are also of interest as feeding barleys by virtue of their high nitrogen contents when grown in fertile conditions but yield assessments have yet to be made.

This screening system has now been applied to two further varieties, Maris Mink and Universe. From 100,000 grains of each variety a total of about 160 selections have been made. Tests on the M_3 generations have commenced and have shown that some of the lines have DP values well in excess of the parent variety.

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)

The objectives of the barley breeding programme are determined largely by the need to produce varieties which will yield consistently well and which will meet the requirements of processors.

There are three main uses for barley in Scotland—namely, as a source of carbohydrate and some protein for livestock, as a source of diastatic enzymes for the degradation of starch (mainly derived from maize) in the production of grain whisky and as a source of various enzymes and their substrates, mostly carbohydrates but also some proteins, for the production of either malt whisky or beer. Barley for diastatic purposes is largely imported and is therefore an obvious target for breeders here.

For the production of feed barleys several widely based composite crosses have been grown at sites in east, west and north Scotland in order to allow "natural" selection to occur. Selection in some of these populations has produced some high yielding lines which will continue in trial for further assessment. Seed stocks of all the unselected populations were produced at The Murrays in 1973. From these a group has been selected and will be grown in a trial in 1974 to estimate the effects of site and of generations on the main characters of agricultural importance in barley. The basic stocks are also being maintained at each site to act as a source of genetic material in years to come.

The composites have been successful in producing high yielding lines but have failed in respect of straw height, as might be expected, since short plants are at a competitive disadvantage in a mixed population. In order to overcome this, two new composites are now under construction. One is based on the older composites and the other on crosses between a group of high yielding varieties and a group of selections from previous composites. They will be subjected to strong selection pressures for characters of major importance such as height, earliness and disease resistance.

An increasing share of the programme for feed barleys is being handled by pedigree breeding methods. The most advanced material was in the F_4 generation in 1973. In an attempt to increase the output of work a small pilot experiment was established in collaboration with the New Zealand Department of Scientific and Industrial Research whereby some F_3 lines were sent, in October 1973, to Gore in South Island, N.Z. and their progeny should be available for sowing here in spring 1974. If the timing proves satisfactory it is hoped to make permanent arrangements.

The breeding objectives of work on high-diastase barley are broadly similar to those for feed barley (high yield, good straw, early maturity, disease resistance and high nitrogen content of the grain) with, of course, the extra character of high diastatic power (DP). Selections made from composite crosses, using the halo-screening technique, were grown in trial but, with one exception, gave poor yields. Screening of such populations with abscisic acid treatments to select high diastase lines was attempted and will be continued. This should enable a population with high DP to be established which could then be put under selection pressure for other characters.

The pedigree programme for high-diastase barleys is at a stage similar to that of the feed barley programme. Selections with high diastatic power, equivalent to Akka which is taken as a standard for this character, and with high yield and short straw have been obtained from the cross Akka × Midas. This is especially encouraging, occurring as it has in a first batch of crosses, but more attention to disease resistance will be given in subsequent crosses. Disease situations rarely remain static and the protection against mildew provided chemically for Golden Promise is unlikely to prove permanent, nor can the present relative unimportance of *Rhynchosporium* on barley in Scotland be taken as a reason to neglect it.

The discovery that the Station stock of Glacier barley contained an abnormally high proportion of the amylose component of starch led to the supposition that it would degrade more completely during the mashing process to which malt is subjected. A backcross and selection programme was initiated in order to transfer the high amylose character (which was associated with a higher proportion of small starch granules) into adapted varieties including Midas and Zephyr. Some of these third and fourth backcross lines, which have over 40 per cent amylose in the starch, are being multiplied in New Zealand. The programme has been extended by making new crosses either amongst the high amylose lines or with high yielding varieties. These will be available as F_1 or F_2 grain for sowing in 1974.

The original supposition and the extent to which amylose content and starch granule size are correlated have not been adequately demonstrated. The doubt about the correlation led to some difficulties during selection but questioning the degradability of high-amylose starch throws into doubt the economic value of this project. Evidence is accumulating both here and elsewhere that high-amylose barley, far from degrading its starch more readily, is in fact more resistant to its own enzyme system. Furthermore, isolated starch and endosperm samples incubated with α-amylase produced twice as much reducing sugar from normal as from high amylose starch. Preliminary results from micro-malting tests now being undertaken also show that high-amylose varieties give low extracts. The levels of α- and β-amylase activity in high amylose Glacier are low even after treatment with hydrogen peroxide (to break dormancy) and gibberellic acid. There remains a possibility that this mutant may have some value in poultry feeding.

Variety-nitrogen trials were again conducted at three sites, one in Fife and two in East Lothian. Twelve varieties were grown with and without mildew control (a single application of Calixin at an average growth stage 7) in three replications, with split-plot nitrogen top-dressing at three levels. The performance of a new Danish variety, SJ678060, was consistently good, this variety being ranked top twice and second in the remaining trial where it was marginally out-yielded by Maris Mink. Maris Mink, Universe and Midas all yielded well although all were later than SJ678060. Mazurka performed poorly but in a trial of this nature, very early genotypes have to remain until over-ripe before being harvested. At two sites where counts were taken, Mazurka shed significantly greater numbers of heads than any other variety and this almost certainly accounted for its poor performance. At one of these sites Julia also showed high levels of head-shedding. Overall yield figures were good at all sites and a number of these interesting new varieties should become available to farmers soon.

ARC Project 4: Oat breeding

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

(Workers: D. Cameron, M. S. Phillips)

Multiplication plots of the old varieties, Sandy, Albyn Empress, Bell and Shearer, together with Pentland Provender, were grown at The Murrays. There has been little demand for seed of Pentland Provender but a request from Iceland, as a result of successful trials there, was much larger than could be met. A new selection, Aa 744, which did not differ sufficiently in performance from Shearer to be useful here, might also find a place in Iceland. Trials were conducted in Nairn and Aberdeen in addition to those at The Murrays and at three selection centres. Three new selections (one of known parentage and two from bulk hybrid populations), amongst those grown in the 1973 trials, significantly outyielded Astor at all centres. Seed for the establishment of multiplication plots was produced from these selections which will be submitted for national trials if they perform well again.

The main effort in oat breeding continues to be by means of composite crosses, the earliest of which was established in 1965 and is now yielding selections which were in trial in 1973 at The Murrays and at the three selection centres. In The Murrays trial the mean yield of selections derived from that part of the composite grown in the Lothians exceeded the means of those from the west and north of Scotland by about 5 per cent but it was impracticable to have trials at the other centres in 1973 to check if the equivalent situation occurred there. A more elaborate set of trials has been prepared for 1974.

A Station selection, Aa 725, which has short straw but matures rather late, has been treated with ethyl methane sulphonate in an attempt to induce mutations for earlier ripening. The first such treatment produced only one early plant but this was also tall; however a second treatment resulted in a number of early M_2 plants which were also short and have been saved to grow again in M_3.

Breeding for oat stem eelworm (*Ditylenchus*) resistance, using controlled laboratory tests, has been part of the programme for many years. Two resistant selections with reasonable field performances on clean land now need to be tested on infested land. Unfortunately (or fortunately) the organism has declined in areas of oat cultivation to a level at which it is difficult to find sites on which an attack could be guaranteed. This makes testing in the field difficult and throws doubt on the need to continue with this work. It should be noted, however, that changes in cultural practice could quite quickly reverse the trend and, in the absence of resistant varieties, agriculture would suffer.

The need for an oat variety tolerant of the highly alkaline machair sands is also in doubt since spraying with manganese to combat deficiency (grey speck) has become a routine practice. In this programme also, testing is difficult because suitable sites giving predictable results on control varieties cannot readily be found. Selections made in Tiree and at Archerfield in East Lothian are available for assessment but in the absence of a strong case for further work this programme will be concluded next year.

The oat collection, now containing just over five hundred varieties, continues to be expanded and documented.

ARC Project 5: Hybrid swedes

Methods of exploitation of known intervarietal heterosis

(Worker: S. Gowers)

If positive heterosis for yield of dry matter in swedes, evidence for which has already been published, is to be utilised commercially, a practicable way to ensure cross-pollination in this largely self-pollinating species will be required. At present the use of incompatibility is the most promising method but, although the necessary S-alleles are abundant in other cultivated Brassicas, they are rare in swedes. A Station line, known as APZ, contains one S-allele which is being transferred to newer varieties by back-crossing. Other sources of S-alleles already in *B. napus* are Panter and Matador rapes and a Station amphidiploid, H52, derived from *B. oleracea*, cv. January King and *B. campestris* ssp. *narinosa*. This amphidiploid was thought to have two alleles which have now been separated, but one of these has continued to segregate so a third allele is presumed to be present.

From Panter, an artificial rape from Svalöf, Sweden, seven self-sterile lines are being examined and have so far yielded two distinct S-allele homozygotes and others may yet be isolated. Similarly, from three lines of Matador one homozygote has been isolated. As they become available these lines are being crossed, and then back-crossed, to adapted swede varieties. Other *B. napus* incompatibles are available but will not be used until more information is available about those now being studied. The use of artificial rapes is important because they may contribute S-alleles from *B. oleracea* to swede breeding.

Compared with *B. oleracea*, *B. campestris* can be crossed relatively easily with *B. napus* thus providing the possibility of introgressing S-alleles from *B. campestris*. Turnip-swede F_1 hybrids have been grown in isolation with swede pollinators. Seed harvested from the hybrid is being surveyed for chromosome number. From 129 seeds examined so far, the expected range of chromosome numbers from 29 to 38 has been observed, 40 per cent having 29 and 12 per cent having 38 chromosomes. The latter group of plants will now be tested for incompatibility. A further set of crosses has been made using *B. campestris* lines known to be homozygous for S-alleles.

The alternative way of ensuring cross-pollination, by means of male sterility, shows less promise. The genetic " male steriles " studied have all produced too high a proportion of male fertility especially at the end of the flowering season. Two cytoplasmic male steriles from an oil seed rape, supplied by Dr K. F. Thompson, are still being studied but these, too, show some fertility.

To provide additional information concerning the levels of heterosis and the gene systems involved, an eight-parent diallel set of crosses has been made. The parents include Bangholm, Wilhemsburger and Pentland Harvester and were chosen because they had performed well in NIAB trials. The extent of natural out-crossing was estimated from a pollination plot grown in 1972 consisting of purple topped swedes into which 12 green topped plants were introduced. Amongst the offspring of these 12 plants the proportion of purple topped swedes, varied from 8 to 93 per cent in samples each of about 1000 plants. The majority fell into an expected range of 8 to 17 per cent but the cause of one intermediate (35 per cent) and three very high (93, 80 and 76 per cent) figures for out-crossing is at present unknown. Incompatibility or male sterility was not suspected in this material.

Two small trials, at Pentlandfield and The Murrays were used to estimate heritabilities. Progenies of 20 plants of the swede variety Scotia, which had been grown in an isolation plot, were sown in May with six replications at each site and harvested in November. Measurements of fresh weight yield, dry weight yield, dry matter percentage and soluble carbohydrate content gave calculated heritabilities of 72, 64, 85 and 92 per cent respectively. These higher values suggest that some of the heterosis should be fixable and that attention should continue to be given to producing inbred lines with high performance.

ARC Project 6: Swede breeding

New swede varieties to replace Pentland Harvester for mechanised cultivation.

(Worker: Miss I. K. Munro)

A selected line of Pentland Harvester previously noted for a low level of raan (internal browning) was sown in a quarter-acre plot for selection on this character. Despite siting the plots in a high pH area of The Murrays, browning was very rare in Pentland Harvester itself so further selection was not possible. The absence of a controlled test for raan is a serious difficulty in this programme. Although higher yielding varieties are becoming available, Pentland Harvester is still of potential value because of its suitability for machine lifting.

Selected F_4 plants of crosses with Pentland Harvester were allowed to flower in selfing bags or isolation cages, but seed sets in 1973 were generally poor.

A set of crosses not derived from Pentland Harvester was grown in trial as F_4 lines. Of the 189 entries only five gave dry matter yields greater than the top control, Bangholm. A few high yielding lines suitable for mechanical harvesting have been selected.

ARC Project 8: Kale improvement

Study of kale breeding systems with object of developing grazing types with a wide genetic base.

(Worker: G. R. Mackay)

An attempt has been made to widen the genetic base used in breeding kale by introducing into the programme a number of other forms of *B. oleracea*, including cabbage and Brussels sprouts. In a trial of 142 polycross progenies harvested early in 1973, more than a third significantly exceeded the dry digestible organic matter yield of Maris Kestrel, the top control variety. Despite the wide genetic base, most of these high yielding progenies were of the marrowstem type. Yields in this trial were low and rather variable due to weed infestation but, despite this, selections were made from the top 20 families and were polycrossed to produce progenies for trial in 1974 at The Murrays.

In a study of the genetic variability in *B. oleracea* nearly 3000 plants were harvested late in 1972 from a trial sown in two blocks of fully randomised individuals. These plants were derived from 52 bi-parental progenies and from selfs of their 104 parents, which were taken from a random-mated population based on four main types:—cabbage, marrowstem, thousand-head and curled kale. Data were collected on height and on leaf, stem and total fresh weights. The analysis is not yet complete but the absence of any effects due to blocks has allowed the data to be pooled over blocks. Heritabilities for stem yield and height were high (>80 per cent) but for leaf yield and total yield were much less (<40 per cent). Partitioning of the variances suggested that the major part of the genetic components for height and for leaf : stem weight ratio was additive. For leaf, stem and total fresh weights, however, there appeared to be considerable non-additive (dominance) components.

Part of the plant material from this biometrical study is being used in a reciprocal recurrent selection programme. The first round of crossing should be completed in 1974.

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: I. H. McNaughton, G. R. Mackay and Miss C. L. Snell)

The production of artificial *B. napus* either by crossing auto-tetraploids of *B. campestris* and *B. oleracea* or by crossing the diploid forms and treating the F_1 with colchicine is a useful but difficult step towards widening the genetic variability in *B. napus*. Attempts, using an embryo culture technique, continued in 1973 but were largely unsuccessful. Two hybrids were produced in the previous year.

One by-product of this work is a number of autotetraploids some of which are of value in their own right. A quantity of seed of tetraploid Maris Kestrel large enough for trials is now available and a tetraploid stock of Proteor, a French variety, is at an earlier stage of production. Two tetraploids from crosses of *B. campestris* involving the subspecies *nipposinica* and either the stubble turnip Tigra or the turnip Bruce are sufficiently uniform to be agriculturally acceptable and gave dry matter yields of leaf much higher than stubble turnips. They have very little "bulb" or stem and may be more suitable for autumn grazing by sheep which frequently leave much of the stubble turnip bulb uneaten. Seed of these two selections is being multiplied by NSDO for further trials.

Estimating the acceptability of plant material by grazing stock is difficult and would be much simplified if an artificial test were available which correlated closely with results of tests with animals. Considerable amounts of rape stem are left ungrazed by sheep and yet estimates of stem digestibility (DOMD) of Nevin and Silona were in excess of 80 per cent in October, November and January. The leaves, on the other hand, had digestibilities lower by 5 to 9 percentage units, a highly significant difference. Alternatives to the artificial rumen analysis are being studied in the Chemistry Laboratory.

Residual heterosis was estimated by comparing two F_2 artificial rape × Nevin rape populations with Nevin rape (the highest yielding parent). Total dry matter yields were 78·6 per cent and 99·8 per cent of Nevin. Corresponding F_1's had yielded 130 per cent and 105 per cent of Nevin respectively. It was concluded that the use of F_1 hybrids or of residual heterosis would not be economic. Useful lines from the now discontinued work with *B. napocampestris* and its hybrids with *B. napus* are now available for inclusion in the rape programme.

Crosses have been made to transfer S-alleles from various sources, including artificial *B. napus* produced at the Station, to agronomically desirable forms of forage rape. These are required as parents for the production of *B. napus* × *B. campestris* hybrids. Such sesquidiploid (or triploid) rape × turnip hybrids have yielded more digestible dry matter than rape controls but, for their commercial production, self-sterile lines of both parents are required. For this purpose the isolation of S-allele homozygotes in turnips was advanced by making a further 14 intra-family diallels. Twenty-five putative S-allele homozygotes have been isolated in two seasons but difficulties in maintaining these are becoming greater. Annualization and inbreeding depression have resulted in the loss of some lines and poor seed set in others. Six of the first lines produced were crossed in an inter-family diallel and demonstrated that each was homozygous for a unique S-allele. Dominance relations will be tested next by back-crossing.

ARC Project 10: Raphanobrassica

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

(Worker: I. H. McNaughton)

Seed fertility, which was very low in early generations of *Raphanobrassica*, has shown improvement in F_4. Plants were selected from large populations over-wintered in the field and placed in isolation; 28 per cent of these were totally sterile but seed yields of up to 30 g per plant were obtained from the remainder and the overall fertility level was considerably greater than in the corresponding F_3 generation.

Transplants from 33 F_4 families were observed in the field. These were mainly based on thousand-head kale as the *Brassica* parent. Marked differences between families were shown in vigour, degree of flowering and plant form. Several families were uniformly vigorous and winter-hardy with little or no flowering. Intra-family differences are probably a reflection of a high degree of selfing, F_4 families being derived from individual F_3 plants in a polycross. An earlier experiment had shown *Raphanobrassica* to possess little or no self-incompatibility.

A tendency to early flowering in the most advanced *Raphanobrassica* material is no doubt a reflection of the annual habit of the commercial *Raphanus* cultivars used as parents in the first crosses. A late-flowering autotetraploid fodder-radish has been established for use as *Raphanus* parent and has also been multiplied by the National Seed Development Organisation for National List Trials.

Hybrids between *R. sativus* (fodder radish) and *R. maritimus* (sea radish: a biennial-perennial wild species) have shown perfect chromosome pairing and dissociation. F_1 hybrids, sown in late June, were completely non-flowering and have proved winter hardy although with some leaf senescence. Fodder radishes, grown under the same conditions, flowered early and were killed by frost. There is, therefore, the prospect of establishing a leafy, biennial radish which might be agronomically useful in itself as well as of value as a parent in *Raphanobrassica* synthesis. Tetraploid hybrids of the two radish species are therefore being produced for inter-generic crossing.

All *Raphanobrassica* plants raised so far have been derived from *R. sativus* as female parent. The cross 4x *B. oleracea* × 4x *R. sativus* was attempted with a view to the possibility of *Raphanobrassica* with *Brassica* cytoplasm being more fertile than with *Raphanus* cytoplasm. Pollen-tube growth, as examined with a U.V. microscope, was good but very few ovules developed. Six plants were obtained but these appeared to be maternals.

F_4 *Raphanobrassica* plants were crossed reciprocally with other *Brassicae*. *Raphanobrassica* was inter-sterile with *B. oleracea* and *B. campestris* but produced four seeds with *B. napus* as female and three seeds with *R. sativus* as male parent. It is concluded that *Raphanobrassica* may be multiplied near or adjacent to the species above with relatively little chance of hybridization. Differences in flower colour leading to discrimination by insect pollinations would reduce the chances of cross-pollination.

Raphanobrassica, obtained by bulking low fertility F_4 families, was compared in a drilled experiment with kale, rape and stubble-turnip cultivars. Some early flowering occurred in *Raphanobrassica* and establishment was erratic. Early flowering plants were severely affected by frost. Giant rape also suffered some frost damage. Dry matter yield of *Raphanobrassica* was 5 per cent lower than Giant rape but 25 per cent and 68 per cent higher than Nevin rape and Dward Essex rape respectively. Leaf to stem ratio, dry matter content and crude protein content of leaf and stem were similar to Giant rape.

F_4 *Raphanobrassica* families have varied in their resistance to virulent cultures of *Plasmodiophora* (the causal agent of club-root disease) but resistance to strains which attack Nevin rape was again demonstrated; one family, however, was susceptible where Nevin was resistant.

All *Raphanobrassica* plants observed at The Murrays proved immune to *Erysiphe cruciferarum* (powdery mildew) which severely affected swedes and Nevin rape in particular.

The original *Raphanobrassica*, described by Karpechenko in 1924, was reasonably fertile but considered of no agronomic value; it was obtained by inter-crossing *Raphanus* with horticultural forms of *B. oleracea* at the diploid chromosome level, allotetraploids, *i.e.*, *Raphanobrassica*, arising by spontaneous chromosome doubling in the F_2 generation (probably by fusion of unreduced gametes). At the Station a few seeds were obtained from diploid F_1 hybrids of *R. sativus* (fodder radish) and *B. oleracea* (various kales) hybrids placed in isolation; 112 F_2 plants raised showed considerable variation in growth habit, colour and degree of dissection of the leaves. Chromosomes number have not yet been ascertained.

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)

The large Italian ryegrass trial of progenies from a North Carolina I mating design (*Ann. Rep.* **52,** pp. 16-17, 1973) was completed in 1973. The trial contained 59 pairs of reciprocal crosses grown as widely spaced plants, as closely spaced plants in narrow rows and as swards. Genetic correlations and heritabilities have been calculated for yields and winter damage; these are given with their standard errors in the table; the figures on the diagonal are narrow-sense heritabilities of family means.

	Total yield (3 cuts) 1972			Winter-kill 1972-73		
	1. Spaced	2. Row	3. Sward	4. Spaced	5. Row	6. Sward
1.	*0·24 ± 0·196*	+0·88 ± 0·156	+0·86 ± 0·315	+0·10 ± 0·495	−0·25 ± 0·388	−0·30 ± 0·395
2.		*0·53 ± 0·218*	+0·85 ± 0·122	−0·09 ± 0·336	−0·25 ± 0·273	−0·31 ± 0·275
3.			*0·34 ± 0·196*	−0·31 ± 0.408	−0·31 ± 0·348	−0·54 ± 0·341
4.				*0·37 ± 0·203*	+0·96 ± 0·194	+0·88 ± 0·194
5.					*1·10 ± 0·124*	+0·81 ± 0·107
6.						*0·51 ± 0·217*

The high positive genetic correlations between yields at the different densities are worth noting since they indicate that the widely held belief, that selection for yield on the basis of spaced plant performance is unlikely to result in improved sward performance, may be unjustified. The negative correlations between yield and winter kill are also encouraging since they suggest that selection for resistance to winter kill in Italian ryegrass need not be at the expense of yield.

The progenies of the crosses attempted between seven Italian and seven perennial ryegrass inbred lines were sown in a field experiment. It was obvious that many of the progenies were not of hybrid origin; those that appear to be so will be assessed for yield and longevity.

Four plots have been established (two to be grazed and two to be mown) of a widely based cocksfoot composite cross which includes some genotypes unadapted to Scottish conditions from, for example, Mediterranean areas. A study has been made of the heritabilities and combining abilities using an incomplete diallel design based on some of this group of crosses. The composite cross plots will be maintained for at least two years.

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)

Analyses of the experiment on winter resistance in perennial ryegrass (conducted jointly with the Welsh Plant Breeding Station and the Plant Breeding Institute, Cambridge) are now available. At all sites there was less winter damage than was expected. The best distinction between hardy and non-hardy varieties was obtained by subjecting the plants to a late cut so that they entered the winter with both a minimum of leaf growth and a minimum in their reserves. At Pentlandfield the effect was less pronounced than at the other sites. A more comprehensive co-operative trial has been sown.

The mass selection of spaced plants of Italian ryegrass for winter resistance appears to be effective; progenies of plants from the first cycle of selection (made in the spring of 1971) were hardier than unselected plants and more than three-quarters of them were also hardier than Combita, a variety generally considered outstanding in this respect. A second cycle of selection has now been completed and the progenies of the selected plants have been prepared for sowing in 1974 for yield assessment.

Selections of winter-resistant plants were also made from the trial of North Carolina I progenies described under Project 11. Selection was on the basis of both sward and spaced plant performances. The plants were grown in two polycrosses to give progenies to be sown in field trials in 1974. Some of the parent plants have been maintained for crossing in an open-pollination plot.

ARC Project 13: Cocksfoot breeding

Selection of nutritious and high yielding derivatives of Scotia cocksfoot.

(Worker: Miss C. J. Williamson)

Scotia cocksfoot, a Station variety, offers good winter hardiness, resistance to drought and a higher digestibility than most cocksfoots. This programme seeks to improve the yield and persistency of Scotia without detriment to its other characters. Scotia was crossed with eleven other varieties, and by a rather complex sequence of further crossing and selection for yield, digestible organic dry matter (DOMD) and associated characters, a base population for further selection was derived. The assessment of all progenies from this for DOMD was not possible in a single season and so there are now two similar groups, one a year ahead of the other.

Both are now in their third cycle of selection prior to the establishment of polycrosses in 1975. Results from a harvest of 110 lines in October 1972 are available for one stock and show that 93 per cent of the progenies exceeded Scotia in yield of dry matter and 61 per cent had higher DOMD percentages. The overall mean DOMD was 66·6 per cent compared with 66·1 per cent for Scotia. Analysis of 110 lines from the other stock is nearly complete. A DOMD threshold of 67 per cent will be used as one selection criterion.

ARC Project 14: Poa breeding

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

(Worker: Miss C. J. Williamson)

Progenies of interspecific hybrids with *Poa pratensis* as one parent and *P. ampla, P. iberica* or *P. longifolia* as the other are being assessed for apomixis, earliness of growth, rhizome development and yield. Ten of the 72 F_1 hybrids gave sufficiently uniform progenies to suggest that they might be apomictic. These ten progenies all resembled the male (*P. pratensis*) parent more closely than the female parent and will be subjected to further testing. The majority of the remaining progenies were less vigorous than their parents and segregated widely for habit. From a field trial of progenies from crosses made in 1970 about 150 plants (5 per cent of the total) have been selected because of their good overall performance. Of these about 30 are very promising. All will be used for back-crossing and progeny tests.

Micro-swards, including white clover, sown at Pentlandfield in 1971 were slow to establish, but after two years with sheep grazing most plots now have a good proportion (50-80 per cent) of the ground covered by Poa and are now suitable for yield tests. Micro-swards established in 1972 were cut six times in 1973 and from plots on Turnhouse Hill (made available by the Hill Farming Research Organisation) estimates of DOMD from 1st harvest on 2nd May ranged from 62 to 67 per cent.

There is a need for a reliable test to distinguish apomictic from sexually reproducing plants. It is possible that this could be done using multi-variate techniques to assess the variability of progenies, by means of a genetic marker, preferably a seedling character or by a study of embryo development. These methods are being examined.

ARC Project 15: Breeding systems

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

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

The computer program simulating breeding procedures has been very little used. It seems that plant breeders prefer real plants to imaginary ones.

A variety trial of *Arabidopsis* was run under two sets of conditions in growth chambers. It provided a basis for choosing attributes to study in breeding work. F_1 and F_2 seed from a diallel set of crosses was produced. The work was then interrupted by the 1973-74 power emergency.

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, A. A. McFarlane)

Thirty advanced clones were grown in the final assessment trials at three centres in England (Gleadthorpe, Arthur Rickwood and Terrington Experimental Husbandry Farms) and at The Murrays, East Lothian. One clone, number 6670c(7), of early-maincrop maturity, emerged as worthy of submission for Plant Variety Rights and for entry to the National List trials. However further development of this clone must be delayed. Restrictions have been placed by the plant quarantine authorities on the movement of potato material from Pentlandfield. These restrictions, imposed as a safety precaution, follow the finding of potato spindle tuber virus in the Commonwealth Potato Collection (see *Ann. Rep.* **52**, p. 26, 1973). These restrictions have had serious effects on the development of three clones currently undergoing National List Trials. Clone 6123b(1) (see *Ann. Rep.* **51**, p. 6, 1972), which completed its second year in Statutory Performance Trials in 1973, has been withheld from entry in 1974 into the Potato Marketing Board's regional trials, a matter of some regret, since these trials would have provided the first data on the performance of this clone when grown, harvested and stored under farm conditions.

In an attempt to extend development work on new varieties and to fill the gap which now exists between the naming of a variety and its availability to ware growers, arrangements are being made with the National Seed Development Organisation for the production and sale of Grade A seed stocks. These stocks, to be known as "Development Stocks", will serve two purposes. They will help to develop an interest in a new variety among seed raisers and ware growers and so prepare the way for VTSC (virus-tested, stem cutting) stocks following on, several years later, in the multiplication sequence; they will also provide valuable information on its performance under farm conditions. For this purpose plots of one-tenth acre of each of the three clones now in National List trials were "Approved" in 1973 under the DAFS certification scheme. The intention was to grow plots of at least ½ acre in 1974 for certification, but again quarantine restrictions will prevent this during 1974.

Material in its first year of selection at The Murrays was derived from three different groups of parents; Neo-tuberosum clones (NeoT), new virus resistant material (VR), and conventional Tuberosum parents (Tbr). Selection of progeny on visual assessment of tuber characters, made without reference to parentage, led to a retention rate more than twice as high from Tbr × Tbr as from Tbr × NeoT progenies. The NeoT progenies on the other hand were rather higher yielding, in both the second-early and early maincrop maturity groups. Cooking quality assessments show that while on average the Tbr × Tbr progenies were superior to either Tbr × VR or Tbr × NeoT, the latter do contain a proportion of high quality clones. The rate of retention from crosses of VR × NeoT was low. Thus, while the widening of the genetic base of the maincrop breeding programme has resulted in a predictable drop in various aspects of tuber quality, this drop is not regarded as excessive and the general level of performance from these exploratory crossings is encouraging. A more detailed assessment of NeoT clones and of their breeding value in relation to other characters, disease resistances for example, is still needed.

Work continues on the programme to produce varieties with high specific gravity (high dry matter content). The oldest material, from crosses made in 1970, grown as single plants at The Murrays in 1972, was selected for specific gravity and about 1,000 clones with higher specific gravity than Record were grown on in 3-tuber plots in 1973. Measurements on this material show that one year's selection has raised the mean specific gravity of the population above that of the unselected parent populations and close to that of the Record controls. Examination of the frequency distribution of these clones shows that 75 per cent had specific gravities greater than 1·090 and 22 per cent equalled or exceeded the median value of the control variety. These results indicate that successful selection for specific gravity can be practised on the basis of data derived from small (5-tuber) samples.

Further crosses were made in 1973 using British and European high specific gravity varieties; 48,000 seedlings were grown in the glasshouse and about 25,000 single plants at The Murrays, alternating with Arran Victory. The single plants in the field were successfully harvested with the single-plant harvester and the development phase of this machine is now satisfactorily completed.

First-early trials were conducted for the first time at four centres in first-early growing areas: Cornwall, the Gower peninsula (Glamorgan), Pembrokeshire and Ayrshire. Analysis of yield data confirms the superiority of one clone, 7169, over the remainder at the three southern centres, where it gave yields similar to the controls Home Guard and Epicure. It was clearly superior to Home Guard in tuber quality after cooking, and to Epicure in shape. The rankings of the clones for yield were identical at these three centres and also at The Murrays but at the Ayrshire centre 7169 gave the lowest yield. It performed badly in Ayrshire in the 1971 and 1972 trials also. The reasons for this anomalous behaviour are not yet clear. It might indicate a genuine genotype-environment interaction but, alternatively, it might reflect a peculiarity of the pre-planting treatment of the seed. A more critical assessment of these clones is planned for 1974 and seed has been multiplied for the purpose at the Glamorgan centre: the 1973 trials were grown from Blythbank seed.

In general, the growth of potato breeding material at The Murrays in 1973 was very satisfactory. Overall yields were considerably higher than in 1971 and 1972. The Pentland Crown control plots in The Murrays replicate of the maincrop regional trials, yielded 78 per cent more than in 1972 despite the fact that less nitrogen was applied. It is worth recording that the frequency of plants with virus leaf roll in the high specific gravity 3-tuber plots (derived from seed grown as single plants at The Murrays in 1972) was from one-fifth to one-tenth of that in other Murrays plots grown from Blythbank seed.

Two conclusions may be drawn from the data. The high specific gravity single plants, raised as seedlings in aphid-proof glasshouses, are virtually free of leafroll and the programme of aphicide sprays, applied in 1972, and designed to prevent multiplication of aphids at The Murrays, appears to have been successful. On the other hand the relatively high frequencies in Blythbank stocks, which occur despite assiduous rogueing, are undoubtedly due to infection of seedlings at source when grown at Pentlandfield in an older non-screened house. Modifications to this house are clearly necessary since regular fumigation has not prevented primary infections.

In Kenya, five new blight resistant clones were named as follows: Roslin Tana, Roslin Athi, Roslin Gucha, Roslin Ruaka, Roslin Karura. All were raised at Pentlandfield and were introduced to Kenya as single tubers in 1971. The names are based on Kenyan rivers.

ARC Project 18: Potato economic genetics

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

(Worker: R. J. Killick)

The main interest in this project is centred at the moment on the estimation of general and specific combining abilities of six parents, crossed in a half-diallel, for a range of characters including yield, specific gravity, disease reactions, tuber number and size distribution. 1973 was essentially a multiplication year when some 1,400 plants from 14 families were grown to produce seed tubers for planting clonal plots in 1974. Data for estimation of combining abilities will be collected from the 1974 plots and their tuber progeny.

ARC Project 19: Potato blight

Mechanisms of field resistance and variability of the pathogen.

(Worker: Miss J. F. Malcolmson)

Further attempts have been made to induce vegetative hybrids between five different races of *Phytophthora infestans*, inoculated into tubers. The material is still under incubation and results are not yet available.

A comparison of field observations and whole plant tests in the glasshouse suggest that tests at different stages of maturity are necessary in assessing a clone's susceptibility. When comparing the reactions of plants of Majestic, inoculated at different ages, a marked increase in stem resistance was noted with advancing maturity, in both lesion size and sporulation. The significance of other differences observed in leaf reactions will be established when analysis of data is complete.

ARC Project 20: Commonwealth Potato Collection

Introduction, quarantine, maintenance and distribution of the Collection.

(Workers: D. R. Glendinning, Miss S. C. Tribble)

The status of the Collection with respect to the various potato spindle tuber virus testing procedures is now very complex. Material grown and tested during 1971 was retested during the winter of 1972-73. Infections were detected in certain lines and these were destroyed. During the summer of 1972 only cleared lines were grown for purposes of seed renewal. During the winter 1973-74 testing was resumed and some further infected lines were detected and destroyed. The present position may be briefly summarised as follows.

Testing is still unfinished. Some lines have been cleared but only some of these have been seeded. Another group is incompletely tested, suspect and incompletely seeded while the third category consists of lines not suspect but still incompletely tested and seeded. The numbers of lines in each of these nine categories is given in the table below as percentages of the Collection total of 1,159 lines.

	Cleared	*Not Suspect*	*Suspect*	*Totals*
Seeded	17	20	9	46
Part seeded	14	6	8	28
Unseeded	7	7	11	25
Totals	38	33	28	

Despite the present difficulties in maintaining and distributing seed, 74 samples were sent to five persons in the UK and 49 samples to four persons abroad: Peru, Colombia and USA (twice). All material was accompanied by the routine warning and despatch was approved by the plant quarantine authorities of the Department of Agriculture and Fisheries for Scotland.

ARC Project 21: South American tetraploids

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

(Worker: D. R. Glendinning)

Detection of potato spindle tuber virus (PSTV) in Commonwealth Collection seed lines of Chilean Tuberosum, vegetative material of which had been grown in proximity to NeoTuberosum material in the field in previous years, placed some of the NeoTuberosum clonal material under suspicion. Subsequent tests revealed some infection in this group and all of it was destroyed. On the other hand, the main NeoTuberosum population of seedlings and seed production plots has had virtually no contact with material of Chilean origin. Nevertheless, some suspicion attaches to this from an independent source. Two of the early Andigena accessions to the CPC were found to be infected with PSTV and both might have contributed seed to the initial NeoTuberosum base population in 1961. For these reasons, the NeoTuberosum work has been severely restricted in the past year. Material grown was subject to strict safety precautions involving special fencing, limited access by men and machinery, and other restrictions which inevitably interfered with the normal processes of data collection. In addition, and in order to take every possible precaution, even when the risk of infection was extremely low, much valuable material was destroyed including seedling progeny from NeoTuberosum parents and the whole of one year's planting of material in the leaf roll trial at Cambridge (some NeoTuberosum but mostly virus breeding material). Pollinations, disease resistance tests and the raising of seedling populations were abandoned. Meanwhile, despite efforts by the DAFS quarantine staff, who are performing the tests, resources are inadequate to meet the needs and no testing has been carried out on the main NeoTuberosum programme to resolve the suspicions. Work on this programme is likely, therefore, to be similarly restricted in the coming year.

Studies on clonal plantings continue to show notable progress towards earlier maturity, higher yields, improved tuber shapes and better cooking quality.

Some controlled pollinations were possible between NeoTuberosum seedlings (pollen parents) and PSTV-cleared Andigena lines from the Commonwealth Collection. The purpose is to introduce fresh germplasm and expand the gene pool of the population.

The best clones selected from the population are now at a stage of development where they can be expected to contribute significantly to the general Tuberosum breeding programme. They have already been involved in the past few years in test crosses and full exploitation can be expected in the near future. Clones have been selected for use as parents in the general programme in 1974, in the expectation that they will shortly be cleared for PSTV.

ARC Project 22: Dihaploids and diploids

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

(Workers: C. P. Carroll, M. J. De Maine)

An experiment to evaluate progress in the diploid mass selection scheme (see *Ann. Rep.* **52**, 1973, p. 27) was continued into the first tuber-grown year, although the representation of the "base line" group was much reduced. Only 45 per cent of plants in this group had produced tubers in 1972. The comparison was made after four generations of selection from the base line. The improved diploid population now has over half the yield of Tuberosum and nearly double the yield of the base line. Improved diploids have significantly more tubers than cultivated Tuberosum or base line Phureja, but this alone does not account for the increase in yield over the base line. There is no evidence that selecting for increased yield has caused any drop in specific gravity. Scores of haulm maturity at harvest showed a shift of improved diploids towards early maturity. Selection has not been accompanied by changes in either stem number or stem length.

Tuber dormancy was evaluated in 83 clones derived from the mass selection population by measuring sprout lengths. Mean sprout lengths of the diploids were almost twice those of commercial Tuberosum controls but there was a wide overlap in the ranges of variation and it would seem possible to select diploids with adequate dormancy within the existing mass-selection material.

The evaluation of dihaploids continued under field conditions. Virus-indexed clones of new primary dihaploids were grown during the year at The Murrays for examination and selection. Crossing and selection among further generation dihaploids has given rise to clones with yields as good as those of the variety Record, grown as a control in the same plots. Progress is being achieved also in selection for increase of tuber size. Studies of dormancy in diploid × dihaploid progeny show that the hybrids do not differ qualitatively from commercial Tuberosum controls in their sprouting characteristics.

Exploratory work has begun with utilization of diploid material at the tetraploid level. Direct crosses are being made between 4x Tuberosum and elite 2x Phureja clones with the aim of obtaining tetraploid hybrids from fertilization by diploid Phureja pollen. As well as being useful in their own right such 4x hybrids can be crossed in turn with Tuberosum × Phureja hybrids (dihaploids × diploids) in order to provide further tetraploid breeding material. It is expected that the advantages of breeding at the diploid level can be rapidly utilized at the tetraploid level, while preserving an equal genetic contribution from the original Tuberosum and Phureja parents. In selecting Tuberosum parents for direct crossing with Phureja, attention has been paid to tuber dormancy so as to minimise the tendency to early sprouting in the Phureja material. Fertility in such crosses is low but more than 500 seeds are available for sowing and chromosome counting in 1974.

ARC Project 23: Aspects of potato cyst eelworm biology

Host-parasite relationships in potatoes carrying *vernei* field resistance.

(Worker: Miss R. M. Ford)

Priority has been given to the routine work of assessing eelworm resistance in the eelworm resistance breeding programme (see ARC Project 25). However, a start has been made on an investigation into the attractiveness to the eelworm larvae of roots of *vernei* resisters, H-gene resisters and susceptibles. No results are yet available.

ARC Project 24: Potato virus resistances

Resistance to viruses (X, Y, leafroll, spraing) in breeding programme.

(Worker: T. M. W. Davidson)

Progress continues in the breeding for resistance to leaf roll virus; 1,300 plots from the 1972 trial were regrown at the Plant Breeding Institute, Cambridge in 1973. Scoring showed that the level of infection in 1972 was average, with 54 per cent of Pentland Crown and 90 per cent of both Majestic and Arran Pilot controls showing leafroll. The frequency of selections, in these trials, showing high levels of resistance to leaf roll is now 10 per cent or more, while the best of them in the second year trial failed to show any infection, and may possess complete resistance. Among the controls Arran Pilot showed 84 per cent infection with virus Y, Majestic 52 per cent and Pentland Crown nil.

Plant quarantine restrictions prevented the growing of the 1973 first year leaf roll trial at Cambridge and, were the restrictions to continue, they would present a serious threat to the success of a long-standing breeding programme, which is now approaching fruition. Continued screening and selection among progeny is essential to prevent the dispersal and loss of the desired gene combinations which are bringing together both high levels of resistance to leaf roll, to viruses X and Y, and satisfactory expressions of other disease resistances and of field characters generally. Experience has shown that the most effective way of assessing leaf roll resistance is to provide the inoculum by suitably spacing infected plants in a field trial, planted in an area where aphid populations are high, and to rely on natural infection. Attempts to substitute a controlled infection procedure in the glasshouse, when known numbers of viruliferous aphids are placed on each clone under test, have met with moderate success, but are not regarded as a satisfactory substitute for the test under natural conditions in the field.

In routine screening work for reaction to viruses X and Y in various classes of breeding material, 20,000 seedlings from the virus-resistance breeding programme were subjected to mass inoculation by both viruses. In addition, determinations of reaction were made, by grafting or inoculation techniques, on advanced clonal material from the virus-resistance programme and from various other potato projects. In all, multiple screening tests were made on 550 clones.

Some 300 clones of advanced breeding material had been grown in 10-tuber plots in 1972 on land infected with potato mop top virus (PMTV). Progeny tubers were scored for spraing symptoms. 25-tuber samples of the progeny were grown in 1973 at Pentlandfield and the plants scored for mop top symptoms in the foliage. The level of infection was less than in previous years, as revealed by the control variety, Arran Pilot, which averaged 20 per cent spraing and 16 per cent mop top. Clones were classified as: worse than Arran Pilot 23; equal to Arran Pilot (susceptible) 89; moderate resistance 71; good 61; and no symptoms 12. This is the first time that breeding material has given a null response but in view of the low general level of infection, many if not all of the 12 no-symptom clones may be escapes from infection rather than resisters. They will be retested at Pentlandfield. New information has come to light during the year from various sources which indicates that mop top symptoms may reappear in foliage, and spraing arcs in tubers, with little diminution for several years following the initial infection. Thus it may turn out to be a more serious disease for growers than was at first thought.

An investigation into the effects of PMTV on the yield of plants and crop was made in 1973. It had been argued that, while the yield of infected plants would be reduced, neighbouring plants might show a compensating increase because of reduced competition, with no net effect on the yield of the crop. Analysis of the yields of individual plants showed that the yield of diseased plants was very significantly lower than that of healthy plants adjacent and once removed in the row. There were no significant differences between the yields of adjacent and twice removed plants and therefore no compensatory yield increase in healthy plants adjacent to mop top infected plants could be inferred.

In addition to the obvious effects of spraing arcs on tuber quality, evidence now accumulating on the persistence of infection and on yield reduction underlines the need to continue this screening work for mop top reaction in breeding material. PMTV, tobacco rattle virus (TRV) and leaf roll viruses are vectored by fungus, eelworm and aphid respectively and the technical problems of substituting glasshouse for field tests are considerable, since factors affecting the biology of the vector must be taken into account. In all three cases, therefore, the most direct and effective way of predicting the reaction of a potato clone to each virus seems to be through field tests of the type in current use. Sources of resistance to PMTV and to TRV useful for breeding purposes have yet to be identified.

The 1973 screening trials for tobacco rattle virus reaction were a failure because of drought. Rainfall from October 1972 until August 1973 was only 50 per cent of the mean in an area which anyway has one of the lowest rainfalls in the United Kingdom. These exceptionally dry conditions have an adverse effect on the eelworm vector and infection levels were satisfactory on only one third of the trial area. However, the conditions were propitious for development of common scab and useful scab data were recorded.

ARC Project 25: Potato cyst eelworm resistance

Resistance to PCE in breeding programme, especially field resistance from *vernei*.

(Worker: Miss R. M. Ford)

Screening of material in the eelworm resistance project continued. The most advanced material with resistance derived from *S. vernei* was selected for field characters, cooking quality and resistance to other diseases and the survivors will be entered into the first year of the Regional Trials. These clones have a level of unspecialised resistance to eelworms, thought to be sufficient when used in conjunction with a nematicide treatment. Four replicates of each of 290 clones, were tested against pathotypes A and E. Resistance to A was either complete (when H_1 was present in progenies derived from Maris Piper) or intermediate; that is, more resistant than the Pentland Crown controls. Resistance to pathotype E had a continuous distribution with generally higher resistance in progenies from intercrosses of *vernei* × *vernei* derivatives than from *vernei* × Maris Piper derivatives. The 1973 results confirmed the general pattern of those from 1972 although the modal level of resistance was lower.

Work was begun on material provided as seed by Dr H. W. Howard, Plant Breeding Institute Cambridge, carrying the H_1, H_2, and H_3 genes for resistance to pathotypes A, B and E respectively. First tests of tuber-planted material revealed a clear cut resistant or susceptible reaction to pathotype A (as expected from a major gene control) but, when tested against pathotype E, cyst numbers on tested plants ranged from fewer than 10 to more than 200 with no clear discontinuity, indicative of pathotype non-specific resistance. There was good agreement between replicates. Clearly, the activity of the H_3 gene against pathotypes E and A needs further study.

ARC Project 26: Potato blight resistance

Resistance to blight in breeding programme.

(Workers: Miss J. F. Malcolmson, Miss H. E. Stewart)

Detached leaflet tests of first-year seedlings again revealed resistance in a number of related families and tuber samples have been retained for a follow-up investigation of whole-plant foliage resistance. Whole-plant tests on 315 clones in year 5 of the selection sequence revealed that 15 per cent of the earlies and 17 per cent of the maincrops showed notable degrees of blight resistance. Nine of the 28 clones (32 per cent) in year 7 were also in this category. The practice of expressing a clone's foliage reaction to blight as a single-figure score has now been replaced by a more informative composite record of reaction of both leaves and stems. Tests for tuber reaction to blight have revealed a high frequency of resistant clones and resistance was confirmed in 68 of the 74 clones retested from 1972. Reasonably good agreement is reported between laboratory and field assessments of tuber blight resistance.

ARC Project 27: Potato tuber disease resistance

Resistance to tuber diseases (wart, scab, gangrene, skin spot, blackleg) in breeding programme.

(Workers: W. G. Rogers, Miss H. E. Stewart)

Tests for resistance to gangrene were made on 250 clones from the general breeding programme. When using the sand-cornmeal mixture for simultaneous abrasion and inoculation, 69 and 13 clones were respectively more resistant than the resistant controls, Roslin Castle and Arran Consul. In duplicate tests, using a standardised wound inoculation method, 129 and 23 were classed as more resistant. High frequencies of resisters were also recorded in the common scab trials; 73 of the same clones were more resistant than the resistant control, Pentland Crown.

Using a modification of a recently published method, a useful start was made on the development of a glasshouse screening method for assessing resistance to common scab. Potted plants were grown from excised eye plugs of six cultivars of known scab reaction, ranging from Redskin and Pentland Glory (very susceptible) to Pentland Crown (resistant). The same varieties were planted at the scab trial centre, Archerfield, East Lothian. The glasshouse scab scores were lower than the highest values recorded in the field, but gave better agreement with the known ranking of the varieties than did the field trial. This result justifies further development of the method as a possible replacement for field assessment. In the field, escapes from infection are common, as are year to year variations in disease incidence due to variations in soil moisture.

Logan and Woodward have reported differences in pathogenicity between E+ and E− isolates of *Phoma exigua* var. *foveata*. It is also known that some isolates of var. *foveata* are free sporing (pycnidial strains) whilst others are not (mycelial strains). An experiment was set up to assess the significance of these differences for the gangrene screening tests. Using four strains of the fungus (E+ pycnidial; E+ mycelial; E− pycnidial; E− mycelial) on three varieties, Pentland Crown, Pentland Falcon and Dunbar Standard, the E+ isolates were markedly more pathogenic than the E− isolates and the E+ pycnidial strain was the most virulent. These conclusions held for all four methods of scoring: per cent area covered by lesions, depth of lesions, longer radius and shorter radius. They highlight the necessity of using a strain of known virulence in future routine tests. Of the four described here, the E+ pycnidial strain would impose the most severe test on the potato clones.

Chemistry Laboratory

(Workers: M. J. Allison, I. A. Cowe and R. B. W. Williamson)

Most of the routine work undertaken in the Chemistry Laboratory was concerned with *in vitro* digestibilities and nitrogen determinations. Three new techniques were developed for routine operation: (i) modified acid detergent fibre (an estimate of digestibility), (ii) total hot water soluble carbohydrates (an indication of frost resistance in Brassicas) and (iii) total insoluble carbohydrate (for the prediction of malt extract).

Techniques currently being developed include cellulase digestion as a possible replacement of the *in vitro* digestibility test, because it requires fewer operations, is quicker and may be a more accurate predictor of *in vivo* digestibilities. Total cell wall components, cellulose and lignin, are being measured by Van Soest's method. The proportion of cell walls in plant material is reported to be closely correlated with estimates of voluntary intake by livestock. The ratio of cellulose to lignin, which is obtained from the same test is said to correlate well with digestibility.

Methods of predicting enzyme activity in barley malts from measurements made on resting grain are being studied. The diastatic power of malt is closely associated with the activity of β-amylase in grain (*Ann. Rep.* **52**, pp. 9-10, 1973). Malt α-amylase activity has been reported to be related to the total RNA content of resting grain; this relationship is being investigated using a colorimetric determination of an orsinol-ribose complex. This method could be automated if it is successful. Prediction of malt amylases by resting grain methods avoids the problems of uneven germination and of dormancy and saves a lot of tedious hand labour.

The Murrays

This has been another comparatively dry year with a rainfall total of 434 mm against the average for the area of 699 mm. Yields of grain and swedes suffered in consequence, though potatoes and leafy brassicas did well.

The cereal area consisted of 16 ha (40 acres) winter wheat (Cappelle Desprez and Maris Ranger), 42 ha (104 a) spring barley (Golden Promise, Midas and Berac) and 6·5 ha (16 a) oats. There were approximately 2 ha (5 a) of cereal trials. One and a half ha (3·5 a) of winter beans were sown but these were a failure and were ploughed up.

Fertiliser application was at the rate of 345 kg/ha (2·75 cwt/a) 20-10-10 compound, except for the oats which received no fertiliser and still lodged badly. Winter wheat and barley suffered some lodging, particularly Berac. Some mildew was noted in the barley but not enough to justify spraying with a fungicide.

The cereal harvest started on 16th August and finished on 9th October. The yield of all grain was low but higher prices kept up cash returns. Cappelle wheat yielded 5t/ha (40 cwt/a), Maris Ranger only about 2·8t/ha (22 cwt/a). Barley yields were: Golden Promise from 2·8t/ha (22 cwt/a) to 3·8t/ha (30 cwt/a), Midas 3·8t/ha (30 cwt/a) and Berac less than 2·5t/ha (20 cwt/a). The barley was sold at harvest and realised £5,952·50; the wheat realised £4,335.

Eleven ha (27a) of winter wheat were sown in the autumn. The principal variety was Cappelle Desprez, with a small acreage of Bouquet.

About 10 ha (24a) of experimental potatoes were grown; prior to planting, the ground was treated with Eptam as part of the couch eradication programme and 88 kg/ha (7 cwt/a) 15-15-19 compound fertiliser was applied. The crop was sprayed five times during the summer with a combined aphicide and fungicide. This was effective in respect of both blight and aphids. Yields were good; tuber size was rather large and there was a tendency to growth cracks in some varieties.

The area under brassicas was treated with TCA, rotosprayed at 28 kg/ha (25 lb/a) for couch control. About 4 ha (10 a) were used for trial and selection plots, and the remaining 7·3 ha (18 a) sown with stubble turnips. The seed bed for the trial areas was treated with Treflan to control annual weeds and fertiliser, at the rate of 88 kg/ha (7 cwt/a) 20-10-10 compound, was applied.

The growth of the swedes was poor throughout the season and bulbs were small. Leafy brassicas grew well as did the stubble turnips.

In preparation for potatoes in 1974, 14·2 ha (35 a) of grass were ploughed and fallowed until June. The field was then rotosprayed with TCA and sown with stubble turnips in late July. The Edinburgh School of Agriculture rented 29·1 ha (72 a) of grass and also took the grazing of the stubble turnips. In the spring 17·8 ha (13·4 a) of barley were undersown with grass and 13·4 ha (33 a) of grass were ploughed up in the autumn.

The fencing programme was completed early in September, with a few minor exceptions, and the land has now been reorganised into units of approximately 12 ha or thirty acres.

2. SUMMARY OF REPORT

1. *Barley genetics*

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

The SPBS is using several composite cross populations in which natural crossing is a desirable feature, to stir up the genetic material, so to speak. Barley is usually thought to be highly inbred but our experiments show a surprisingly high rate of natural crossing. Good progress was made in describing and analysing the collection. A big experiment on the genetical control of economic characters has been completed and efforts to promote efficient selection by sophisticated statistical treatment of many economic characters simultaneously made good progress.

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.

Good progress is being made in analysing the biochemistry and genetics of this complex group of enzymes, the amylases. The first induced " high diastatic power " mutant on record, reported last year was confirmed and a number of new ones, yet to be evaluated, were made in Maris Mink and Universe.

3. *Barley breeding*

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

Several high yielding lines have been isolated from the composite crosses started in the middle 1960s. They tend to be rather tall, so new composites are being set up and will be intensely selected towards shortness, earliness and disease resistance. A pilot experiment was run designed to see whether we can speed up pedigree breeding by growing winter generations in New Zealand. The high diastase programme made excellent progress with the emergence of high-yielding, high-diastase lines from Akka × Midas. Paradoxically, it begins to look as though such lines may find their principal niche as high-N feeding barleys. The high amylose work approached a point of decision with the isolation of Midas and Zephyr backcrosses with 40 per cent amylose in their starch (normal about 23 per cent). Critical tests as to the value of such lines for whisky making have not yet been possible; the potential may have been overestimated but there is some evidence that such barleys have value for poultry feeding.

4. *Oat breeding*

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

Three promising selections, all outyielding Astor in trials, are on hand and one or more may be submitted for Rights in the autumn of 1974. The only significant demand for Pentland Provender has been from Iceland. Two good eelworm-resistant lines have emerged but this resistance is, nowadays, of doubtful agricultural value, the pest having declined along with its host. Work on oats tolerant of alkaline soils is being run down. Documentation of the collection continued.

5. *Hybrid swedes*

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

Swedes tend to be self compatible and readily self pollinated but theoretically it should be possible to build up incompatibility and good progress has, in fact, been made. Incompatibility genes from swedes, rapes, artificial *napus*, and even turnips are being put together by suitable crosses. A cautionary note was sounded by the finding, in a suitable biometrical experiment, that heritabilities of economic characters were high; this would imply the use of inbred lines rather than hybrids.

6. *Swede breeding*

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

A few high yielding F_4 lines suitable for mechanical harvesting were selected but the immediate prospects of really good new varieties from this material do not look very good. A presumptively raan-free line of Pentland Harvester is on hand but could not be retested because of the difficulty of inducing raan in the field. It is an extraordinarily erratic disorder.

8. *Kale improvement*

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

The background was described in the last Report (**52**, p. 32, 1973). One third of 142 widely based families (based on crosses between kales, cabbages and sprouts) outyielded Maris Kestrel. Biometrical studies of similar materials continued. The practical implications are not yet clear.

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.

Further attempts to make a range of artificial *B. napus* by crossing *B. campestris* with *B. oleracea* were unsuccessful; the cross is very difficult and embryo culture methods did not help as much as had been hoped. Attempts to develop lines suitable for mass-crossing of turnips by rapes (a very promising hybrid combination) were continued. An interesting, and potentially useful, by-product of the work on artificial *B. napus* emerged in the form of leafy tetraploid lines of *B. campestris*—in effect, bulbless turnips.

10. *Raphanobrassica*

Objective: to test the idea that polyploid 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.

There was further improvement in the seed fertility of hybrid lines on hand but there is still some way to go. Attempts to discover whether reciprocal crosses (with kale as female parent) were more fertile failed (this cross is a very difficult one) but will be continued. A small trial suggested that the relatively undeveloped Raphanobrassicas already available are comparable with giant rape in yield and superior to dwarf types. The presence of clubroot resistance was confirmed and high resistance to mildew noted.

11. *Grass breeding methods*

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

Biometrical experiments with Italian ryegrass suggested that, as selection criteria for sward performance, spaced-plant measurements were much more useful than is usually thought. Winter damage scores showed high heritabilities which means that selection for resistance should be effective. Attempts to develop Italian-perennial hybrids ran into trouble. A genetically widely-based cocksfoot composite was established in four plots for grazing or mowing and subsequent selection.

12. *Winter kill in ryegrass*

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

The joint SPBS-PBI-WPBS trial of perennial ryegrass varieties was completed with results which indicated that field selection should be based on plots cut late in the season. Another trial has been sown. As noted above (11) evidence that Italian ryegrass can be effectively selected for resistance is now good and polycrosses of resistant lines have been set up.

13. *Cocksfoot breeding*

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

Advanced lines contain many that are higher yielding and even more digestible than Scotia. The potential in the species for DOMD values approaching 70 per cent appears to be established.

14. *Poa breeding*

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

Some promising lines emerged with the possibility (not yet proved) of the necessary constancy of breeding (due to a behaviour called apomixis). Micro-swards established well but did so only slowly. If these hybrids have a place it will be as a component of a permanent " bottom-grass " under shorter-lived perennial ryegrass.

15. *Breeding systems*

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

A diallel cross of Arabidopsis was set up but the work was severely interrupted by the power emergency.

16. *Potato breeding*

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

The submission of a new early-maincrop clone, 6670c(7) for official trials has been prevented and the development of three other clones already in trials has been seriously impeded by restrictions placed on the Station by the plant quarantine authorities in connexion with potato spindle tuber virus (PSTV). These restraints will add years to the development time of new varieties. The genetic base of breeding populations is being steadily broadened by the use of Neotuberosum clones (from Andigena) and virus-resistant materials developed independently; results were encouraging though the selection rate, inevitably, tended to fall. The high specific gravity programme, designed to produce a large body of material for breeding clones for processing, went well. First-early trials were conducted at four centres and revealed one promising clone. These trials will be severely restricted in 1974. Five new blight resistant Roslin varieties were named in Kenya.

17. *Potato disease resistance*

This project, listed in last year's Report, was too heterogeneous and so has been divided into five (see 23-27, below).

18. *Potato economic genetics*

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

Potatoes, being autotetraploid, cannot be studied by conventional biometrical-genetic methods. An alternative approach, using "combining abilities" as measures of breeding value is available. The big experiment mentioned in the last Report has been set up and should yield important results in 1974 and 1975.

19. *Potato blight*

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

The extreme complexity of the potato's reaction to blight is once again apparent. A single-figure description of response is desirable but would seem to be impossible. Further attempts to induce vegetative hybridity in the fungus have been made.

20. *Commonwealth Potato Collection*

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

The year has, again, been dominated by PSTV. A number of lines have been destroyed. Testing proceeds but, given the uncertainties of the test procedure, no end can be foreseen.

21. *South American tetraploid potatoes*

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

The Neotuberosum population, derived from the Andigena Group (the South American ancestors of our domestic potatoes) progressed very well but work was severely hampered by PSTV restrictions. Hybrids with ordinary Tuberosum parents are now flowing strongly into the breeding programme (see 16) and so the basic objective of the work is being attained.

22. *Dihaploid and diploid potatoes*

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

Progress in the diploid population (analogous to Neotuberosum) was assessed and found to be good; both yields and maturity have improved. Selection among the progeny of dihaploids (derived from Tuberosum but with diploid chromosomes) made good progress and a start was made on introducing some of the best available diploids into Tuberosum breeding material at the tetraploid level.

23. *Potato cyst eelworm biology*

Objective: to investigate host parasite relationships in potatoes carrying *vernei* field resistance.

Field resistance, derived from *Solanum vernei*, believed to be effective against all pathotypes of the eelworm, has been extensively developed in

SPBS breeding stocks. The question is: how does it work? A modest start was made in trying to answer this question.

24. *Potato virus resistances*

Objective: to develop resistances to viruses (X, Y, leafroll, spraing) in the breeding programme.

Excellent levels of resistance to the most important viruses, Y and leafroll, are now relatively frequent in breeding stocks and satisfactory test procedures are available. The situation would be very good indeed were it not for the disruption of field testing occasioned by PSTV restrictions. Progress was made in developing assays of resistance to spraing (due to two viruses: potato moptop virus, PMTV; and tobacco rattle, TRV) but the work is likely to be disrupted in 1974.

25. *Potato cyst eelworm resistance*

Objective: to develop resistance to eelworms in potato breeding programme.

Most of the effort has gone into field resistant clones derived from *S. vernei*. Potential varieties are now approaching Regional Trials. The signs are that, in relation to pathotype E, *vernei* resistance is of the same order as that conferred by the gene H_1. Thus neither resistance alone will be enough on badly infested land; but both should be valuable in conjunction with nematicides.

26. *Potato blight resistance*

Objective: to incorporate resistance to blight in breeding programme.

Twenty years of work is now beginning to pay off with the emergence last year of the first two field-resistant clones (see *Ann. Rep.* p. **52,** 19, 1973) and evidence this year of substantial (and rising) frequencies of resisters in the breeding pipeline. Attempts are being made to refine the whole plant-scoring system.

27. *Potato tuber disease resistance*

Objective: to incorporate resistance to tuber diseases (wart, scab, gangrene, skin spot, blackleg) in breeding programme.

Results relate to gangrene and scab and good progress with both was made. There is available plenty of resistance and tests are workable though not perfect; indeed efforts to improve them further were made. Work on skin spot must await storage facilities in the new laboratory wing; work on blackleg is at an impasse because the disease is so erratic as to be experimentally unmanageable.

3. SIR JAMES DENBY ROBERTS

Sir James Denby Roberts, Bt., O.B.E., M.A., J.P., died in Cyprus on 9th July 1973. Sir James, the second Baronet, was born in 1904 and succeeded his grandfather, Sir James, in 1935. He was educated at Rugby and at University College, Oxford, where he read physics under Professor Lindemann, later Lord Cherwell. Though trained as a scientist, he devoted his life to agriculture and public affairs. He was a prominent pioneer in seed potato raising and active for many years in the affairs of two Research Councils, the Central Agricultural Executive Committee, the Royal Agricultural Society of England and the Nature Conservancy. He was Chairman of the Board of the SSRPB 1958–71 and latterly a Trustee of the Society. He became O.B.E. in 1959.

The bare facts outlined above convey nothing of the universal respect and affection in which he was held by all who had the good fortune to meet him at all frequently. His personal charm and gentle manner did little to reveal the excellent brain—had he not been a farmer he would have been a physicist—and the keen appreciation of practical affairs. He was not only a leader in the adoption of technical advances in seed potato production but knew better than any how to guide a confused meeting with humour, tact and firmness.

Sir James was held in affection bordering upon veneration by Directors and staff alike. He was extremely good company, fond of good food and drink (he was a keen cook himself in Cyprus) and prolific of amiable anecdotes. Despite a stiff leg in later years he remained active and took pleasure in walking guests round the potato fields or along the banks of the Earn to see whether any salmon were showing in the Machany or the Hut pool. He was himself a keen angler and cast a beautiful fly.

The warmest sympathy of the Society and Station goes to Lady Roberts and their daughter and two sons. Sir James will be sorely missed.

Note—Thanks are due to *The Times* for permission to incorporate quotations in the above paragraphs.

4. PLANT GENETICS AND CROP IMPROVEMENT*

N. W. Simmonds

In this lecture I hope to show that genetics and plant breeding is an area of agricultural research and development that is at once scientifically exciting and practically valuable. I hope also to show that neither the science nor the practice alone is enough; sustained achievement demands a continuous and imaginative interaction between the two. No one, I think, has yet invented a better way of promoting that interaction than an institute supported by a research council. In the context of this lecture, of course, the relevant council is the Agricultural Research Council. It supports two institutes which are wholly devoted to genetics and crop improvement and it offers scientific guidance to the Department of Agriculture and Fisheries for Scotland which supports the work of another—the one of which I have the honour to be Director. In addition, some work in this area is carried on by several other institutes, so the total ARC commitment is quite large. Over the years these institutes—or their predecessors in pre-ARC times—have made notable contributions both to science and to practice; and will yet make more.

The nature of plant breeding

It is a common observation that wild plants and their cultivated relatives are different. The differences are a measure of the evolution that has taken place since the beginning of domestication. Certainly, crop evolution began with agriculture and it continues today in the shape of plant breeding; for current plant breeding is merely the contemporary phase of crop evolution. When conscious plant breeding began is not known but it was certainly thriving in Europe in the eighteenth century. And it was highly successful, even though it had, at that time, no underlying scientific rationale. The science came later and it was genetics. Mendel's paper of 1865 laid the foundations but it was not until around 1900 that his ideas caught on and not until 1906 that Bateson coined the word "Genetics". This science is therefore very much an invention of the twentieth century even though its roots go further

* A Keynote Lecture given at the Science Museum, London, on 7th June 1972. The occasion was an exhibition, entitled Search, of the work of the Research Councils. The exhibition was sponsored by the Department of Education and Science and chosen fields were elaborated in several accompanying lectures, of which this was one.

back. Bateson, incidentally, then at Cambridge, was later the first Director of the John Innes Institute.

That crop and stock improvement is fundamentally a matter of evolution was recognised by Darwin, who wrote a book about it: " Variation of Animals and Plants under Domestication " (1868). Darwin never assimilated Mendel's ideas—and Mendel was no evolutionist—but the two streams of thought came together most brilliantly in this century in what would now be called neo-Darwinian evolutionary theory. This theory interprets micro-evolutionary change—and does so very satisfactorily—in terms of natural selection of better adapted gene substitutions, cytological changes, isolation, polymorphisms, mating patterns and so forth. The plant breeder's populations evolve by just the same methods as wild species evolve so he—the plant breeder—is an applied evolutionist who seeks rather to bend his populations than to understand them. But sustained advance demands understanding; the empirical *ad hoc* attack has done great things but it has its limits. And understanding means, in this context, genetic and evolutionary understanding. Hence my title.

Genetic elements in plant breeding

This section demands a book but a paragraph will have to suffice. Genes and chromosomes, their structure, action and integration: these are the great themes of significance for plant breeding. First, Mendel's great achievement was to show that the determinants are particulate—hence the ratios. The plant breeder constantly handles major genes that behave in regular Mendelian fashion. Second, Johanssen's distinction between genotype and phenotype is at the very root of plant breeding practice, indeed at the root of all biology. Johanssen showed, very simply and elegantly, that the genetic potential of an individual was realised, to varying degree, in the phenotype through the impress of environment. This is the old Nature and Nurture problem of course; for our present purpose, I note that agricultural research seeks to change the phenotype of a crop plant (*i.e.*, its performance) by changing both its environment (by altered husbandry) and its genotype (by plant breeding). Usually there are subtle interactions such that the best results are attained by changing both genotype *and* environment in concert. Third, it was soon evident that Mendelian segregation was not all; many characters—and, conspicuously, most important economic characters—were governed by polygenes which segregated discretely but governed continuous variation and therefore had to be studied by statistical rather than Mendelian methods. Fisher had laid the essential foundations by the early twenties and biometrical genetic ideas entered plant breeding from then onwards. Incidentally, Sir Ronald Fisher was for years Head of the Statistical Department at Rothamsted and Professor K. Mather, another notable worker in this area, was at the John Innes Institute and is now (1972) a member of the Agricultural Research Council.

Fourth, that genes were borne on chromosomes had been proved by 1910 and cytological techniques good enough to make (some) chromosome cytology into a workable routine became available in the twenties. Nowadays, the use of polyploidy (multiple chromosome sets) and what have come to be called "chromosome manipulations" have wide currency in plant breeding. The fifth and last element I want to mention is chemical genetics. Despite some prescient studies early in the century, chemical genetics really only arrived in the late nineteen thirties with Beadle and Tatum's great work on Neurospora; this work related genes to enzymes, in practice usually to the products of enzyme activity. It led on to molecular genetics but its significance for us is that plant breeding is becoming ever more concerned with specific gene-controlled products of enzyme function.

Examples

Let us now take some examples of plant breeding under six convenient headings and try to discern their genetic contexts.

First, we have *population improvement*. This is the very stuff of plant breeding, whether of inbred or outbred crops, seed propagated ones or clones, The successful varieties of one generation become the parents of the next in a pattern called, technically, generationwise assortative mating. The barleys and potatoes that my colleagues at the Scottish Plant Breeding Station are now using as parents are the varieties that farmers are now growing (*plus* of course a few special fancies of their own that didn't quite make it as varieties). Thus each generation builds on the preceding one and it is a measure of the success of plant breeding that old varieties of two or three generations back rarely have any place in the programme. The methods of isolation of new varieties appeal essentially to biometrical genetics so a good deal of statistical sophistication is needed. The problem is: how to choose the best parental combinations and then isolate the best descendent genotypes in the presence of large environmental effects and genotype-environment interactions? I'm not going to answer that question; I shall simply assure you that practical—though imperfect—answers can be given.

This, the steady grind of plant breeding, with no cytological or chemical glamour, has been immensely successful. In Britain since 1950 cereal and potato yields have increased (somewhat erratically) by about 2 per cent per annum and new varieties have been a major component of this advance. In Malaysia rubber yields have more than doubled this century and more than another doubling is within reach, largely as a result of the breeding of new clones.

Sometimes, a major surge of advance is due to the introduction of a foreign breeding stock which "clicks" both genetically and agriculturally. Brilliant examples are provided by several cereals. European wheats and barleys, U.S.

and Mexican wheats and Philippines rice have all, at various times, shrunk in stature following the use of dwarf parents in breeding programmes. Borlaug's great achievement, the Mexican dwarf wheats, won him a Nobel prize and were the foundation of what has been called the Green Revolution. The result, in all these cereals, has been plants which are not only intrinsically more efficient grain producers but ones which, having short straw, can tolerate more nitrogen fertilizer; this is an outstanding example of phenotypic advance through mutually adapted genotype and environment.

Sometimes, again, the population improvement approach makes a major advance by altering the genetic structure of the crop. Maize is the outstanding example of the use of controlled "hybrids" in plant breeding. Genetically, "hybrids" go back to studies of the effect of inbreeding by Shull, Jones and East in the U.S.A. around 1910-20. They found that excellent varieties could be bred by crossing inbred lines, by substituting uniform heterozygosity, so to speak, for the random heterozygosity of the parental populations. Exploitation followed and, by the late 1940s, virtually the entire U.S. corn acreage was sown to hybrids with an estimated yield gain of 30 per cent. In 1958, Griliches reckoned that hybrid corn gave between 500 and 900 M$ net discounted annual return to the U.S. economy. Fired by this success, other breeders followed and "hybrids" became popular: onions, sorghum, sugarbeet, Brussels sprouts and kale are examples. Now big efforts are being made to breed hybrid wheats and barleys but, for technical reasons, success with these crops is not yet assured. Paradoxically, just as hybrid corn really triumphed, genetical scepticism arose. The problem is one of biometrical genetics and is yet insoluble. In principle, we have to answer questions about gene-action, about what is called over-dominance. In practice, the question is: are hybrids really necessary, after all? Some workers believe that they are not. The practical value of many hybrids is not in doubt; but perhaps there are cheaper and quicker ways of doing the job?

Incidentally, though the details lie far beyond the scope of this lecture, the making of commercial hybrid seed has called forth some of the neatest bits of genetics in the history of plant breeding. The cytoplasmic male sterility-plus-restorer system developed in maize and sorghum, the slightly different system used in onions and sugarbeet are examples and the (very different) incompatibility system that goes to make the kale, Maris Kestrel, from the Plant Breeding Institute, Cambridge, is another.

Second, *chemical genetics* is having an increasing influence on plant breeding. Breeders have long been accustomed to selecting for characters such as bread-making quality in wheat, malting quality in barley, starch content in potatoes, digestibility and low fibre content in animal feeding stuffs, sugar content and juice purity in beet and cane and so forth. These are mostly chemically fairly well defined but genetically ill defined (polygenic) characters and their genetic analysis must usually appeal to biometrics. More interesting for this discussion, however, are instances in which specific substances are produced (or balances between specific substances are altered) by specific Mendelian genes.

Perhaps the most dramatic example is high-lysine maize. Lysine is an essential amino-acid, one of several, which is often in rather short supply in cereal protein. Maize is deficient in it and maize-eating people are therefore at nutritional risk. Nelson and his colleagues in the U.S.A., around 1964, argued that a highly-lysine maize mutant *ought* to exist, sought it and found it. The task was made possible by modern analytical equipment; it could not have been faced thirty years ago. The mutant, when found, turned out to be well known in its morphological effect on the grain, though previously unknown as to biochemical basis. A simple backcrossing programme transferred it to other maize stocks and now, some eight years later, the mutant is starting to make a useful contribution to human nutrition in tropical America. In principle, mutants that alter the production of *any* amino acid could be sought with a fair prospect of success; a high lysine barley has already been identified by Swedish workers. So, just as biochemical-genetic engineering has already "arrived" in the context of micro-organisms (*e.g.*, in penicillin production), we seem to be on the threshold of a similar state in breeding higher plants.

Another example comes from nearer home. The whisky distillers told us at the Scottish Plant Breeding Station that they would like a barley with more amylose (straight chain starch) and less amylopectin (branched chain starch). We looked, and found one in our own barley collection. In looking we were fortified by the knowledge that, though such a mutant had never been found in barley, one was known in maize. It turned out that our mutant had starch grains slightly different from the normal and, like high lysine maize, a backcross programme was set up to transfer the gene to standard varieties. There have been snags, but the final result should be barleys that may offer a modest gain in efficiency to the malt whisky distiller. At least, we shall have the materials to test whether the biochemical expectations were correct.

These two examples have in common one thing that may or may not be significant. They both involve mutants that shift the balance between complex substances, proteins in maize, polysaccharides in barley. No doubt we shall someday be using mutants that determine presence/absence of useful end-products; mutants with no erucic acid in oil seed rape approach this state.

Third, consider *cytology*, the study of chromosomes, the structural basis of genetics. Some degree of cytological control has long been an essential part of many plant breeding programmes but cytology is sometimes more than a handmaiden. One of the classic cases is the transfer of a chromosome of a wild tobacco, *Nicotiana glutinosa* to a cultivated *N. tabacum.* The chromosome carried a valuable virus-resistance gene but some undesirable genes as well. After much breeding, some occasional pairing between unlike chromosomes of different origin allowed the extraction of a *tabacum* plant into which had been inserted a small piece of *glutinosa* chromosome bearing the desired gene. The bad characters had gone and the result was an acceptable and virus-resistant tobacco. A similarly elegant job has also been done, by Sears and his colleagues, on inserting a piece of *Aegilops* chromosomes into wheat; one of the last steps in the process was an irradiation designed to break the chromosomes preparatory to restitution in the desired configuration. The wheat workers have gone even further and, thanks to Riley and his colleagues at the Plant Breeding Institute, now have the means to provoke genetic recombination between wheat chromosomes which have never paired before: a "shattering of heredity" indeed—to use a phrase of Lysenko in a way he didn't quite intend.

Haploids are plants that have only half the normal chromosome complement and they have great attractions for the breeder as a source of inbred lines or certain specialized breeding stocks. They are difficult to make but certain genetical tricks involving the use of marker genes are a help. Considerable numbers of them have been made in maize and potatoes (which are tetraploid, so their haploids are diploid). They have not yet had any big practical impact but they probably will have, especially if *in vitro* culture techniques, now being developed, work really well. These techniques seek to grow immature pollen grains (which are haploid) into tissue cultures in flasks in the laboratory and then provoke those cultures into differentiating vegetative shoots. The trick was turned in tobacco by the late J. P. Nitsch very beautifully but it remains to be seen how widely applicable it will be.

The complement of haploidy is polyploidy. Many crops are already polyploid and higher ploidy still is normally useless; nature has generally already tried it out. But a few diploid crops turn out to be better for an increase of chromosome number; so, triploid sugar beets and tetraploid red clovers and ryegrass have been successful. For making polyploids, the cytologist has recourse to an array of chemicals but perhaps the best is still colchicine, known to ancient and modern pharmacopoeias alike as a drug for gout. This is odd enough but it is perhaps odder still that *Colchicum autumnale*, the autumn crocus, is a diploid.

Fourth in our list of six headings we have *wide hybrids*. We have already considered some examples under the previous heading, cytology; but there have been a multitude of other cases in which species distinct from the crop in question have contributed valuable genetic characters by simple crossing and backcrossing without notable cytological complexity. For example, modern potatoes either already have (or soon will have) contributions from no fewer than six wild species; and the tetraploid cottons are similarly extensively introgressed by their relatives. But, in some crops, the use of wide hybrids has gone further. Since the early thirties, the sugarcanes of the world have been entirely reconstructed genetically; complex interspecific hybrids have replaced the old noble canes. Modern canes have the highest chromosome numbers recorded in crop plants and some 7 per cent of their 100-plus chromosomes derive from a wild grass, *Saccharum spontaneum*. Trials in Guyana showed that sugar yields doubled in the process.

A somewhat different approach to wide hybrids is exemplified by the Brassica crops. Several Brassicas (but not all) are allotetraploids; that is, they are tetraploid interspecific hybrids. Thus the swedes and rapes originated long ago from turnip-relatives crossed by kale-relatives. Swedish workers successfully resynthesised several such allopolyploids and the approach has now been used in several places as a basis for deliberately widening the scope for selection. It is being adopted thus at the Scottish Plant Breeding Station where the attempt is being made not only to resynthesise established kinds, but to create wholly new kinds with new chromosome numbers. At the limit we are trying to turn radish-Brassica hybrids into new forage crop plants; such hybrids have been known for fifty years but this is the first attempt to put them to use.

Disease resistance is the fifth heading. Ever since Biffen in Cambridge in 1905 showed that a yellow rust resistance in wheat was controlled by a Mendelian gene, plant breeders and pathologists have laboured to confer resistance to the multitude of fungi, viruses and bacteria that assail our crops. Sometimes they have been very successful, as in the case of wart disease and some viruses of potatoes, blackarm disease of cotton and smuts of cereals. Sometimes, however, they have been less successful and the history of disease resistance breeding is littered with disappointments and disasters. The explanation lies in genetics, but in the joint genetics of the pathogen and host, rather than of the host alone.

Hosts and pathogens have generally lived together for a very long time; indeed they have evolved together. Often, it turns out that the two have developed mutually interacting genetic systems whereby a resistance gene in the host is matched by a virulence gene in the pathogen, and *vice versa*. So a "new" resistance challenges the pathogen and the result is very commonly either a mutation or a recombination or both, a new race of the pathogen and a seeming "breakdown" of resistance. So consistent is this pattern that, as a generalization that admits of few exceptions, breeding by the use of Mendelian specific resistance genes against airborne fungal pathogens such as the rusts, mildews and potato blight has failed. Hence the existence of what Suneson aptly called "boom and bust cycles"; resistance is, at best, transient.

For reasons which need not concern us here, the same is broadly *not* true of other kinds of pathogen (for example viruses and soil-born fungi), as much successful breeding attests. So what can we do about the airborne fungi? It is a standing reproach to plant breeders that we still spray our potatoes against blight and still have epidemics of rusts and mildews in our cereals.

The short answer is that we can use "field-resistance", which is polygenically controlled, is non-specific as to race of pathogen, is much harder to breed than major gene resistance but, once attained, is (or, cautiously, seems to be) permanent. This important conclusion was first established for potatoes in Mexico by Niederhauser and his colleagues of the Rockefeller Foundation. At the Scottish Plant Breeding Station we are just now, after nearly twenty years of effort, just beginning to produce highly field resistant potatoes that are also good potatoes. The cereal breeders have begun to get the message and the time may yet come when major gene resistances to these difficult airborne fungi are generally regarded as we now regard R-genes in potatoes: as nuisances to be got rid of.

Sixth and last I want to consider *conservation and the genetic base*. No small evolving population can be expected to make progress indefinitely under selection; response always falls off, as genetic theory predicts and much experimental evidence shows. Simultaneously, genetic variability is reduced. Similarly, plant breeding cannot be expected to make indefinite progress on a narrow genetic base. Nor does it, though the failure to respond sometimes goes unnoticed. A well founded breeding programme is therefore supported by the development of locally adapted breeding reserves. Thus there is a good operational reason for developing subsidiary breeding populations in excess of immediate short-term needs. There is also a much wider reason for doing so.

Modern agriculture makes do with remarkably few varieties in comparison with the more primitive agricultures. Advancement of performance incurs genetic loss and diversity is replaced by uniformity. The reasons for this trend are complex: they are partly economic, social, aesthetic and bureaucratic. Whatever the cause, the fact of decay is there and the faster the progress the greater the decay. But, what is being lost is, in effect, irreplaceable. Once gone, all those Afghanistan wheats, Mediterranean beans, Aethiopian coffees, and Andean potatoes cannot be replaced. That we are faced with a serious, potentially a disastrous, situation has been recognised fairly widely for a decade or so. Thus, FAO has made valiant efforts to conserve crop variability for posterity. The means of conservation are various and I shall not try to enumerate them. I simply observe that there are a number of feasible approaches and that the needs of conservation and of the genetic base can sometimes be met in one operation.

As examples, consider barleys and potatoes. Suneson and his colleagues, using genetic male sterility as a technical aid, made a composite cross of the entire US world barley collection, some 6200 lines. Other experiments show that such a population, if wisely used, will be of immense long-term value to barley breeders but this is also a quick, rough, cheap way of conserving genetic variability; inelegant and imperfect, no doubt, but very practical.

In potatoes, a population of South American tetraploids (the ancestors of our cultivated kinds) that was started at the John Innes Institute in 1959 and later taken to the Scottish Plant Breeding Station has provided three things: fairly decisive evidence as to the mode of evolution of the European potatoes, a breeding reserve (which has already started to flow into our programme) and a form of conservation. If all the Andean tetraploids disappeared tomorrow our population would provide at least a partial substitute for the future.

Conclusions

Despite current over-production of food locally, the world is hungry and is, on the whole, getting more hungry, the Green Revolution notwithstanding. Agricultural research is therefore of profound human importance; along with mammalian reproductive physiology, indeed, agricultural science can probably be said to be of *central* human importance. Plant breeding is a major component of advancement in crop production; it provides the genotype part of the genotype-environment-phenotype relation. Much effective plant breeding can be done—and has been done—on an *ad hoc* basis, a sort of unreflective grind. Discontinuities, however, demand something more; they demand understanding, imagination and often great patience and persistence as well. The understanding needed is essentially genetical, as I have tried to show in this lecture. It is probably true that, in the past five decades, plant breeding experience has more often influenced genetical ideas than the reverse; now, I believe, the flow is in the other direction. Genetical control will be at the heart of future progress.

5. *FOURTH SSRPB LECTURE*

The following is a summary of the fourth SSRPB lecture planned, at the time of writing, to be held at the Bush at 16.00 hrs on Thursday, 11th April 1974. Prof. A. H. Bunting, C.M.G., M.Sc., D.Phil., LL.D., F.I.Biol. is Professor of Agricultural Development Overseas at Reading University.

PROCRUSTES, OR TIME, ENVIRONMENT AND GENETIC RESOURCES IN CROP IMPROVEMENT

A. H. Bunting

An adapted crop in a temperate climate can accumulate up to 20 or 25 tons of dry matter per hectare per season, and of this from one-third in winter wheat to five-sixths in potato may be yield which is available for consumption by humans or animals, or for sale. To increase yield, it is necessary to increase either the total amount of dry matter produced, or the yield fraction, or both.

Yield and time

In all crops that have been examined, most or all of the yield is produced on current account, as a net result of current assimilation while the yield-forming organs are increasing in weight. Very little, if any, of it is produced by the transfer to the yield-forming organs of previously-accumulated reserves —except for the dry matter which is transferred with nitrogen remobilised from senescing leaves and other organs.

Consequently the length of time during which the yield-forming organs, as sinks, increase in weight is an important determinant of yield, alongside the integral with time of the size of the sources (for example green area duration), the rate at which they assimilate, and the proportion of the dry matter so assimilated which goes into the yield sinks.

The genotypic determination of yield is consequently complex, and the environmental relations are not simple either. The nature of the environment, during the time when the sinks are filling, the way in which it is managed agronomically, and losses due to pests, diseases and weeds during the time when the sinks are filling, are all important; the available time has to be efficiently used.

Put generally, the objective is to fill as much of the available time as other constraints will allow with efficient yield-forming activities. The plant breeder appears (maybe without realising it) to have done much in this direction in the past: he has much more to do in the future.

Limitation by climate: the time available

The total time available for the growth of the crop (the accumulation of total dry matter) is determined by external limitations imposed by climate—for example by radiation receipt and cold in temperate regions; by cold at one end and drought at the other in many Mediterranean climates; and by drought at both ends in the seasonally arid zones of the tropics and subtropics. There seem to be few or no direct climatic limits to growth in the warm and perpetually moist humid tropics.

These geographical considerations define the size of the bed of Procrustes to which both ideas and crops from other regions are obliged willy-nilly to conform.

Structural limitation by the crop on the amount of time which can be used

In respect of the proportion of their life-span which can be used to form yield, crops fall into three broad phenological classes.

In the first, yield is the product of vegetative growth and may be produced throughout much or all of the period in which growth is possible. Examples are wild and cultivated grazing and fodder plants, sugar cane, many root and tuber crops, rubber, tea and sago.

The second group consists of indeterminate-flowering species in which yield is produced in fruits produced on a series of lateral inflorescences which may begin to appear early in the crop's life—grain legumes, tomatoes, cotton, many tree crops and the prolific forms of maize with many cobs.

In the third group, yield is produced late in the life of the crop in terminal inflorescences. The chief members are the great cereal crops, which, in spite of a seemingly inefficient source-sink strategy, provide, in around 1,200 million tons of grain a year, the bulk of the energy needs and maybe two-thirds of the protein needs for the 3,900 million members of our species. Crops of this phenological group seem to offer most opportunities for still better use of time.

Internal limitations in the crop

Much of the interest of plant breeders in physiological questions has been directed towards questions of the rate at which yield is accumulated—particularly the rates of assimilation and growth. They include photosynthetic pathways, respiration rates, canopy structure, and leaf characteristics. Such ideas have contributed to the concept of plant type in the selection of the rice and wheat varieties of the so-called 'Green Revolution'. Others are concerned with water relations, such as root form and the effects of water deficits on gas and energy exchanges. Yet others are biochemical, including the activities of mitochondria, of particular enzyme systems (including nitrate reductase), and of hormones.

The inherited programmes which help to determine the partition of materials between different parts of the plant are of particular interest. This topic is linked with Gregory's ideas of internal competition and with Jackson's concept of the reinvestment ratio—the proportion of the new material accumulated in a particular time period which is used to make new vegetative growth rather than to fill reproductive sinks. These phenomena have much to do with the extent to which a plant behaves as an annual or a perennial, and so with the way it uses its time.

Heuristic simulation modelling

Information about the actual features of the weather during a season and the patterns of structure and of physiological behaviour of the crop allow the environmental, structural and internal limitations to be combined numerically in heuristic models of crop growth. A model of this sort has been able to account for from 80 to 95 per cent of the observed variation between time intervals in growth and development in actual crops of groundnuts and other grain legumes.

Such models not only describe the size of the Procrustean bed; they can suggest ways in which the guest must be modified to fit it, and the directions in which the agronomic system might be developed to enable an improved variety to make better use of the unalterable features of the environment. They can also be made to take into account the economic and logistic constraints, as has indeed been done for some sheep enterprises.

Some examples and possibilities

In 1947 Watson pointed out that many of our crops use the crop season in south-east England less effectively than they might. One result has been the already partly successful search for new forms of sugar beet which are less likely to bolt than the older ones, so that they can be sown, and reach full canopy, rather earlier in the season. In the same way, we could probably bring the date of flowering in our cereals forward a fortnight, and so permit the filling of still larger sinks by taking advantage of the peak of radiation receipt and potential net assimilation rate in late June, and lessening the risk of losses in the hotter drier weather of late July and August. Grain drying has already decreased our dependence on just those drier conditions to bring the grain to harvest dryness. We might increase yet further the duration of ear filling in our cereals by producing types in which larger ears are associated with longer-lasting activity in the source organs. Maize improvement in Britain depends in part on tailoring the duration of the crop to the available conditions by manipulating node number. Perhaps the known cold tolerance of certain Andean and Mexican types will ultimately permit earlier sowing, while the multi-cob (prolificacy) character increases the proportion of the season which the crop devotes to making yield.

In our own circumstances, the existing patterns of capital investment tend to limit the scope for Procrustes, but in the less advanced agriculture of many developing countries new farm systems are being more confidently sought. Like the traditional systems, many will use mixed, sequential and multiple cropping to increase the proportion of the growing season in which yield of one sort or another is formed. Perhaps in maize, sorghum and other cereals which can accumulate sugar in their stem internodes, we can find forms which will translocate some or all of it into the developing ear. In this way part of the vegetative phase would be added to the yield forming period.

Time regulation in plants

The modifications we shall need to use time better are determined by both external and internal phenomena: the latter have already been mentioned.

The *external phenomena* include variations in day-length and temperature. The photo-periodic maincrop sorghums of the wetter parts of northern Nigeria flower as the rains end in their own localities no matter when they are sown, while the local cowpea types, which are intersown with the sorghum, begin to flower as the leaf area index of the maturing sorghum begins to decline.

In these seasonally-arid regions, the early sown crop which breaks the " hungry gap " is a day-neutral form of the drought-adapted bulrush millet, which flowers and yields as early as possible. Similar varieties of both sorghum and bulrush millet are the maincrops in the drier and far less predictable climates of the more arid north. On the other hand, in the still wetter south, where human energy needs are supplied by virturally protein-free, but perennial, root crops, the hungry gap is a time of protein shortage. Not surprisingly, the break crop is a day-neutral and very early type of cowpea, grown alone, from which the earliest possible crop of seed is harvested.

From so wide a range of forms, it is possible to suggest types whose phenology is likely to be adapted to a very wide range of time constraints.

Though time relations often express themselves as complex and continuously variable characters, the complex can often be broken down into simpler components. In a cereal, time to anthesis may be regarded as the product of average time-interval per node and the number of vegetative nodes, plus the time from initiation of the inflorescence to anthesis. It may well be more useful to study the inheritances of the components separately than to analyse the whole complex by conventional methods of quantitative genetics.

Where a fairly radical phenological or physiological reconstruction of a crop is necessary, the required ranges of variation in the components of a complex character may not be present together in the existing breeding material. In such a case it may be necessary to seek elsewhere the specific characteristics needed, perhaps in unimproved material or wild forms, much as in breeding for disease resistance.

Genetic resources for plant breeding

All this strengthens the arguments for the exploration, collection, evaluation, recording and conservation of plant genetic resources for current or future crop improvement and for evolutionary studies. An International Board for Plant Genetic Resources has recently been established, under the authority of the Consultative Group on International Agricultural Research, and in collaboration with FAO. Among other things, it will advise the potential funding agencies on the priorities for financial support. It will seek to ensure that the field observations of collectors include data from which the adaptive features of the material they collect can be estimated. This will often have to be buttressed by physiological screening, in controlled environments, to define more precisely the ranges of environmental adaptations available.

6. VARIETIES BRED BY THE STATION

The following varieties are on the market:—

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

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. Elite stocks of the oat Bell are in the hands of Messrs Macfarlan, Shearer & Co., Greenock.

7. 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:*

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J. D. G. DAVIDSON.
H. F. D. ELDER.
W. H. M. GILL
G. B. R. GRAY.
Sir DAVID LOWE.
R. L. SCARLETT.
VICE-CHAIRMAN (*ex officio*).

Research Committees

Forage Crops

H. F. D. ELDER, *Convener.*
H. P. DONALD.
G. CLAPPERTON.
J. L. DAWSON.
G. B. R. GRAY.
O. T. GRIFFIN.
J. B. D. HERRIOTT.
M. JOUGHIN.
Sir DAVID LOWE.
D. MORRISON.
A. PATTULLO.
W. STEVEN.
J. WATSON.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

Potatoes

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

Farm Advisory

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

10. ADMINISTRATION

Finance

The abstract of audited accounts on pages 76 to 82 reveals the Society's financial position at 31st March 1974. The cost of the research programme at the Scottish Plant Breeding Station was met by a maintenance grant of £342,500 from the Department of Agriculture and Fisheries for Scotland. Sundry items of income at Pentlandfield amounted to £905. The unspent balance of the maintenance grant for the year amounted to £7,329. This sum has been added to unspent balances of grants from previous years, increasing them to £15,582.

Capital expenditure at Pentlandfield amounted to £13,534 on buildings and £9,426 on equipment for which DAFS grants were received. At The Murrays Farm DAFS spent £23,885 on the new steading, two farm workers' cottages, fencing and renovation of the farmhouse. 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 1974 the total membership was 333, comprising 199 life members and 134 annual members. Eight 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 O. T. Griffin, Mr A. Pattullo, Mr J. M. Roy and Mr W. Steven. Dr D. W. Williams retired, with the good wishes of the Board, after many years' service as member nominated by the Secretary of State and was replaced by Mr W. O. Kinghorn, Chief Agricultural Officer, DAFS.

The Board learned with great regret of the death of Mr J. E. Rennie, C.B.E., on 27th November 1973. Mr Rennie had given distinguished service on the Potato Marketing Board of which he was Chairman from 1958 to 1973; he became a member of the Society in 1949 and served on the Board from 1970 to 1973.

Election of Trustee

To fill the existing vacancy the Board recommends the election of:—

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

Election of Directors

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

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.

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

J. Leslie Dawson, B.Sc. (S.A.I. Ltd.), West Mains of Ingliston, Newbridge, Midlothian, EH28 8NZ.
O. T. Griffin, B.Sc., Balnafoich, Dores, Inverness-shire.
James R. Marshall, Duncrub Park, Dunning, Perthshire.
Douglas V. Rennie, South Belton, Dunbar, East Lothian.
G. A. Storrar, M.C., B.Sc., J.P., Rossie, Auchtermuchty.
H. A. Waterson, West of Scotland Agricultural College, Agronomy Department, Auchincruive, Ayr, KA6 5HW.

Meetings

The Board met four times: on 12th April 1973; 7th June 1973; 26th July 1973; 9th November 1973.

The Potatoes Research Committee met on 11th October 1973.

The Finance Committee met on 7th June 1973.

The Farm Advisory Committee met on 31st May, 5th July, 19th September and 13th December 1973.

Fifty-Second Annual General Meeting

MINUTE OF PROCEEDINGS at the FIFTY-SECOND 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, 26th July 1973.

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

Minute. The Minute of the 51st Annual General Meeting, held at the Scottish Plant Breeding Station on Thursday, 20th July 1972, having been circulated prior to the meeting, was taken as read and was approved and signed.

Apologies. Apologies for absence were intimated by the Assistant Secretary.

Annual Report and Accounts. The 52nd Annual Report of the Directors embodying the audited accounts for the year ended 31st March 1973, which had been distributed to members before the meeting, was submitted by the Chairman.

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

Election to the Board of Directors. Moved by Mr James Gray, O.B.E., T.D., Stirling, and seconded by Mr W. H. M. Gill, Rosskeen, Invergordon, a motion was unanimously adopted to elect to the Board of Directors the following members:—

John Arbuckle, O.B.E., Logie, Newburgh, Fife, KY14 6ML.
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. Sheriff (Sheriff & Sons Ltd.), The Mill, Great North Road, Hatfield, Herts.
W. Steven, The Brax Farm, by Arbroath, Angus.

Appointment of Auditors. On the motion of the Chairman and seconded by Mr H. F. D. Elder, Haddington, Messrs Brown, McDonald and Fleming, Chartered Accountants, were appointed Auditors of the Society.

This concluded the business of the meeting.

In the informal business of the meeting, the Chairman, in the course of his address to members, paid tribute to the late Sir James Denby Roberts. Sir James had been a member of the Society for almost thirty years and had either been Chairman or Vice-Chairman for most of this time. He had been a most helpful and constructive colleague and had proved an outstanding Chairman; his services to the Society and the agricultural community would be greatly missed.

The Chairman also intimated to the meeting that Mr R. J. L. Gallie, Secretary of the Society, was in hospital recovering from a heart attack but was making good progress. The meeting concurred with Mr Arbuckle in wishing Mr Gallie a speedy and full recovery.

In his address on the Annual Report the Chairman said he thought that the layout of the report was improved and that it would be more readable and more widely understood. He went on to express the Board's thanks to the staff of the Station and to Dr Simmonds for the work that had been done during the past year; he also thanked his fellow directors for the help and support they had given him.

The Chairman remarked that the past few years had seen considerable expansion of the Station and he acknowledged the Society's gratitude to the Department of Agriculture and Fisheries for Scotland for continued financial support.

Mr J. I. Smith, Secretary of the Department of Agriculture and Fisheries for Scotland, during his address, also paid tribute to the late Sir James Denby Roberts, and sent the Department's best wishes for a speedy recovery to Mr Gallie. Mr Smith spoke of current developments under the 'New Order' and reaffirmed the Department's intention to be guided in scientific matters by the Agricultural Research Council.

Staff

The following appointments were made during the year:—

SPSO	R. N. H. Whitehouse, M.A.
HSO	Miss F. G. A. Megginson, B.Sc., M.Sc.
SO	Mrs G. McConnell, B.Sc.
	Miss R. M. Solomon, B.A.
	J. S. Swanston, B.Sc.
Senior Photographer	A. M. Devlin
ASO	S. S. Bachoo, B.Sc.
	J. Brown

	J. R. Curran Miss R. F. Edwards Mrs I. C. Fraser Miss S. E. Millar R. McHale Miss D. Pollock J. A. Scott Miss E. J. H. Taylor Mrs P. A. Toulin Miss J. D. Watt Miss A. Williamson
LA	Miss S. Byiers Mrs M. Dugan Mrs S. I. Graham
Field and Works	J. G. Butt B. Warburton G. D. Williams
Administration	Mrs I. C. Fraser Mrs J. E. Heritage Miss G. J. Thomson

The following staff left employment:—

SSO	T. J. Riggs, B.Sc., Ph.D.
HSO	Miss A. R. Hutchinson, B.Sc. W. G. Rogers, B.Sc., Ph.D.
SO	Miss S. C. Tribble, M.Sc.
Senior Photographer	A. M. Devlin
ASO	S. S. Bachoo, B.Sc. R. W. Hutchinson Mrs C. Kinnaird Mrs K. E. Mann D. T. Millar P. W. T. Nairn L. G. Newman Miss D. Pollock A. Shaw, B.Sc. Miss A. Williamson

LA	Mrs S. I. Graham Mrs I. Macanulty Mrs M. Stewart
Field and Works	J. Campbell
Administration	Mrs E. McNeill
Retirement	Mr R. J. L. Gallie, F.C.I.S. (Secretary) Mrs E. Gray (LA)

We have to record, with deep regret, the loss of two members of staff by death during the year. Mr J. D. Hanratty (ASO) died suddenly on 15th November 1973 and Mr Alec Lawrie on 12th February 1974. Mr Lawrie, a highly skilled tractorman and a much respected and liked member of staff, had worked for the Station for thirty-four years. He will be greatly missed.

As intimated in the minute of the 1973 Annual General Meeting above, Mr Gallie had suffered a heart attack. We are happy to record that he made an excellent recovery; nevertheless, he decided to retire at the end of the year and his resignation was received with regret. His twenty-three years' of service to the Station and Society were preceded by an early career in life assurance in Aberdeen followed by twelve years in the service of the Church of Scotland Mission in Malawi (then Nyasaland) and of the YMCA in Scotland. He was elected FCS (later FCIS) in 1961, having joined the Staff in 1951. No Station ever had a better Secretary nor any Director better administrative support. Mr Gallie stepped down with warmest good wishes from Staff and Board for a long and happy retirement—in which, we hope, his favoured pursuits of angling and golf will play a prominent part.

Mrs E. Gray (LA, Potatoes) retired in May 1973 after eighteen years' service; she, too, left with warmest good wishes from Staff and Board.

Four members of staff made visits abroad during the year with the aid of travel grants from ARC. Dr J. H. W. Holden and Mr C. P. Carroll attended a Eucarpia meeting on potato dihaploids in the Netherlands and then visited the Max Planck Institute at Cologne (25th-29th June 1973). Dr T. M. W. Davidson attended and read a paper at the Second International Congress of Plant Pathology, Minneapolis, U.S.A. (5th-12th September 1973). Mr G. R. Mackay attended a Eucarpia meeting on Brassica fodder crops in the Netherlands and then visited Brassica workers at Göttingen (21st-25th May 1973).

Dr R. J. Killick attended a MAFF Middle Management Course at Littlehampton (14th-18th May 1973). Dr J. F. Malcolmson attended, by invitation, a Late Blight Project Planning Conference held under the auspices of the

International Potato Centre (CIP), Peru. The Conference took place in Mexico (22nd–27th August 1973) and was judged a success. Subsequently, she attended the second International Congress of Plant Pathology at Minneapolis, Minnesota, U.S.A. (5th–12th September 1973). Her attendance at the former meeting was supported by the CIP, her subsequent travel by the SSRPB, to both of which bodies warm thanks are due.

Members of staff presented several papers or seminars to scientific and agricultural 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 1974. Mr Fyfe again acted as external examiner for the M.Sc. degree in agricultural botany at the University College of Wales, Aberystwyth.

The Director gave five lectures to various audiences during the year and visited Barbados in connection with sugar cane breeding in December 1973. He continued to serve on SADC and on several committees concerned with Research Councils' computing affairs and on the Forestry Commission Advisory Committee on Forest Research. He ceased to serve on the ARC Directors' Advisory Committee, the Directors' Steering Committee and the BBC Agricultural Advisory Committee but was appointed to the JCO Crops Board Potato Committee and the PMB Research and Development Committee during the year.

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.

11. PUBLICATIONS

ALLISON, M. J., and ELLIS, R. P. (1973). The inheritance of β-amylase in developing barley grain. *Biochemical Genetics*, **10**, 165–173.

CARROLL, C. P. (1973). The use of dihaploids and their hybrids in breeding potatoes at the diploid level (Abst.). *Potato Research*, **16**, 322–323.

DAVIDSON, T. M. W. (1973). Assessing resistance to leafroll in potato seedlings. *Potato Research*, **16**, 99–108.

ENGLAND, F. (1974). Genotype × environment interactions in mixtures of herbage grasses. *Journal of agricultural Science, Cambridge*, **82**, 371–376.

ENGLAND, F. J. W. (1974). The use of incompatibility for the production of F1 hybrids in forage grasses. *Heredity*, **32**, 183–188.

HAYTER, A. M. and RIGGS, T. J. (1973). Environmental and varietal differences in diastatic power and four associated characters of spring barley. *Journal of agricultural Science, Cambridge*, **80**, 297–302.

KILLICK, R. J. and SIMMONDS, N. W. (1974). Specific gravity of potato tubers as a character showing small genotype-environment interactions. *Heredity*, **32**, 109–112.

MACKAY, G. R. (1973). Interspecific hybrids between forage rape (*B. napus* L.) and turnip (*B. campestris* L. ssp. *rapifera*) as alternatives to forage rape. I. An exploratory study with single pairs of crosses. *Euphytica*, **22**, 495–499.

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

McNAUGHTON, I. H. (1973). Resistance of *Raphanobrassica* to clubroot disease. *Nature, London*, **243**, 547–548.

McNAUGHTON, I. H. (1973). *Brassica napocampestris* L. (2n = 58). Synthesis, cytology, fertility and general considerations. *Euphytica*, **22**, 301–309.

RIGGS, T. J. (1973). The use of canonical analysis for selection within a population of spring barley. *Annals of applied Biology*, **74**, 249–258.

RIGGS, T. J. and HAYTER, A. M. (1973). Diallel analysis of the number of grains per ear in spring barley. *Heredity*, **31**, 95–105.

SIMMONDS, N. W. (1973). A note on somatic segregation of the spectacle pattern in potatoes. *Heredity*, **31**, 405–407.

SIMMONDS, N. W. (1973). Plant Breeding. *Philosophical Transactions of the Royal Society of London, Series B*, **267**, 145–156.

Other papers by staff:

BUTT, D. J., KIRBY, A. H. M. and WILLIAMSON, C. J. (1973). Fungitoxic and phytotoxic effects of fungicides controlling powdery mildew on apple. *Annals of applied Biology*, **75**, 217-228.

EVANS, G. M., REES, H., SNELL, C. L. and SUN, S. (1972). The relationship between nuclear DNA amount and the duration of the mitotic cycle. *Chromosomes Today*, **3**, 24-31.

SIMMONDS, N. W. (1973). Optimal replanting time for sugarcane. *International Sugar Journal*, **75**, 107-108.

11. ABSTRACT OF ACCOUNTS

ABSTRACT OF ACCOUNTS

For Year ended 31st March 1974

INCOME

1973		
£191	Sales of Produce and Stock on Hand	£259
432	Sale of Vehicle	191
134	Subscriptions—Annual	139
208	Rent of Cottages	316
£965	*Total Ordinary Income*	£905
	Grant received from the Department of Agriculture and Fisheries for Scotland—	
326,000	Maintenance	342,500
£326,965	*Total Income*	£343,405
37,124	Capital—The Murrays	23,885
	Balance at 1st April 1973—	
	Department of Agriculture and Fisheries for Scotland—	
6,759	Maintenance Grant	8,253
£370,848		£375,543

EXPENDITURE

1973			
	Salaries:—		
£138,229	Scientific and Technical Staff	£155,365	
13,907	Administrative and Clerical Staff	17,154	
4,174	Pension Supplementation	7,683	
£156,310			£180,202
13,108	Superannuation Contribution		14,967
32,894	Wages		38,346
9,654	National Insurance and Graduated Contributions		11,744
18,696	Apparatus and Equipment		8,765
16,382	Chemicals and Materials		16,297
4,151	Travelling and Subsistence		6,109
4,365	Rates and Rents		4,571
12,095	Power, Heat and Light		10,805
690	Library Books and Periodicals		996
784	Printing and Binding		1,055
4,138	Stationery, Postages and Telephones		4,442
2,583	Vehicles—Purchased —		
2,883	Maintenance £3,768		3,768
350	Audit and Legal Expenses		385
2,062	Property Repairs		2,218
690	Property Alterations		2,277
538	Trial Centres		690
2,544	Edinburgh Centre of Rural Economy		2,219
2,523	Repairs, Servicing		4,143
610	Seed Testing Fees		661
297	Transport		261
852	Staff Training		382
1,642	Advertising		2,320
1,671	Furniture and Fittings		367
154	Miscellaneous—Hosp. £204		
718	Misc. including C.S.B.F. 830		1,034
706	Rentals		827
31,328	The Murrays—Net Cost		16,190
53	Land Improvements		35
£325,471			£336,076
37,124	The Murrays: Improvements		23,885
8,253	Balance DAFS Maintenance: Grant		15,582
£370,848			£375,543

BALANCE SHEET

as at 31st March 1974

1973				
	I Funds—			
£410,329	1. Balance at 31st March 1973			£443,446
31,226	Grants received from DAFS—Capital Works. . .			13,534
1,891	Grants received from DAFS—Capital Equipment . .			9,426
£443,446				£466,406
	II Current Liabilities:—			
5	1. Sundry Creditors		£926	
8,253	2. Balance of DAFS Maintenance Grant . .		15,582	
8,258				16,508
£451,704				£482,914

1973		*Cost*	*Amounts Charged to Revenue*	*Net*
	I Fixed Assets:—			
£398,498	1. Heritable Property . . .	£412,033		
44,456	Capital Equipment . . .	53,871		
£442,954		£465,904		£465,904
30,215	2. Implements and Tools. . .	26,175	£26,175	
8,749	3. Vehicles	7,314	7,314	
48,807	4. Laboratory Apparatus. . .	55,119	55,119	
12,792	5. Furniture and Fittings. . .	13,489	13,489	
8,079	6. Library Books	9,156	9,156	
£442,954		£577,157	£111,253	£465,904
	II Current Assets:—			
14	1. Stocks		—	
1,698	2. Due to Society		£110	
7,038	3. Cash and Bank Balance		16,900	
8,750				17,010
£451,704				£482,914

Edinburgh, *24th May, 1974*.—The undersigned, having had access to all the Books [illegible]counts 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 sam[illegible]nd 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

for the year ended 31st March 1974

1973	*Income*	
£793	Dividends and Interest	£959
50	Donations	50
120	Life Subscriptions	60
—	Profit from Sale of Investments (Imperial Group U.L.)	613
10	Refund Andes Travel Grant	—
12,163	Balance at 1st April 1973	13,036
£13,136		£14,718

W. J. REID AND JAMES MUNRO BEQUESTS

£123	Dividends and Interest	£130
2,147	Balance at 1st April 1973	2,267
£2,270		£2,397

DR. WILSON MEMORIAL FUND

£30	Dividends and Interest	£33
590	Balance at 1st April 1973	618
£620		£651

1973	*Expenditure*		
£50	SSRPB Lecture		£75
10	Gift to staff member		10
9	Insurance		7
2	Hospitality		121
3	Friendly Society Fee		3
—	Travel Grant		58
26	Bank Fees		31
	Balance at 31st March 1974		
11,565	Investments (see Appendix) at Cost	£13,065	
278	Recoverable Income Tax	290	
—	Due from Bank of Scotland	65	
1,069	Cash in Bank—Current Account	696	
124	Savings Account	297	
13,036			14,413
£13,136			£14,718

£3	Bank Fees		£5
	Balance at 31st March 1974		
1,990	Investments (see Appendix) at Cost	£2,216	
42	Recoverable Income Tax	41	
235	Cash in Bank—Current Account	135	
2,267			2,392
£2,270			£2,397

£2	Bank Fees		£1
	Balance at 31st March 1974		
566	Investments (see Appendix) at Cost	£566	
12	Recoverable Income Tax	10	
40	Cash in Bank—Current Account	74	
618			650
£620			£651

APPENDIX

LIST OF INVESTMENTS

Life Membership Subscriptions and Donations Fund

Cost	Nominal Value		Gross Interest or Dividend Received 1/4/73 to 31/3/74	Market Value at 31/3/74
£794·57	£710·00	Claverhouse Investment Trust Ltd. 1,420 Ordinary 50p shares	£49·70	£781·00
1,508·39	1,581·40	6½% Funding Stock 1985-87	102·80	925·12
607·45	82·75	Guardian Royal Exchange Association 331 Ordinary 25p shares	31·94	503·12
608·82	345·00	Imperial Chemical Industries Ltd. 345 Ordinary £1 Stock Units	50·72	710·70
290·99	290·25	Imperial Group 1,161 Ordinary 25p shares	71·62	708·21
1,498·89	41·50	London Manchester Assurance Co. 830 Ordinary 5p shares	37·14	1,016·75
864·09	495·00	National Commercial Banking Group 1,980 Ordinary 25p shares	52·74	1,069·20
1,372·87	86·25	Shell Transport and Trading Co. Ltd. 345 Ordinary 25p shares	51·92	750·38
1,099·96	1,153·00	Stirling County Council 7¾% Loan 1977-79	89·36	853·22
2,253·58	2,359·35	Treasury Loan 1997, 8¾%	206·44	1,480·49
2,165·37	2,480·00	Treasury Loan 1980-82, 8½%	88·83	1,934·40
		Interest from Imperial Group U.L.	113·40	
		Interest from " B " Savings Account	12·66	
£13,064·98	£9,624·50		£959·27	£10,732·59

W. J. Reid and James Munro Bequests

Cost	Nominal Value		Gross Interest or Dividend	Market Value
£517·45	£430·00	English International Trust 7% Convertible Stock 1986	£14·00	£322·50
1,333·85	£1,359·29	6½% Funding Stock 1985-87	88·36	795·19
165·59	80·00	Imperial Chemical Industries Ltd. 80 Ordinary £1 Stock Units	11·76	164·80
199·70	208·00	Stirling County Council 7¾% Loan 1977-79	16·12	153·92
£2,216·59	£2,077·29		£130·24	£1,436·41

Dr. Wilson Memorial Fund

Cost	Nominal Value		Gross Interest or Dividend	Market Value
£102·40	£70·00	English International Trust 7% Conversion Stock 1986	£4·90	£52·50
265·77	276·60	6½ Funding Stock 1985-87	17·98	161·81
198·24	26·75	Guardian Royal Exchange Association 107 Ordinary 25p shares	10·33	162·64
£566·41	£373·35		£33·21	£376·95

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

State-aided Institutes in Scotland:

Animal Diseases Research Association	Moredun Institute, 408 Gilmerton Road Edinburgh EH17 7JH
Hannah Research Institute	Kirkhill, Ayr
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

Part of The Murrays Farm in September 1974

Key	Key	Key	Key
1 Cereal plots	5 Italian ryegrass	9 Grass plots	13 New steading
2 Bean plots	6 Barley	10 Oat multiplication	14 Farm house
3 Potato plots	7 Wheat	11 Diploid potatoes	15 Old steading
4 Stubble turnips	8 Pasture		