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

REPORT

TO THE

ANNUAL GENERAL MEETING

OF

THE SCOTTISH SOCIETY FOR RESEARCH IN PLANT BREEDING

24th JULY 1975

BY THE

BOARD OF DIRECTORS

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1. REPORT BY THE DIRECTOR

General

Last summer there were fears that severe restraint of public expenditure, especially if grants could not be adequately adjusted to inflation, would lead to very damaging disruption of institute programmes. In the event, the DAFS has not yet had to be as restrictive as might have been feared. Strict economy, even closer scrutiny of estimates, redeployment rather than initiation, all these are in force (and probably permanently); there may yet be worse to come but one hopes not. Indeed, as the Secretary of the ARC pointed out in a speech in London last autumn, the country will probably need more rather than less agricultural research in what could well become the hungry years ahead.

That research will have to be applied to the right objects and an essay elsewhere in this report seeks to enquire whether and to what extent economic analysis can help. Long before economics as such can become useful, however, the three sponsors of the JCO will have to take decisions on the basis of advice offered by the committees and boards (as outlined in last year's report). A response by the sponsors to preliminary recommendations was published in January 1975. The appropriate adjustments of programmes will no doubt follow.

A revised project costing system is now in operation. It is more comprehensive, and more rational but inevitably more complex, than the Mark I system. The processing has been transferred to the Rothamsted computer. Given experience in working it and quicker outturn of results, the system should provide excellent information for the sponsors and the JCO. The question will then be: of what use is that information? I only ask the question.

In Scotland, DAFS lists packages (aggregates of ARC projects) along with price-tags with its annual letters-of-grant so there is general consciousness of what particular bits of work are costing, even if the probable outcomes are not subject to any formal analysis.

Readers of this report will notice that our new potato is called simply Croft, not Pentland Croft. This was done in response to a ruling by the International Union for the Protection of new Varieties of Plants (UPOV), of which Britain is a member, to the effect that "stable" names would no longer be admissible. There is some sense in this; does any potato man ever refer to the three varieties other than as "Edwards", "Crowns" and "Dates"? And containers have been known to be labelled simply "Pentland" or "Maris", with unhappy results. But there will be some regrets at the change.

Building of the eastern extension of the laboratory began in November 1974 and should be completed in autumn 1975. It will contain facilities for potato blight and tuber disease work, a common-room and a seminar-meeting room. At present we have no controlled-storage chambers, common-room space is quite inadequate, seminars are uncomfortable or overflow and a Board meeting pre-empts the library. So the new facilities will be very welcome.

The fourth SSRPB lecture was given by Professor A. H. Bunting, C.M.G., M.Sc., D.Phil., LL.D., F.I.Biol., on 11th April 1974 to a highly appreciative audience.

The fifth, summarised elsewhere in this report, will be given by Prof. R. L. Wain, C.B.E., Ph.D., D.Sc., F.R.I.C., F.R.S., Wye College and Honorary Director of the A.R.C. Systematic Fungicides Unit, on 10th April 1975.

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, R. J. Giles)

The statistical analysis of the diallel cross data on diastatic power and α-amylase activity is proving very informative. The diallel involved 13 parent varieties, crossed in all combinations as well as selfed; nine parents were crossed reciprocally; four parents were six-row varieties. The F_1 and F_2 plants were individually randomized within two replications, in each of two years, 1970 and 1971. Enzymatic measurements were made on the F_2 grains produced by individual F_1 plants. The six-row parents all had higher diastatic power (DP) than the two-row parents and three of them were also high in α-amylase (AA), the exception being Scotch Bere. The only two-row parent with high DP was Mosane, but Boreham Warrier, Maris Baldric and, to a lesser extent, Golden Promise exhibited high AA. The 1971 material, grown at The Murrays, averaged much higher in both DP and AA than the 1970, grown at Pentlandfield.

In the case of DP, there were no reciprocal differences and so all the information is provided by the 13 × 13 diallel. The within-family variances of the untransformed data were significantly heterogeneous and correlated with family means. These violations of the statistical assumptions of the analysis of variance were reduced by transformation to square roots and virtually eliminated by transformation to logarithms. In whatever form the data were analysed, they revealed large additive effects and dominance of high DP. Heterotic effects were apparent and many crosses (mainly six-row by two-row) exceeded both parents; the general mean of hybrids was higher than the mean of the parents. Jinks's variance-covariance analysis gave a regression close to unity, with a negative intercept, suggesting that over-dominance was involved in the heterotic effects. General combining ability was positively correlated with parent mean and all six-row parents showed high positive and statistically significant GCA's. Crosses of six-row parents with the two-row, short-strawed varieties Golden Promise and Midas also showed large positive, consistent and statistically significant specific combining abilities. However, all crosses involving six-row parents were too weak in resistance to mildew to be transferred to the breeding programme without further crossing.

In the α-amylase data, within-family variances were not significantly heterogeneous and so transformations were not applied. There were no consistent maternal effects in the reciprocal crosses, but in one year (1971) there was evidence of significant residual differences between reciprocals. Additive effects gave rise to a large mean square and there was evidence of dominance, which tended to favour high AA, but was not unidirectional. Jinks's variance-covariance analysis consistently gave a slope less than unity, suggesting the operation of epistatic interactions.

Because of the importance of α-amylase as the heat-stable diastatic enzyme, it was considered desirable to analyse the sub-diallel consisting only of two-row by two-row matings. In this restricted set, the genetical situation became simpler, in that dominance was unidirectional (favouring high AA) and epistatic interactions vanished. General combining ability effects were significant, very consistent and correlated with parental means. Specific combining abilities were small, often inconsistent and rarely significant.

The implications of these results for the breeding of varieties with high diastatic power seem to be: (*a*) that the choice of parents simply on the basis of their mean DP and AA activity is justified; (*b*) a considerable improvement in DP should be attainable by breeding exclusively from two-row parents; (*c*) to achieve the very high DP, combined with high AA, characteristic of imported Canadian barley, crosses with six-row parents will be needed and here the genetical situation is more complex. A further point is that the diallel material has amply confirmed that the well-known correlation between DP and nitrogen content is genotypic as well as phenotypic. The highest yielding varieties are usually lowest in nitrogen content and so some sacrifice in yield may have to be made to achieve high DP.

In 1973 an estimate of 4·6 per cent crossing (random mating) in one of the Station's composite cross populations was obtained. As this seemed a very high figure, the same bulk was tested in 1974, using a different technique and an estimate of 7·0 per cent was obtained. Another bulk tested in 1974 gave another high estimate of 5·4 per cent. There seems little room for doubt that our composites do a surprising amount of random mating. It was observed that cross-bred plants almost invariably had large lodicules; although the small (bib-type) lodicules are not rare in the composite crosses, they severely limit the plant's potential for cross-fertilization.

The barley museum has been enlarged to about 1,400 entries. Field characters were recorded on about a quarter of them in 1974 and arrangements have been made with the Plant Breeding Institute, Cambridge, and the Welsh Plant Breeding Station to incorporate our material in a data bank, using the internationally applied program called TAXIR.

ARC Project 2: Barley biochemistry

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

(Workers: M. J. Allison, J. S. Swanston)

Sub-lines of an induced mutant of Ymer barley, originally selected using an abscisic acid screen, were grown in New Zealand in 1973-74. Green malt derived from the produce had a diastatic power of 220 degrees Lintner, compared with 160°L for Ymer and 310°L for Akka which had both been grown with the mutant lines. In a yield trial at Pentlandfield the mutant showed no significant difference in yield from Ymer (it actually yielded about 11 per cent more than Ymer but plot error was very large). This mutant retains the resistance to abscisic acid which led to its being selected in the first place. As abscisic acid is an antagonist of gibberellic acid, the simplest explanation of the resistance is that the mutant produces more gibberellic acid but, rather surprisingly, it does not differ from Ymer in α-amylase activity, sometimes used to assay gibberellic acid. Other attributes it has in common with Ymer are the isozymes of α- and β-amylase that it displays on electrophoresis of malt extract and the content of bound β-amylase. The important differences seem to be a higher content of free β-amylase and a tendency to produce grain of high nitrogen content when excess nitrogen is available; Ymer's response to excess nitrogen tends to be in extra yield of grain rather than increased nitrogen content and so it does not reach as high a diastatic power as the mutant.

The same system, of screening with abscisic acid after inducing mutation with ethyl methane sulphonate, applied to Maris Mink and Universe, has produced 17 lines from Maris Mink and five from Universe with intermediate to high diastatic power.

The different isozymes of β-amylase described in the 1973-74 Annual

Report (p. 7) and those of α-amylase are easily detected by electrophoresis. If they were to differ in diastatic activity, they could be useful markers in early-generation selection for diastatic power. To make comparisons against a common genetic background, heterozygous F_2 plants are being identified in each of three crosses, segregating for both Sd1 *vs* Sd2 in β-amylase and DC1 *vs* DC in α-amylase. The segregation of Sd1 *vs* Sd2 is normal (74 Sd1 : 121 heterozygotes : 51 Sd2) from all the three crosses but one parent seems to have been heterogeneous for DC1 *vs* DC. Nevertheless, enough heterozygotes have been identified to make the exercise possible. The heterozygotes were identified by testing six F_3 grains from each F_2 plant.

ARC Project 3: Barley breeding

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

(Workers: R. P. Ellis, A. M. Hayter, Fiona G. A. Megginson)

In collaboration with the New Zealand Department of Scientific and Industrial Research, a pilot experiment was run in 1973-74 in which F_3 seed was sent to raise progenies at Gore, in the South Island, and F_4 seed of selected progenies was returned to be grown at The Murrays. The experiment was successful and the procedure is continuing on a reciprocal basis. It allows the first four generations of a cross to be grown in two years, using a greenhouse to produce F_2 seed in the first winter.

The objectives of our barley breeding were extended in 1974 with the initiation of a breeding programme and associated genetic and biochemical studies of barley for brewing. The first cycle of pedigree crossing was completed in 1974 and F_2 selection will begin in the field in 1975. In addition to crosses made at Pentlandfield, some F_4 lines and F_3 bulk populations were obtained from the Plant Breeding Institute, Cambridge, and these have been incorporated in the same programme. The F_4 lines were grown in New Zealand in autumn 1974 and will be sown in our F_5 yield trial in spring 1975. The F_3 bulks are being grown over winter by the modified pedigree method, otherwise known as single seed descent. Investigations of routine laboratory methods of assessing malting quality for brewing purposes have also begun. These include small-scale tests for prediction purposes in addition to the conventional micro-malting methods. This will extend the facilities already available for measuring diastatic power, alpha-amylase and wort fermentability.

One of the existing parts of the breeding work is coming to an end, the transfer, by back-crossing, of a single locus determining high-amylose starch, from our mutant of the six-row American variety, Glacier (Ac38), to barley varieties adapted to Scottish conditions. Grain produced from single plants of high-amylose lines was sent to New Zealand in autumn 1973 and selected progenies were returned and grown in a yield trial in 1974 at The Murrays. The best high-amylose lines yielded at the level of the best recurrent parent, Midas. Unfortunately, as often happens with back-crossing programmes, the recurrent parent has subsequently become outclassed. Midas yielded only 80 per cent of Abacus, the best yielding variety in the trial. Other lines, derived from Zephyr rather than Midas, were lower yielding. The theory behind the high-amylose project was that an increase in the simpler " straight-chain " starch molecules in distillers' worts would lead to a more complete fermentation and hence to a higher spirit yield. It was impossible to investigate this theory in Glacier as this variety is extremely dormant when grown in Scotland. Attempts were made to overcome dormancy by using gibberellins. The results indicated that high-amylose starch was not more readily broken down than normal-amylose starch. Tests with isolated starch from unmalted high-amylose and normal-amylose Glacier confirmed these findings. In further malting experiments, with samples of near-isogenic lines differing in amylose content, significant depression of hot water extract was found in those lines with high-amylose contents. Development of existing lines is continuing but at present there does not appear to be any advantage to high-amylose content, especially as the suggestion of improved efficiency for non-ruminant feed was not confirmed by the Poultry Research Centre.

The pedigree breeding programme for high diastase varieties for grain whisky has continued, with the most advanced material in F_5 trials in 1974. Lines from the cross Midas × Akka again performed well and other, less advanced, generations, also based on two-row sources of high diastase, looked promising. Attempts to transfer high diastase from six-row sources ran into trouble with mildew susceptibility and further crossing is being undertaken with this material. The six-row genotypes are the only source of high diastase combined with high alpha-amylase. The two-row sources of high diastase possess only intermediate levels of alpha-amylase. Although the six-row crosses will take longer to exploit, they should eventually result in adapted varieties with even higher levels of enzyme activity than the first high diastase varieties based on two-row sources.

The breeding objectives for feed barley are very similar to those for high diastase, namely high yield, good straw, early ripening, disease resistance (primarily to mildew but also considering leaf-blotch (*Rhynchosporium*) and both yellow and brown rust); high nitrogen content is also desirable but not at the expense of high yield. Since high diastase is highly correlated with high nitrogen content, it is quite possible that the two breeding programmes will arrive at similar end products. The most advanced material, at F_5 in 1974, performed well and lines of F_4, derived from an F_3 New Zealand generation, performed extremely well in yield trials in 1974. In autumn 1974, 1,500 lines were sent to New Zealand, a threefold increase on the 1973 pilot experiment. Material derived from composite cross populations, using canonical selection methods, has been reduced to a single line, 698C, which again performed well in advanced trials. This line is being tested further and multiplied for possible submission for plant breeders' rights. Work with composite cross populations has continued but now includes strong artificial selection pressure for characters such as plant height which are adversely affected by natural selection.

Increased awareness of the worsening disease situation among cereal varieties in commercial agriculture has prompted an expansion in pathological studies. In cooperation with the East of Scotland College of Agriculture, the Eucarpia milstem trial was grown for the second consecutive season. In addition, preliminary studies have been made of quantitative variation in the level of background resistance to mildew, both within and between established varieties. These investigations were conducted in conjunction with DAFS Scientific Services, East Craigs. Differences were detected between varieties with the same major gene for resistance and between different stocks of the same variety. Investigation of a quantitative assay for chitin in plant material, in order to quantify variation in level of infection, showed that the method was feasible but impractical, because it was too time-consuming. For the first time, barley breeding material and potential parents were screened for resistance to leaf blotch, using plots grown at the Welsh Plant Breeding Station. This proved extremely worth while and is to be continued. In addition leaf blotch, yellow rust, brown rust and mildew are being propagated over winter on susceptible varieties in polythene isolation chambers. This is to provide inoculum for artificial epidemics in the field early next season. To select for non-race specific resistance to the major diseases, a composite cross population has been constructed incorporating reputed field resistance from diverse sources, short stiff straw and male-sterility. It is hoped that strong mass selection will eventually provide a population consisting of lines with more stable disease resistance than that conferred by major genes alone.

According to the Britton Report, the area devoted to barley in Scotland has been restricted by the relative intolerance of the crop to low soil pH. It has been estimated that 95 per cent of the soils in the major Scottish barley-growing areas are acid brown earths. Regular liming is necessary to maintain soil pH in the optimum range of 5·5–6·5. Mean annual rainfall and consequently leaching of applied lime is greater in Scotland than in the barley-growing areas of England. There are indications that economic pressures, particularly the cancellation of the liming subsidy, have reduced the use of lime and therefore reduced soil pH. Acid-tolerant barley varieties should perform more reliably where leaching has reduced soil pH and would avoid replacement of barley by more acid-tolerant crops such as oats. Workers in Denmark, Holland and Japan have demonstrated the existence of acid-tolerance and it is noteworthy that, in one such study, Scotch Bere was the most tolerant variety found. A small-scale laboratory method has been developed to test potential parents. Preliminary results suggest that Gerkra is the most tolerant modern variety. A composite cross has been started by crossing this variety and a number of other sources of pH tolerance to male-sterile genotypes in 1974.

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)

Three lowland-type oats have been submitted for National List Trials and for Plant Variety Rights, and have been given Station index numbers Aa748, Aa749 and Aa752. All three are similar in maturity to Astor, rather longer in the straw and, under Scottish conditions, more mildew resistant than Astor and Selma. An early maturing oat, Aa754 for upland use, is under consideration, further trials in appropriate areas being planned for it. Aa744, another early selection, has been offered for trial in Iceland where Pentland Provender is regarded as an outstanding forage oat. Aa744 is earlier maturing and longer in the straw than Pentland Provender.

During 1974 no crops infested with oat stem eelworm were available from which eelworm larvae could be extracted for the purpose of carrying out laboratory tests for resistance. The laboratory testing programme is being run down and tests during the winter of 1974/75 are being conducted with larvae collected and stored from earlier years. A composite cross population derived from resistant parents has been established as an insurance against the recurrence of the pest should changing agricultural practice result in its resurgence.

That part of the programme which has been concerned with tolerance of manganese deficiency, causing grey speck disease, prevalent on machair soils, has been concluded. The surviving selections, from Tiree and from Archerfield in East Lothian, have been offered to, and accepted by, the agricultural adviser in North Argyll for exploitation on Tiree where high freight charges have increased the dependence on fodder, particularly oats, grown on the island.

The composite cross populations, upon which the main breeding effort is based, are currently yielding some 600 selected lines per annum for screening and subsequent evaluation. Lines from the oldest of the composite crosses, produced in 1965, are in final trials with a view to possible National List submission after the 1976 harvest.

Half the varieties in the oat collection plus new accessions were grown and documentation is now nearing completion. The remaining varieties will be grown in 1975 and the collection handed over to the Pure Stocks Unit.

ARC Project 5: Hybird swedes

Methods of exploitation of known heterosis

(Worker: S. Gowers)

The short-term aim of this project is to produce inbred lines of swedes, homozygous for *S* (self-incompatibility) alleles, ultimately to be used in the commercial production of hybrid seed. The main effort is on seeking and identifying *S* alleles in various types of *B. napus*, including artificial *B. napus*. So far, seven different *S* alleles have been identified and a further six self-incompatible lines have still to be cross-checked. Further self-incompatible, swede-like plants have been obtained from the cross (turnip × swede) × swede. The *S* alleles are in course of being transferred by back-crossing to selected swede cultivars; the most advanced material has completed three of the four generations of back-crossing planned.

Of the seven *S* alleles identified so far, five are fully functional when heterozygous with self-compatible swedes. These alleles could, therefore, be used in a modification of the double-cross method whereby self-incompatible lines are crossed with self-compatible lines to produce self-incompatible hybrids for the final cross.

To decide which cultivars to use in the production of F_1 hybrids a knowledge of combining abilities is required. An initial examination was made this year by sowing an 8 × 8 half-diallel trial. Although somewhat obscured by a differential herbicide effect, the results showed marked heterosis in most crosses. The highest yielding hybrid, Wilhelmsburger Danila × Pentland Harvester, produced 32 per cent more dry matter yield than its higher-yielding parent, W. Danila. The diallel has been enlarged to a partial 10 × 10 design by crosses with two further parents.

From a crossing plot experiment, in which 12 green-topped plants flowered among an excess of purple-topped plants, three parents were detected to have crossed to a very high degree, 76 to 93 per cent, and one intermediate (25 per cent). The green-topped progeny of the three plants with the highest degree of outcrossing were found to have very high proportions of male sterile plants in the selfed offspring. It is assumed, therefore, that the sterility was produced by recessive genes. In the case of the fourth plant, the flower morphology of the selfed progeny appeared normal. On testing this line for pollen tube growth it was found that there was an approximate 1 : 2 : 1 ratio for self-compatible : partially self-compatible : self-incompatible. The parent plant must, therefore, have been heterozygous for an *S* allele which is only partially active in that state. This is only the second known case of self-incompatibility occurring naturally in swedes. It would, perhaps, indicate that more *S* alleles are available naturally in swedes if a large enough survey was carried out. Another 50 lines are being tested for their degree of natural outcrossing.

ARC Project 6: Swede breeding

New swede varieties to replace Pentland Harvester for mechanised cultivation.

(Workers: Isabel K. Munro, S. Gowers)

In 1974, inbred material from crosses not involving Pentland Harvester were producing F_5 seed, either by selfing selections or multiplying 10 lines for 1975 trials. Material from crosses involving Pentland Harvester should have been in F_5 trials, but the seed set in 1973 was so poor that the F_4 selection work had to be repeated.

A constituent line of Pentland Harvester, having shown less raan (internal browning) than the other constituents, was tested for raan by the North of Scotland College of Agriculture at Craibstone. Its lower incidence of raan was confirmed and it will be useful as a parent, though it shows too much raan for a commercial variety.

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)

A replicated trial of 128 single plant progenies, derived from a polycross of the selections from the highest yielding families of the 1973 polycross trial, was grown at The Murrays. Despite a late sowing and a severe potato ground-keeper problem the trial matured well. Three of the four replicates sown were harvested in December and samples have been passed to the Chemistry Laboratory for analysis. All but nine of these single plant progenies outyielded Maris Kestrel in fresh weight. Selection for the next seed generation will follow the completion of the analyses.

Analyses of the biometrical data described in *Ann. Rep.* 1973/74, p. 14, were continued. Heritabilities of final height, fresh weight yield of stem and leaf : stem ratio were demonstrably high ($>$60 per cent) and there was a large additive genetic component; but fresh weight yield of leaf and total fresh weight yield had low heritabilities (<30 per cent) and were largely non-additive in the genetic sense. The evidence suggests there is little purpose in the selection of individuals by purely visual assessment of phenotype, particularly for the latter two characters. The indications are that some form of reciprocal recurrent selection based on family performance might be more suitable.

Further experimental work concerned with these biometrical studies has been put in abeyance, whilst work continues on the breeding side. Analyses of the existing data continue and seed samples have been retained in storage.

The crossing for the planned reciprocal recurrent selection programme was completed in 1974 and seed will be sown for trial and selection in 1975.

ARC Project 9: Brassica wide crosses

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

(Workers: I. H. McNaughton, G. R. Mackay and Carol L. Snell)

The relatively simple embryo culture technique, adopted to raise hybrids between *B. campestris* and *B. oleracea*, has proved unsatisfactory and has now been abandoned in favour of a more sophisticated culture system. Alternative methods of incorporating the genotypes of the parental species into *B. napus* are under review. Utilizing the artificial *B. napus* already available, F_3 families from two artificial rapes × Nevin rape were grown in observation plots. The best of these developed more rapidly than commercial rape cultivars in adjacent plots and appeared generally promising. Screening for *Plasmodiophora* resistance is currently being carried out. Sufficient residual seed is available for a replicated trial in 1975.

In attempts to introduce higher stem edibility into *B. napus* from *B. oleracea* over 2,600 pollinations were made between *B. oleracea* and *B. campestris* at different chromosome levels. One (2n = 28, acc) hybrid was obtained from 2x *B. campestris* (leafy stubble-turnip: Chinese cabbage selection) × 4x *B. oleracea* (marrow-stem kale).

A number of 4x *B. oleracea* varieties and inter-varietal hybrids were observed as possible parents for artificial *B. napus* and *Raphanobrassica* synthesis. F_2 4x hybrids of Maris Kestrel × fodder kohl-rabi were grown with a view to introducing higher stem edibility into rape. A 4x *B. oleracea* thousand-head × curly kale hybrid, a by-product of this work, has been multiplied by NSDO and marketed by leading seed firms as a vegetable named Pentland Brig. The NSDO reports that it has attracted wide interest.

Another by-product, a 4x *B. campestris* hybrid (CA57, parentage ssp. *nip-*

posinica × Tigra stubble-turnip) was compared in a trial with Nevin rape and Ponda stubble-turnip at two sowing dates, the intention being to assess yield before grazing and residue afterwards. Failure of the rape to produce stemmy growth, as in a normal season, precluded this. Dry matter (DM) yields were, however, assessed in late December. DM yield of CA57 was 75 per cent above the rape from an 8th July sowing and over 570 per cent greater from a 6th August sowing. Total yield of CA57 was slightly below Ponda from the earlier sowing but 50 per cent greater from the late sowing. CA57 was considerably leafier than either Nevin or Ponda and showed less premature leaf senescence than a range of stubble-turnip cultivars.

In a small experiment, involving Maris Kestrel kale, DM yields, expressed as percentages of the commercial triple-cross, were as follows: modified double-cross (99 per cent), double-cross once multiplied (93 per cent), PBI mass selected (89 per cent) and SPBS tetraploid (75 per cent). This result confirms earlier findings that tetraploids in the kale group are inferior to corresponding diploids.

To produce hybrids of *B. campestris* and *B. napus* on a commercial scale, lines homozygous for *S* alleles are needed. Test crosses between turnip lines continued and the indications are that of the 10 tested so far only two share a common *S* allele. Seed of a further 14 putative *S* homozygotes was sown in 1974 for further testing. Test crosses between F_1s and their parents provided further information on dominance relationships between *S* alleles.

Losses in the 1973/74 winter prevented an attempt at field scale production of *napus-campestris* (aac) hybrids using turnip *S* allele homozygotes as seed parents. It is hoped that *S* homozygotes and F_1s now available will enable us to repeat the attempt in 1975.

Test pollinations of 15 putative self incompatible (s.i.) "rape" (*B. napus*) lines confirmed that 12 carried fully functional *S* alleles. These s.i. "rapes" are of extremely diverse origins including some artificially synthesised *de novo* from *B. oleracea* and *B. campestris*. They have now been crossed to agronomically desirable rape cultivars, with a view to transferring the *S* alleles into more suitable material. Progenies from these crosses have been successfully annualized to allow s.i. plants to be back-crossed to the rape cultivars.

ARC Project 10: Raphanobrassica

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

(Worker: I. H. McNaughton)

Transplants of 28 F_5 single plant progenies of *Raphanobrassica* were under observation in replicated plots at The Murrays. These families derived from the most fertile F_4 plants in a polycross. Premature flowering was negligible but in general growth was poorer than in 1973. A number of F_4 families, over-wintered and selected in spring 1974 were placed in isolation plots for seed production. In a season not conducive to pollination and good seed setting, results have been disappointing. Seed of the most fertile F_4 families has been sent to New Zealand for " out of season " multiplication and similar material sent to NSDO.

Tetraploid *B. oleracea* was crossed with 4x *R. sativus* with a view to producing *Raphanobrassica* in *Brassica* cytoplasm, all previous material being in *Raphanus* cytoplasm: 30 seeds were obtained from over 1,000 pollinations; their hybridity or otherwise has not yet been finally determined, but the young seedlings resemble *B. oleracea*. Some 700 4x *R. sativus* × 4x *B. campestris* pollinations failed completely.

Plasmodiophora (club-root) studies had to be abandoned during winter and spring 1973-74 due to power restrictions. New club-root material has been collected for testing from a number of sources. *Raphanobrassica* lines resistant to four club-root populations have been multiplied. The 15 agreed European differential hosts are currently being used to obtain more accurate information on the race status of cultures (populations). A trial by NIAB at Cambridge, to assess *Erysiphe* (powdery mildew) resistance of *Raphanobrassica*, unfortunately failed because of drought.

F_2 seed has been obtained from *R. sativus* (fodder radish) × *R. maritimus* (sea radish) hybrids placed in isolation. Hybrids have been back-crossed to *R. sativus* at both 2x and 4x chromosome levels, with a view to producing improved leafy, biennial *Raphanus* for future inter-generic work. A late-flowering, 4x fodder radish has been multiplied by NSDO as a potential new cultivar and has been submitted for National List Trials.

In hope of facilitating wide crosses, successful grafts have been made involving all stock and scion combinations of 4x *B. oleracea*, 4x *B. campestris* and 4x *R. sativus*.

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)

Further analyses of extensive data collected from the North Carolina I experiment with Italian ryegrass at three plant densities have been completed (see *Ann. Rep.* for 1973-74, p. 18). They show that useful information about sward yields can be obtained via genetic correlations with certain attributes of spaced plants. This should contribute to solving the perennial problem of the grass breeder: he has to be able to identify individual plants but is ultimately aiming at sward performance.

Seed of the fourth generation of mass multiplication of a cocksfoot bulk hybrid was harvested. It is available for distribution to any grass breeders who may be interested. It is based on some 450 accessions, ranging in provenance from Leningrad to Morocco and including material from the US Department of Agriculture collection at Ames, Iowa. During the first three generations equal quantities of seed from each maternal line (tracing back to one population) were used to produce the next generation. The plants that produced the seed now being offered were grown at wide spacing at Pentlandfield and about 5 per cent of them would have merited further study in a selection programme.

ARC Project 12: Winter kill in ryegrass

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

(Worker: F. J. W. England)

In collaboration with the Welsh Plant Breeding Station and the Plant Breeding Institute, Cambridge, a second experiment to investigate winter hardiness in perennial ryegrass was established in 1973. Like the first experiment, its main aim is to find agronomic treatments which will give the best discrimination between varieties for winter hardiness. As before, cutting sequences and applied nitrogen are varied but, in this experiment, swards are included as well as spaced plants. The winter has again been too mild (up to the latter half of February) to get the best out of the trial, at Pentlandfield, as at Aberystwyth and Cambridge. So far, two distinct types of damage have appeared. Where long herbage was left, leaves have turned brown and eventually formed a slimy mass, especially with high nitrogen applications. With frequent cutting, there have been deaths of plants in swards and of fairly large sectors of spaced plants. Between the two extremes of herbage length there is relatively little damage.

Two trials have been sown at The Murrays with material from the recurrent selection project for winter hardiness in Italian ryegrass. One trial consists of single drills, each representing one progeny. In the other, each plot has been broadcast with a bulk of eight progenies, which have a common grandparent.

Promising, winter-hardy plants from ARC Project 11 were cloned and planted in a polycross nursery. The polycross seed was used to establish a small trial at Pentlandfield in 1974.

ARC Project 13: Cocksfoot breeding

Selection of nutritious and high yielding derivatives of Scotia cocksfoot.

(Worker: Cynthia J. Williamson)

The general aim of this project is to select a cocksfoot variety with the high digestibility of Scotia but better yield and persistency; the material under selection derives from rather complex crosses of Scotia and other varieties. The third cycle of selection was completed in 1974 when dry matter yields and digestibility were recorded from 860 plants, which had been cut five days after ear exsertion. The cellulase method for digestibility was used and the 120 most digestible were checked by the *in vitro* digestibility method, using sheep's rumen liquor and pepsin. The mean yield of the 49 plants selected was 173g and the mean DOMD (*in vitro*) was 71·4 per cent. The plants have been cloned for a polycross nursery to be planted in 1975.

ARC Project 14: Poa breeding

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

(Worker: Cynthia J. Williamson)

The objective is to derive a rhizomatous Poa, with good productivity in the early spring as well as later, from interspecific crosses of *P. pratensis* with *P. ampla*, *P. iberica* and *P. longifolia*. The three exotic species are all bunch grasses, and so rhizomatous offspring got by exposing them to *P. pratensis* pollen may be taken to be hybrids. In spite of complications arising from apomixis, 72 hybrids have been obtained. Chromosome counts have now been obtained from nearly all the F_1 hybrids. Somatic numbers range from 45 to 115. About half have between 65 and 80 chromosomes and probably resulted from fusion of reduced gametes. Some of the remainder probably resulted from fusion of an unreduced female gamete with a reduced male gamete and there are very probably other categories of hybrids which cannot easily be distinguished. Pollen development of the hybrids is generally good, as judged by stainability; only six plants with less than 20 per cent stainable pollen have been found; they all had poorly developed anthers.

Seed from 163 selected F_2 plants was germinated in February 1974. Records on seedling habit were taken in the greenhouse, and 40 plants per progeny were planted at wide spacing in the field in June. A rough assessment of within-progeny uniformity indicates that 19 per cent of the seed parents were probably apomictic.

Yields from six cuts in 1973 of small simulated-sward trials in the Pentland

Hills and at The Murrays were analysed. The trials involved five apomictic hybrids and five *P. pratensis* parents. Although there had been no selection for early growth, dry matter yields from the first two cuts (May and June) were higher in the hybrids than in *P. pratensis*, an encouraging result. There were no significant differences in total yield.

Duplicate trials comparing seven hybrids and seven parents were sown with companion white clover at Pentlandfield (altitude about 180m) and in the Pentland Hills (House o' Muir Farm, about 360m). Seedling counts showed a mean establishment of 177 seedlings per m^2 at Pentlandfield and 77 at House o' Muir. Thanks are due to the Hill Farming Research Organization for providing facilities for this and the preceding trial in the Pentlands.

ARC Project 28: Exploration Unit

Explore unfamiliar crops for breeding potential in Scotland: wheat, beans, oilseed rape, maize, white clover.

(Workers: R. N. H. Whitehouse, I. M. Chapman, M. S. Phillips)

Work on a composite cross of winter wheat started in 1972. The growth-regulating substance 2-chloroethylphosphonic acid (Ethrel) was used to try to induce male sterility and thus favour crossing. The seed was initially supplied by the Plant Breeding Institute, Cambridge. The proportion of crossing obtained was too low and cytoplasmic male sterility is now being used; lines were supplied by Rothwell Plant Breeders Ltd. and the Plant Breeding Institute.

A composite cross with spring beans (*Vicia faba*) was also started and, in 1974, selection was begun for early ripening. The initial material was supplied by the Plant Breeding Institute and comprised European varieties and more exotic material. A variety trial was conducted at The Murrays for the Plant Breeding Institute. Yields were surprisingly high, averaging 6·2 t/ha (50 cwt/a). Two new synthetic varieties were four days earlier in maturity than Maris Bead, with somewhat higher yields.

Workers at the Hill Farming Research Organization are of the opinion that a white clover which starts growing earlier than these currently available would be valuable for their system of hill improvement. The SPBS has assembled a collection of about 1,400 plants to screen for this attribute. About 1,000 were obtained from the Welsh Plant Breeding Station and originated in or around the Mediterranean region. The remainder were mostly collected in Scotland.

A spring-sown variety trial of oilseed rape was sown at Ormiston, East Lothian. There were seven spring varieties of swede-rape, one of turnip-rape and two winter varieties of swede-rape. One winter variety failed to set seed and the other gave a poor yield. The two best spring swede-rapes, Cresus and Maris Haplona, yielded over 3·5 t/ha (28 cwt/a). The turnip-rape, Torch, gave a low yield, 1·7 t/ha (14 cwt/a). A trial of winter varieties was sown in August 1974 at Eyemouth, Berwickshire. There seems to be increasing interest in oilseed rape in Scotland, and the experience being accumulated with the crop may well be valuable.

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)

Work on this and other potato projects continued to be subject to the restrictions imposed to contain and ultimately eradicate potato spindle tuber virus (PSTV) from the Station's material. The prospect has brightened during 1974 in two respects. Firstly, the DAFS Scientific Services (East Craigs), having previously feared that some rather slight and ill-defined effects on test plants might be caused by "mild" strains of PSTV, are now satisfied that they do not reflect the occurrence of the internationally recognised disease, potato spindle tuber. Diagnosis thus becomes somewhat easier. Secondly, in consultation with East Craigs, arrangements have been made to grow PSTV-free material in the Cheviots. Land has kindly been made available by Roxburghe Estates and storage facilities by the Hill Farming Research Organisation at their Sourhope hill farm. The Station's thanks are due to East Craigs, HFRO and the Roxburghe Estates for their generous help in coping with this difficult problem. There is now a feeling of seeing light at the end of the tunnel.

The parents used for breeding this year were drawn from 131 clones and cultivars, ranging from old-established parental clones like 11-79, the pollen parent of Pentland Crown, to the newest Neo-tuberosum selections. All had been tested for PSTV and passed. They were grown in insect-proofed glasshouses and pollinated by staff who kept out of contact with all other potato material. Extensive use was made of Neo-tuberosum and blight-resistant clones.

The 16-plant seed stocks at Blythbank, of 226 advanced clones in their fifth year of selection, were tested on a basis of one leaflet per plant, the 16 leaflets then being bulked for one test on tomato, and showed no evidence of infection. The next phase of multiplication, 100-plant seed plots of selected clones, will be at Sourhope, where the material is already in temporary store.

The Station's new variety, Croft, completed its official trials and tests; the Plant Variety Rights' Office awarded royalty rights to the Station and the National Seed Development Organisation. The PVRO's report follows:

AFP 4/74 (CROFT)

VARIETY: F	NATIONAL CONTROL VARIETY: MAJESTIC
Breeder	: Scottish Society for Research in Plant Breeding, Pentlandfield, Roslin, Midlothian.
Applicant	: as above, jointly with NSDO, Cambridge.
Variety Origin	: 2895 (6) × Pentland Dell [2895/6 = Roslin Riviera × 2534 (36)].
Test Centres	: Department of Agriculture and Fisheries for Scotland, Edinburgh. Department of Agriculture for Northern Ireland, Belfast. National Institute of Agricultural Botany, Cambridge.
Duration of Trials	: 1972–74.

1. General Characteristics

(*a*) Emergence	: slightly earlier than Majestic.
(*b*) Vigour and Habit	: low to medium height, semi-erect, open, spreading, less vigorous than Majestic; leaflets mid grey-green, dull, narrow; flower coloured, moderate frequency.
(*c*) Cover	: fair, less complete than for Majestic.
(*d*) Root System	: stolons short to medium; tuber numbers variable, mainly similar to or slightly more numerous than for Majestic, clustered at the root, readily detached from stolons.
(*e*) Tubers	: oval; skin white, slightly netted; flesh cream; eyes shallow; sprout pink.
(*f*) Maturity	: early maincrop, similar to or slightly earlier than Majestic.

2. Reaction to Diseases and Pests

A. *Fungi*

(*a*) Wart Disease	: field-immune from the Common European Race (Race 1).
(*b*) Blight	: field-immune from the common race; foliage and tuber showed some degree of field resistance.
(*c*) Gangrene	: occasionally susceptible.
(*d*) Dry Rot	: usually susceptible.
(*e*) Skinspot	: moderately resistant to resistant.
(*f*) Common Scab	: moderately resistant.

B. *Viruses*

(*a*) Viruses X, A, B and C	: field-immune from viruses X, A, B and C.
(*b*) Virus Y	: more resistant than Majestic.
(*c*) Leafroll	: no special resistance.

C. *Eelworm*

(*a*) Heterodera rostochiensis (Pathotype A) : susceptible.
(*b*) Heterodera pallida (Pathotypes B and E): susceptible.

3. Consumer Quality

At Harvest

(*a*) Steamed : moderately firm to mealy; flesh cream, occasional discolouration; flavour mild, occasional reports of off-flavour.

(*b*) Crisped : light brown, slightly darker than Record, uneven colour distribution.

(*c*) Specific Gravity : medium, similar to Majestic.

(*d*) Enzymic Browning : slight, similar to Majestic.

(*e*) Stem-end Blackening : nil.

February—Post Storage

(*a*) Steamed : moderately firm; flesh cream, occasional discolouration; flavour mild, slightly sweet, no off-flavours.

(*b*) Crisped : mid to dark-brown, similar to Record.

(*c*) Enzymic Browning : very slight, less intense than for Majestic.

(*d*) Stem-end Blackening : nil.

March—After Conditioning

(*a*) Crisped : light brown, similar to Majestic and darker than Record.

4. Remarks

An early maincrop of similar maturity to Majestic. Yield figures for ware and for total yield compared favourably with those of Majestic. Tubers were mainly medium to large, inclined to boldness, of even shape and moderate in numbers. Yield figures at Belfast were poor, particularly in one year of trial when poor plant development and 15 per cent blanking were recorded.

The variety was field-immune from the mosaic viruses X, A, B and C, and showed some degree of hypersensitivity to virus Y. It was field-immune from the common race of blight and had some field-resistance to that disease. Good resistance to skinspot and to common scab and slight susceptibility to gangrene were other features of the variety.

Apart from occasional reports of off-flavour at harvest, cooking quality was satisfactory. Dry matter content was similar to Majestic, but the variety was less suited to crisping than Record.

Rate of sprouting slow to moderate.

Official testing of the varieties Corrie (6123*b*1) and Strath (6456*ab*50) was interrupted by PSTV restrictions and the clone 6670*c*7, entered for rights in 1973, will not start official trials till 1976. In 1974, two further clones were entered for rights. They are: 7495(6), which has good resistance to late blight and viruses X, Y and leafroll, good crisping quality and exceptionally high dry matter content; 7683*a*12 which is extremely field resistant to late blight.

Two other potential crisping varieties were selected for field, storage and processing trials (by Golden Wonder Ltd.), with a view to filling two particular market niches, for earlier crisping in the case of 7432*ab*11 which is, for practical purposes, an earlier version of Pentland Ivory, and for crisping after prolonged storage in the case of 8372*a*13, a much later sprouting variety than Record.

Despite restrictions on the use of machinery and other stipulations designed to prevent virus spread, material was accepted for first-early Regional Trials in Cornwall (Rosewarne E.H.F.), the Gower Peninsula (Glamorgan) and in Pembrokeshire, but not in Ayrshire. Seed grown in Pembrokeshire and thus allegedly "acclimatized", was used for the first time but, partly because of adverse factors at two of the sites, nothing of substance was added to what was known of 7169(10) and 6834(4) in 1973. Then they were considered probably worth trying in commerce, after official trials, and that is still the position. The most promising "newer" early was 8906(11), of ex-*vernei* × Maris Piper breeding and excellent quality.

Conditions at planting time and throughout the growing season at The Murrays and Blythbank were excellent and resulted in record yields, the record now standing at 165 lb (75 kg) from a standard 12-plant plot of a Neo-tuberosum hybrid at The Murrays. Unfortunately, at the time of writing, most of the material has still to be weighed, checked for specific gravity, cooked and looked at critically, because wet weather prolonged the harvest until mid-November. The data are expected to show that the new material dating from 1969, comprising Neo-tuberosum hybrids, ex-*vernei* eelworm-resistant material and new virus-resistant material, will show something of the same order of yield advantage over the older, well tried material that became evident in 1973. The difference is of the order of 20 per cent, similar to the usual difference between Pentland Ivory and Pentland Crown in 12-tuber plots. Interestingly, under the ADAS "Blueprint Plan" for maximising yields, Pentland Crown outyielded Pentland Ivory by about 20 per cent.

The first of the newer material is due for final year Regional Trial in 1975, when there will be a noticeable increase in the frequency of red-tubered clones and ex-*vernei* eelworm resistance will be a feature of about half of the clones. It is believed that this resistance, when used in conjunction with nematicidal treatment, will control potato cyst eelworm, including pathotype E (*Heterodera pallida*). In this context, it is important to distinguish between the control of yield losses due to eelworm (which can be achieved by nematicidal treatment alone) and control of potato cyst eelworm infestations by ensuring that post-harvest populations are lower than initial populations at planting time (which cannot usually be achieved by nematicidal treatment followed by full scale multiplication on a susceptible variety). In a small trial conducted by ADAS in Derbyshire in 1973, ex-*vernei* resistance in conjunction with nematicidal treatment controlled Pathotype E in every plot of several clones. It was not possible to repeat the trial on a larger scale in 1974 because of spindle-tuber restrictions, but permission to resume in 1975 has been granted.

The first of the material produced primarily for selection for high specific gravity (indicating high dry matter content) at The Murrays (HSG material) came under third year selection and was crisped for the first time. In laboratory tests, some 57 per cent of the surviving clones were rated at least equal to the control variety Record in crisping quality.

The agreement between crisping results obtained under laboratory and factory conditions was tested by submitting to Golden Wonder Ltd. 79 different tuber samples which had been previously subsampled, crisped in the laboratory and rated generally acceptable. The Golden Wonder results were very encouraging and are given below:

Visual acceptability of 100-crisp samples of 79 clones

Percentage crisps acceptable	100%	95-99%	Below 95%
Number of clones	34	27	18

The most advanced HSG material must now be tuber-indexed to enable virus-free seed stocks to be established at Blythbank. Twenty-one per cent of these HSG clones showed some leafrolled plants and, overall, 7 per cent of the plants were infected. Despite regular aphicidal spraying, therefore, three years is probably the longest that a seed stock can be maintained in a reasonably healthy state at The Murrays, excepting, of course, very virus-resistant material.

Leafroll was much more prevalent in all classes of breeding material than in 1973. This, and a probably large over-wintering population of *Myzus persicae* (1973-74 was another mild winter) could mean a serious build-up of infection becoming evident in 1975.

At Blythbank a severe blight epidemic was deliberately and successfully promoted and enabled the younger material to be selected for tuber resistance as a matter of course.

The red-tubered Neo-tuberosum parents were intercrossed with a view to using red-tubered Neo-tuberosum seedlings as "separators" between HSG seedlings grown for mechanical harvesting at The Murrays. The red-tubered seedlings could then be subjected to selection as possible future parents. Hitherto, the HSG seedlings have been separated by purple-tubered plants of Arran Victory.

The newly developed single-plant harvester performed badly and rapidly clogged up, but the same would probably have happened to any commercial harvester in one of the wettest harvests in memory.

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 six-parent half-diallel cross consisting of all the crosses between Pentland Ivory, Pentland Raven, Pentland Squire, Roslin Castle, 228a(2) and 3653a(1) (except Pentland Raven × Roslin Castle) was grown at The Murrays.

There were 25 clones from each of the 14 progenies, grown in each of four randomised blocks. Each clone was represented by a three-tuber plot. Infection by leafroll resulted in about 20 per cent of the plots being rogued. A crude assessment of maturity was made. Resistance to late blight could not be measured because the field was sprayed before there was any opportunity to collect leaflet samples. The produce has been stored for later examination and analysis in respect of yield, specific gravity, tuber number and size distribution.

ARC Project 19: Potato blight

Mechanisms of field resistance and variability of the pathogen.

(Worker: Jean F. Malcolmson)

Three clones known to have a high degree of resistance in the adaxial leaf surfaces showed a high degree of resistance under epidemic blight conditions at Blythbank. This resistance could be attributed, in part, to a low frequency of infection in the leaves, possibly due to the above mentioned resistance and also, in two of the clones, to the development of lesions which were smaller than average. In plots of these clones planted on three dates, with intervals of two weeks between, the youngest plants were most resistant and the oldest most susceptible, but even the oldest plots maintained a level of resistance considerably higher than that in comparable plots of the commercial cultivars Majestic, Pentland Crown, Maris Piper and Record.

In laboratory tests of the three clones, planted on four dates a week apart, the most resistant clone showed a marked resistance of the axillary buds. None was infected in the youngest series of plants nor in those planted one week earlier. Of the older material the buds were infected in 28 per cent of the oldest plants and in 12 per cent of those planted a week later. In comparison, Record showed infected buds in 100 per cent of the plants of both the first and last plantings.

Plots of 34 field-resistant clones, planted on three dates two weeks apart, also showed the youngest plants to be the most resistant. On the scale 1 (most susceptible) to 9 (most resistant) now used for recording, seven clones were graded 6 or better just prior to normal harvesting time and after four weeks under epidemic conditions. Additional checks with one clone, finally graded 9, confirmed that its resistance was not due to *R* genes.

In families selected for resistance exhibited in the 1973 leaflet tests, a high level of resistance was evident in tests of whole plants in the laboratory and under epidemic conditions in the field.

Studies with mixtures of races of *Phytophthora infestans* on leaves and tubers indicated the presence of antagonism, possibly associated with the type of inoculum used.

ARC Project 20: Commonwealth Potato Collection

Introduction, quarantine, maintenance and distribution of the Collection.

(Worker: D. R. Glendinning)

There is little to report this year because, while problems connected with potato spindle tuber virus still dominate activities, the plant quarantine authorities of the Department of Agriculture and Fisheries for Scotland have been unable to test Collection material because they were involved with other material. However, it now appears that what had been regarded as "mild"-strain infections were not caused by the PSTV agent (see p. 21). The major area of uncertainty is therefore much reduced and it seems improbable that any genuine PSTV remains in the Collection; but further testing is required.

ARC Project 21: South American tetraploids

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

(Worker: D. R. Glendinning)

Because of the problems with potato spindle tuber virus (PSTV) mentioned in last year's report, no Chilean material remains in this programme and work with Andigena-derived material (Neotuberosum) is restricted.

The apparent "mild" infections previously detected in the Chileans and some Neotuberosum clones associated with them are not now attributed to the PSTV agent (see p. 21) and no certain cases have yet been detected in Neotuberosum. However, of 28 Neotuberosum clones proposed for use in our commercial Tuberosum breeding programme (ARC Project 16), 27 proved healthy and one was suspected of infection with "mild" virus (presumptively not PSTV). The latter was a seedling from a clone which had been grown alongside the Chileans. Some 1,000 plants of the main Neotuberosum population were screened by a "pyramidal" procedure in which 10 were inoculated into a tomato plant and then 10 such tomatoes were inoculated into one tester, which thus involved 100 Neotuberosum plants. Eight tests were satisfactory and revealed no PSTV; two tests were spoiled by virus Y infection.

At The Murrays, as previously at Pentlandfield, severe losses of Neotuberosum clones due to leafroll are being experienced, about 50 per cent being eliminated in 1974.

Pollinations from Neotuberosum seedlings on to PSTV-cleared Andigena lines from the Commonwealth Potato Collection continued, with the object of generating a new wave of variability and a second mass selection programme.

In 1973, seed from our 1966 seed-production plots was sown. Comparison with current material in 1973 and 1974 shows that selection since 1966 has brought forward maturity, reduced plant size and improved tuber shape. It also seems that the frequencies of yellow flesh and of anthocyanin in the flesh have declined, though no conscious selection for flesh colour has been made.

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)

One of the ways in which dihaploid potatoes may contribute usefully to commercial potato breeding is through their use by chromosome doubling to increase homozygosity for desirable genes such as those for various disease resistances. It is not clear, however, whether horizontal ("field" or non-specific) resistances could be increased by the dihaploid route, since their inheritance appears to be polygenic and success would depend upon the distribution of such genes within the genome. To investigate the possibilities, the dihaploid production programme during 1974 was concentrated on tetraploid clones with high horizontal resistance to late blight, supplied by Dr Malcolmson, and on clones from Dr Dunnett's *Solanum vernei* crosses, having horizontal resistance to potato root eelworm races. The tetraploid clones chosen as parents were selected having regard to their sexual fertility as well as to agronomic criteria.

Diploid potatoes of the group Phureja/Stenotomum have been the subject of investigation into late blight and gangrene resistance. In previous seasons it has been found difficult to relate resistance to blight as observed under field conditions in trial plots at Rosewarne EHS, Cornwall, with the results obtained for the same material in leaflet tests in the laboratory. A randomized glasshouse experiment to test reaction to whole plant inoculation was carried out during the summer. This was only partially successful in that significant differences were found between individual clones, but no differences were observed between clones grouped according to their reaction in the field. The results may, however, have been influenced by adverse conditions in the glasshouse. Tuber tests for gangrene resistance undertaken during winter 1973-74 were subjected to statistical analysis. While there were quite large variations in resistance between different diploid clones the results suggested that changes in sample sizes and testing procedure would be advantageous for future work.

Work with direct crosses between 4x Tuberosum cultivars and élite 2x Phureja clones continued during 1974. When crosses were made between different cultivars and Phureja pollen parents, different ratios of 3x and 4x hybrid progeny appeared. Thus, Arran Consul which fairly easily sets seed in such crosses gave 253 triploids to 8 tetraploids, whereas the less fertile Pentland Crown gave 5 triploids to 16 tetraploids. The cultivars Golden Wonder, President and Maris Piper gave intermediate ratios, tending towards the Pentland Crown results. It was concluded that Arran Consul was less suitable for use in this work. The more recent cultivar Ulster Concord was included in the 1974 crossing scheme. Contrary to expectations based on work done in the USA, crosses in the direction 2x Phureja ♀ × 4x Tuberosum ♂ were signally unsuccessful. However, any tetraploid hybrids so produced would have the advantage of a cytoplasm free from factors which could give rise to a type of male sterility.

ARC Project 23: Aspects of potato cyst eelworm biology

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

(Worker: None)

Work on this project was suspended during 1974-75.

ARC Project 24: Potato virus resistances

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

(Workers: T. M. W. Davidson, Ruth M. Solomon)

The most advanced material in the virus-resistance breeding programme was in trial at The Murrays, an English trial being precluded by PSTV restrictions. A *stoloniferum* derivative, G5457(4), has resistance to viruses X and Y and very good resistance to leafroll; the clone G5503(1) has resistance to X and leafroll. Both are good yielders, with no obvious weaknesses and were selected to go forward for PSTV testing and subsequent trial. From 32 clones which had been selected for preliminary trial in England, but were perforce grown at The Murrays, 15 were selected for preliminary trial in England and two for a main trial there. All 17 are free of PSTV and so can be propagated at Sourhope.

The breeding work on resistance to leafroll was set back when the 1973 infection plot at Cambridge had to be destroyed as part of the precautions against PSTV. In consequence there was no produce from it for testing in 1974. An infection plot at Long Ashton Research Station contained 1,500 three-tuber plots, representing 325 clones plus control varieties; infector plants were used to encourage a natural spread of leafroll and virus Y. Infection of the control varieties was about a third less than was usually obtained at Cambridge.

The propagation of breeding and seedling material at Pentlandfield and The Murrays went well, with little loss by leafroll infection. About 100 PSTV-tested parents with virus resistance were used for breeding. All parents had been tested for cooking quality. The potato breeding project (No. 16) received nine clones for use as parents.

In routine greenhouse testing, advanced material from this project, from Project 16 and from Project 21 (Neotuberosum) were tested for resistance to viruses X, A, B, C and Y, and less advanced clones for resistance to X and Y. Some of the Neotuberosum clones gave an immune reaction to X and a few had comprehensive resistance to Y, the first found in Neotuberosum.

PSTV restrictions also prevented planting of any field trials in connection with resistance to potato mop top and tobacco rattle viruses, the soil-borne agents of spraing. The fields used for potato trials at The Murrays have been routinely surveyed for the presence of these viruses. The presence of tobacco rattle virus has been detected by using cucumber as trap plant, and tobacco and *Chenopodium amaranticolor* as test plants, but little or no spraing has resulted from it, though there has been fairly light infection with mop top and its associated spraing. This may be because the strain of tobacco rattle virus is always a weak type, producing local lesions on tobacco but not multiplying to give systemic infection. On the other hand, it may be that recent cool springs have inhibited eelworm movement and build-up or that our practice of bastard-fallowing in preparation for potatoes reduces the eelworm vector as well as the couch infestation it is designed to control. A strain of tobacco rattle virus which is capable of multiplying on tobacco has been isolated from soil at Vicarsford. It is being used to develop a greenhouse test for spraing resistance, by innoculation of leaves and young tubers.

ARC Project 25: Potato cyst eelworm resistance

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

(Worker: Rosalind M. Ford)

The main emphasis in 1974 testing was on screening large numbers of seedlings or young clones.

In tests against pathotype A (*Heterodera rostochiensis*) more than 6,000 seedlings of crosses between fairly E-resistant H_1H_3 clones and Pentland Ivory were transplanted into soil infested with pathotype A at the rate of 40 eggs/g. Obviously, there was no replication and the scoring was a straightforward presence/absence of cysts. The plants grew well despite fears that a three-week-old seedling might not withstand eelworm attack as well as a rooting tuber piece and control progenies confirmed the reliability of the results.

It was easy to determine the genotype of the H_1H_3 parent with respect to the H_1 gene from clearcut ratios of resistant: susceptible in the progenies. On the hypothesis that the presence of the H_3 gene might confer resistance also to pathotype A, note was made of the numbers of plants in each cross which had more than five cysts (*i.e.*, were h_1) but notably fewer than the controls. There were some progenies where a number of seedlings fell into this category, and it will be interesting to see whether there is a greater degree of E resistance among them.

Little account of the eelworm score was taken when these seedlings were selected for growing as singles at The Murrays in 1975, but A-resisters were kept separate from susceptibles, and the survivors of the two classes of material will be tested for E resistance in 1976.

An attempt was made to combine H_1H_3 resistance with ex-*vernei* resistance, unfortunately without much success. Flowers of known ex-*vernei* resisters were cut in the field and kept in the glasshouse in water but, despite a fair number of pollinations, only six berries resulted.

In the programme of outcrossing and intercrossing ex-*vernei* material, the fourth generation has been reached and was planted in 1974 as threes at The Murrays. In 1973 they were grown as Murrays singles and tubers kept in excess of 1974 planting requirements were tested for resistance to E (*H. pallida*). At best, replication was never more than three-fold, pot conditions were rather variable from table to table, scoring had to be rapid (more than one thousand clones replicated), and so it was only possible to divide the clones roughly into three classes: (*a*) resistant—few enough cysts to count the whole number by eye, (*b*) fairly resistant—enough cysts to require a sample count using the mask method but with less than half those found on control plants, (*c*) susceptible—at least half the cysts found on control plants with a sample count. These results were taken into account in the selection of the clones at The Murrays and retesting of the survivors in 1975 will demonstrate the validity or otherwise of the 1974 testing.

Clones further on in the selection programme were tested more rigorously, with at least two replicates for H_1 gene testing and at least four for ex-*vernei* A and E resistance. Pot conditions are critical for producing reliable results, and several variations were investigated. The best rooting systems were obtained when the plants were grown in clay pots sunk in sand and watered both from below and above. This is unfortunate, because square plastic pots are more economical of space.

The degree of resistance to E in some of the more advanced clones tested this year was promising; the most resistant clone produced 83 per cent fewer cysts than the susceptible Pentland Crown. Ex-*vernei* clones a year " younger " than these have shown a range of resistance to E, with cyst numbers varying from 24–120 per cent of those found on Pentland Crown controls. Clones on the whole display the same level of resistance from year to year. In clones without major gene resistance to A, good resistance to E seems to be correlated with few cysts when grown in A soil. This observation provides some support for the hope that when an ex-*vernei* variety is eventually produced it will be, in some measure, resistant to all known pathotypes and thus less likely to bring selection pressure to bear on a mixed eelworm population and build up a pathotype which can attack it.

ARC Project 26: Potato blight resistance

Resistance to blight in breeding programme.

(Workers: Jean F. Malcolmson, Helen E. Stewart)

Of the 42 clones in the seventh year of selection, 16 showed a higher level of resistance than Record under epidemic blight conditions at Blythbank. This confirmed the resistance forecast by laboratory tests. Unfortunately, resistance in the foliage was not always correlated with resistance in the tubers, and only 8 of the resistant clones had 3 per cent or less infected tubers. The clone with the most resistant foliage had 31 per cent infection of the tubers. Thus the need for separate assessment of foliage and tubers in routine screening is emphasised.

From routine tests of whole plants, parents well established as conferring resistance on their progeny were recognised. Other sources of resistance were noted in parents from the Andigena group and from the programmes for breeding for resistance to viruses and eelworms. In routine screening tests of tubers, a satisfactory level of resistance has been noted among clones in the 5th year of selection.

ARC Project 27: Potato tuber disease resistance

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

(Workers: R. L. Wastie, Helen E. Stewart)

Clones under selection at The Murrays were screened for resistance to common scab (*Streptomyces scabies*) at Archerfield, where a sandy soil of high pH favours the disease. Replicated, single-tuber plots of clones and five control varieties were planted. The disease scores of the controls ranged from 7·6 for Craigs Royal (resistant) to 14·3 for Redskin (susceptible). Of the 126 clones selected at The Murrays, 25 had a score less than 7, more resistant than Craigs Royal.

To develop a glasshouse test for scab, small axillary tubers were produced by growing stem cuttings of Majestic in a mist-propagator for five weeks. The tubers were buried in dry cultures of *S. scabies* on 5 per cent cornmeal in sand or peat, with the pH adjusted to 7·0; after six days at 25°C numerous discrete lesions had developed. The lesions were more distinct, though no more numerous, in the sand culture. They did not increase in size or number after a further eight days' incubation.

In tests of clonal material for resistance to gangrene (*Phoma exigua* var. *foveata*) the cornmeal-sand method of inoculation was used. The tubers came from 340 clones under selection at The Murrays and from the breeding programmes with Neotuberosum and with diploids. The tubers were inoculated in pairs of mesh bags, the contents of one bag of each pair being hand-riddled after three weeks. Riddling had no consistent effect on disease development, and clones and control varieties were assessed on the mean of both treatments. A surface-area score was used; assessing the depth of penetration of gangrene gave unreliable results with the controls. The scores ranged from 3·5 for Roslin Castle (resistant) to 19·5 for Dunbar Standard (very susceptible). Some 3 per cent of the clones from the commercial breeding programme were about as resistant as Roslin Castle and Arran Consul, and 58 per cent were rated very susceptible. Nearly half the clones from the Neotuberosum and diploid material were rated as resistant.

The progress of *P. exigua* along cut stems of 10 varieties differed from one variety to another but not so as to reflect the known susceptibility of tubers of these varieties.

Chemistry Laboratory

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

The routine work of the chemistry laboratory continued along much the same lines, the major load being determinations of *in vitro* digestibility (over 2,600 for cocksfoot and *Brassica*), Kjeldahl nitrogen (2,250 mainly on barley), diastatic power and α-amylase activity of barley malt (1,000 of each). In addition, 284 determinations of soluble and insoluble carbohydrates were made on barley and *Brassica*.

Investigations on possible new routines were also pursued. The haemolytic factor (S-methyl cysteine sulphoxide, SMCO for short), occurring in all *Brassica* crops, was successfully detected by thin-layer chromatography, but a quantitative assay is needed for breeding work. A method of estimating fungal infection, by deacetylation of fungal chitin to chitosan, the glucosamine of which can be assayed colorimetrically, was shown to be applicable to mildew-infected barley. Unfortunately, the method is much too laborious for a routine procedure in plant breeding. A cellulase digestion method developed at the Welsh Plant Breeding Station was applied to 1,000 samples of cocksfoot. The 120 most digestible samples had also high *in vitro* digestibility; there are prospects that cellulase digestion, which requires fewer operations and less time than *in vitro* digestion, could usefully replace the latter in early stages of breeding. Other methods which relate to digestibility and to voluntary intake by ruminants are the Van Soest method and the measurement of energy needed to grind dry material to a given particle size range; both are still under investigation. Little progress has been made with relating α-amylase content of malted barley to RNA content of the unmalted grain.

Cytology Laboratory

(Worker: Rosemary J. Low)

The services provided for projects in potatoes, *Brassica* and grasses reached the limit possible with the staff available. Chromosome counts at mitosis were made on 2,500 plants, and extensive studies of pollen stainability, pollen measurements and meiotic studies were also performed. An annotated photographic record of methods used at the Station is in preparation.

Statistics and Computing

(Workers: R. J. Killick, Gillian McConnell)

The service supplied by the Edinburgh Regional Computing Centre continues to be excellent, with job entry possible by van, by remote-entry terminal on the Bush Estate and by our own teleprinter. Usage of computer time has dropped by almost half, important factors being a reduction in the work of program development, completion of certain large jobs and, perhaps, improvements in skill. Now that the Station itself can provide professional help for the non-expert, more of the staff are making use of the computer.

Photography and Illustrations

(Worker: Joyce Sutherland)

The studio and dark room have been busily occupied on a variety of tasks. Some of them are aimed at photographic recording of the work and the development of the Station, such as stages of building work and disposition of plots at Pentlandfield and The Murrays by aerial photography, in collaboration with the National Institute for Agricultural Engineering, Scottish Station.

Slides, prints, diagrams and graphs for internal and external lectures, for publication and for display boards have been produced. An amply illustrated handbook showing the cytological techniques in use at the Station is in preparation.

The Murrays

(Farm Superintendent: G. R. White)

A total precipitation of 599 mm made 1974 the wettest year since we acquired the farm, though the long-term average for the district is 100 mm greater. Wet weather in spring and autumn made both spring operations and harvest difficult.

The measures to bring couch grass under control continued. In preparation for potatoes in 1975, rotavation and TCA spraying were carried out on 8·1 ha (20 a) and also on 4·0 ha (10 a) for the 1974 Brassica plots. The 1974 potato ground was treated with Eptam as a further measure. Control of couch has so far been very good.

Sowing of farm barley began at the end of March and was not completed until the beginning of May. In spite of the late sowing, yields were good, with 26·3 ha (65 a) of Golden Promise averaging 5·3 t/ha (42 cwt/a) and 8·9 ha (22 a) of Midas giving 5·0 t/ha (40 cwt/a). Nitrogen contents were unusually high for The Murrays, and most of the produce was sold for feeding. Harvesting lasted from 9th September to 26th October; fortunately, there was not much lodging.

Winter wheat was a rather disappointing crop and slow to ripen. Yields were 5·6 t/ha (45 cwt/a) from 10·9 ha (27 a) of Cappelle Desprez and 5·1 t/ha (41 cwt/a) from 2·8 ha (7 a) of Bouquet.

Planting of early potatoes was held up by wet weather until the beginning of April; main crop potatoes were planted in mid-April. Pre-emergence control of weeds with Sencorex was very effective. Regular spraying against aphis, using dimethoate, began early in June; from the beginning of August this was combined with spraying against blight. The foliage remained healthy and growth continued until harvest. Lifting the main crop started in mid-October and finished on 20th November. Some very high yields were obtained, though growth cracks in tubers were a problem.

The kale plots grew well, but swedes and other Brassica brairded unevenly and grew slowly. The TCA spray gave good initial control of weeds, but annual weeds and potato ground-keepers became troublesome later. In fact, with a succession of mild winters, potato ground-keepers are threatening to become our worst " weed ".

A short-term hay mixture on 11 ha (27 a) was mown in preparation for cereal plots in 1975 and another was sown for hay in 1975. The aim of these hay crops is to give the cereal workers more control over soil fertility. Two fields of barley were undersown, for grazing in 1975 and 1976, amounting to 23·5 ha (58 a). The Edinburgh School of Agriculture rented 28·3 ha (70 a) for grazing by cattle and sheep.

Autumn ploughing was held up by the weather, but 3·2 ha (8 a) of Atou and 8·9 ha (22 a) of Cappelle Desprez winter wheat were sown.

The fencing programme was completed, dividing the farm into 10 units of about 12 ha (30 a) each, with smaller parcels amounting to 12 ha for ex-rotation plots.

Engineering Workshop

(Worker: A. E. Hamilton)

Several field implements were modified to adapt them to the requirements of plot work. The Garvie plot combine was extensively altered to improve its threshing, its ease of cleaning and its stability. A forage harvester-chopper was fitted with a box and a statimeter, to allow weighing of produce on the machine. Similar additions were fitted to a root harvester for swede plot work. For the system of growing single tubers of new clones of potatoes, alternating with a colour-marked variety, a potato planter was modified to give more regular spacing. The potato harvester already modified for this work was further developed.

Several minor jobs on field machines and on laboratory apparatus, such as making manifold boxes for auto-analysers, were also carried out and a two-ton gantry for handling heavy loads was installed.

Routine maintenance and running repairs on all machines and vehicles continued.

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 large biometrical experiment (diallel cross) has proved very useful in helping to define breeding methods, especially in relation to high diastase. Remarkably high rates of natural cross-pollination in the field were confirmed; this is favourable for the use of composite crosses.

2. *Barley biochemistry*

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

That the induced mutant line of Ymer is indeed high in diastatic activity has been confirmed and several new mutants, of Maris Mink and Universe, have been made. Biochemical-genetic studies proceed. Mutants of this kind are potentially of value for whisky making and may throw new light on the old problem of yield-nitrogen relationships in barley, of great importance for feeding aspects of the crop.

3. *Barley breeding*

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

Prospective feeding and high diastase varieties are coming into view and this programme as a whole is being expedited by growing winter generations in New Zealand. There is no doubt that varieties relatively high in diastase can be bred; very high enzyme levels may take another cycle of crossing. It looks as though the biochemical assumptions involving the high-amylose work were wrong. The grain is not likely to be favourable for malt distilling; nor does it have any special value (previously suspected) for poultry feeding. Some attention has been given to beer malting quality, to diseases and to the possibility of adapting the crop to more acid soils than usual.

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 oats have been submitted for National List Trials. Pentland Provender, unsuccessful in Scotland, is doing remarkably well in Iceland. Oat stem eelworm no longer seems worth much effort and this aspect of the work is being run down, but a resistant composite cross is being retained as an insurance.

A considerable volume of materials from the earlier composite crosses will be approaching trials from 1976 onwards.

5. *Hybrid swedes*

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

This project makes good progress and it is now clear that workable incompatibilities can be built up. The occurrence of high yield heterosis (up to 30 per cent over the best parent, itself high yielding) has been confirmed.

6. *Swede breeding*

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

The most advanced material is approaching variety level but progress was retarded by poor seed-setting. A line of Pentland Harvester somewhat resistant to raan has been isolated and will be useful in breeding.

8. *Kale improvement*

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

A large trial of families derived from a wide range of *B. oleracea* material confirmed earlier observations of very high yield potential; nearly all lines outyielded Maris Kestrel in fresh weight. The indications are that conventional kale breeding methods are inefficient and should be replaced by more sophisticated breeding plans.

9. *Brassica wide crosses*

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

This prospect becomes even more complex as the extraordinary breeding potential of these Brassicas becomes more apparent. Artificial rapes (which are still very difficult to make), autotetraploids as breeding intermediates, and interspecific triploid hybrids all have a place. In practical terms, the most promising materials are F_1 turnip-rape hybrids (utilizing, like hybrid swedes, self incompatibility) and, an unforeseen by-product of the work, a leafy stubble turnip substitute which looks very promising.

10. *Raphanobrassica*

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

Poor seed fertility continues to be an obstacle, despite agronomic promise (disease resistance) mentioned in the last report. An attempt is being made to make the cross the other way round (with *Brassica* female) since there are grounds for thinking this may improve fertility. A late-flowering, tetraploid radish line developed as a parent for this work shows some promise as a cultivar on its own right.

11. *Grass breeding methods*

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

Further analyses of very extensive data from a breeding experiment with Italian ryegrass have confirmed the usefulness of non-sward characters as predictors of sward performance. Seed of a genetically widely based cocksfoot population is offered to breeders.

12. *Winter kill in ryegrass*

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

A second collaborative experiment with PBI and WPBS was set up. Two types of damage, not yet interpretable, have been distinguished.

13. *Cocksfoot breeding*

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

The third cycle of selection was completed and excellent DOMD values (71 per cent) were again noted.

14. *Poa breeding*

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

About 19 per cent of 163 interspecific hybrids gave signs of apomixis, which means that some hybrids should be, for practical purposes, true breeding. There was evidence of the hoped-for early growth in May and June.

16. *Potato breeding*

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

This project has again been very severely hampered by PSTV restrictions but the situation seems to be improving insofar as levels of actual infection are certainly very low and a large amount of material has been cleared. A "third centre", carrying only cleared material is being established in the Cheviots. The new variety, Croft, has been granted rights but its successors, Corrie, Strath and three yet unnamed, will all be variously delayed by PSTV restrictions. The material in the pipline gives promise of outstanding yielding ability, attributable to the wide genetic base of our breeding populations: there is now a substantial flow of Neotuberosum, *vernei*-derived and widely based virus-resistant stocks into the programme. Some of the potential varieties and much less advanced material carry good field resistance to blight (the fruit of 20 years' work) and much excellent crisping quality is apparent. Valuable contacts with potato processors were maintained.

18. *Potato economic genetics*

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

A large biometrical experiment was grown for the first year. It has taken several years to be set up and should yield valuable guidance for breeding plans.

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 presence of excellent resistance in breeding stocks is clear but the mechanisms remain obscure; certainly they are complex and different parts of the plant may behave in quite different ways in different clones. Only experience, on the field scale, will test which kinds of resistance are more valuable in agricultural practice.

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 but little testing has been done. However, it is certain that very little infection remains (it was never more than rare) and the collection may indeed now be clean.

21. *South American tetraploid potatoes*

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

The work has been much hampered by PSTV restrictions: no certain cases have been detected in the Neotuberosum material, which is now flowing into the breeding programme. The genetic base is being broadened by recourse to Andigena potatoes (the original source of Neotuberosum). An experiment designed to detect change in the population showed that good progress has been made.

22. *Dihaploid and diploid potatoes*

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

Efforts to build up field resistance to blight and eelworms in these materials progress, though there are considerable difficulties and uncertainties. Introduction of genetic material from the best diploids to breeding tetraploids is in hand.

23. *Potato cyst eelworm biology*

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

Work on this project was suspended during 1974-75.

24. *Potato virus resistances*

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

The work was severely hampered by PSTV restrictions. Comprehensive Y-resistance and leafroll resistance superior even to that of Pentland Crown is now present in promising advanced clones, and there is a steady flow of parents into the general breeding programme. Little work could be done on spraing.

25. *Potato cyst eelworm resistance*

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

The main effort went into testing large amounts of material varying both for *vernei* field-resistance and the major genes H_1 and H_3. Interactions are complex but it looks as though no resistance to race E will be as good as H_1 resistance to A; "integrated" control using resistance and nematicides will probably be the outcome.

26. *Potato blight resistance*

Objective: to incorporate resistance to blight in breeding programme.

The routine screening went well and the predictive value of leaflet tests and the lack of correlation between foliage and tuber reactions were again apparent. Tuber resistance must be separately assayed.

27. *Potato tuber disease resistance*

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

Much resistance to gangrene and scab was again apparent. A possible method of achieving a quick laboratory test for scab reaction was investigated.

28. *Exploration unit*

Objective: to explore crops which are not otherwise being studied at the SPBS but which might have breeding potential in Scotland.

This project, a new one, is designed to provide experience and the "feel" of possible new breeding projects. The effort is small but could be very valuable. Composite crosses of wheat and beans are in hand, a collection of white clover (with an eye to the hills) has been assembled and an oil seed rape trial was carried out.

3. THE PLACE OF ECONOMICS

N. W. Simmonds

Introduction

The expenditure of public funds always involves decisions about where and how to use scarce resources for the public benefit. Inescapably, potential benefits have to be compared. Politicians have to reconcile the competing demands of defence, health, communications and a host of others. Inevitably, most decisions must be made more or less subjectively because of the complexity of the issues involved and because there simply are not scales upon which comparisons can be made. Some sort of consensus of informed judgment must rule.

Smaller scale judgments, however, may be open to more objective analysis. Since the late war, the idea has been gaining ground that it should be possible to compare competing projects on an economic basis with the object of maximising the return to society from public expenditure. If this were to be possible, the basic need is clearly to convert all the costs and benefits, both direct and indirect, into common terms—namely, cash. The public expenditure can then be regarded as an investment and appraised by conventional financial methods.

In this essay I want to sketch out (no more) some of the issues that arise in social cost-benefit analysis and indicate applications to agricultural research. The issues are very complex indeed and the treatment unavoidably superficial. A mixture of general and highly technical essays will be found in Layard (1974).

Investment appraisal

The easiest bit of cost-benefit analysis is doing the sums, which are simple, though tedious. The basic idea concerns the time-value of money (or the resources it represents). Cash today is worth more than cash next year because it can be invested at the going rate of interest (a statement which has nothing to do with inflation). Conversely, it is nearly always worthwhile economically to defer expenditure. Many methods of taking this into account in investment appraisal have been proposed and used but only one, nowadays universally accepted, need be considered: the discounted cash flow (DCF).

A DCF calculation starts from the compound interest rule:

$$S_t = S_0 F$$

A sum S_0 is worth S_t at time t (in years) where:

$$F = (1 + r)^{t-t_0}$$

In this equation F is the discount factor, r is the discount rate and t is time, as before. The expression $(t - t_0)$ may be positive or negative, depending on whether one is looking backwards or forwards, so to speak; when it is negative, F declines and money is discounted; when positive, F increases and money is accumulated. So accumulating and discounting are complementary processes and which of them enters a DCF calculation depends upon the choice of t_0 when time equals zero, or " now ".

TABLE 1

AN EXAMPLE OF DISCOUNTED CASH FLOW (DCF)
(see Note (1))

	Cash		5%			10%			15%		
Years $(t-t_0)$	*Out* —	*In* +	*F*	—	+	*F*	—	+	*F*	—	+
0	50	0	1·00	50	0	1·00	50	0	1·00	50	0
— 1	100	0	0·95	95	0	0·91	91	0	0·87	87	0
— 2	200	0	0·91	182	0	0·83	166	0	0·76	152	0
— 3	80	40	0·86	69	34	0·75	60	30	0·66	53	26
— 4	0	120	0·82	0	98	0·68	0	82	0·57	0	68
— 5	0	190	0·78	0	148	0·62	0	118	0·50	0	95
— 6	0	250	0·75	0	188	0·56	0	140	0·43	0	108
TOTALS	430	600		396	468		367	370		342	297
NET	+ 170			+ 72			+ 3			— 45	
ACCUMULATED TOTALS				532	628		648	657		789	688
(see Note (2)) NET				+ 97			+ 9			— 101	
B/C RATIO	1·40			1·18			1·01			0·87	
(see Note (3))											

Notes:

(1) The interested reader may try plotting totals and net totals, discounted and accumulated, against the discount rate. It is also intructive to plot cumulative net totals against time at different discount rates.

(2) The same figures as above accumulated instead of discounted—*i.e.*, time scale is changed from 0... — 6 to + 6... 0, so that *F* rises instead of falling.

(3) The B/C ratio is the same at any given value of r, whatever the choice of t_0.

The example in Table 1 shows all the essential features of DCF calculations. The final net sums are called net present values (NPV) because they represent positive and negative cash flows brought by discounting to a common point in time (t_0, " time now "). NPV declines with increasing interest rate because returns are delayed in time and so are much more affected by discounting than are costs. In this example, discounted costs and returns balance at 10 per cent ($r = 0{\cdot}10$), at which point the NPV = 0 and the B/C ratio = 1. Clearly, the return on this investment (the " internal rate of return ") is almost exactly 10 per cent. If it had turned out to lie somewhere between, say, 10 and 15 per cent, the NPV = 0 point could have been got by plotting a graph and interpolating or by iterating the calculation.

The last four lines of the table show that choice of t_0 (*i.e.,* whether one discounts or accumulates or both) affects the NPV but not the B/C ratio nor the estimate of rate of return when NPV = 0. Clearly, to compare projects in respect of NPV at a given interest rate, one must get the time scales right.

Private and public

As I said above, the sums are simple. The hard part is estimating the figures to go into them. For a company appraising a possible investment this will be difficult enough. It will have to estimate labour, materials, equipment, building, maintenance, distribution and marketing on the cost side and sales and possible second-hand or scrap value of capital at the end of the project as returns. It will have to take various uncertainties into account and estimate the probable effects of taxation and legislation on its operations. It will not need to take into account any social implications of its plans unless, either, relevant legislation exists or can be expected, or it considers it prudent to do so. Until very recently the oil companies and car makers did not have to bother about lead in exhaust fumes.

When all this is done the company will have to decide on an appropriate discount rate, r, and do its sums. The choice of r will depend upon what the company thinks it could do with its money used otherwise, on the rate at which it could borrow money and on several other factors. At the end of the day it will have to decide whether the cash flow looks attractive or not. If the predicted NPV were negative, decision would be clear: no go. If it were zero or positive, decision would still be open and the company would have to think very hard about competing options, risks and other factors.

So, for the company, investment appraisal by DCF methods, though comparatively circumscribed, is far from simple and, having been done, is still only a preliminary to decision making. Where public investment is concerned, the process usually becomes infinitely more complex because the factors considered must relate to economic returns to society at large, not merely to company profits; in addition, the time scales of social cost-benefit analysis will usually be longer than those of commercial investment appraisal, which means that uncertainties increase and the value chosen for the discount rate, r, becomes more critical.

A department of government is considering the pros and cons of building a new road. The direct costs can probably be reasonably well forecast (though this could hardly be said of Concorde!). The list might run: do survey, buy land, pay compensation, build road, adjust existing roads, maintain road and bridges when built, and so on. The benefits might include: improved communications (estimated as reduced transport costs for goods travelling in a hypothetical future flow pattern); shorter journey times (working time can be more or less valued); improved safety (fewer crashes, less material damage, reduced NHS costs, conserved human resources). Already, the analyst is faced with formidable problems of evaluation and forecasting. But worse is yet to come.

The new road will certainly be regarded by some as damaging to the amenity of their village and it will cause intolerable noise in some unfortunately placed houses. It may engender, in places off the actual route, traffic problems which are not only unpleasant but hazardous. (An underpass has been described as the shortest distance between two traffic jams.) On the other hand, the landladies of seaside town X might find their trade enhanced (but at whose expense?). Again, altered patterns of employment resulting from the road might have substantial effects on the need for housing and social services. Truly, the ripples spread out.

Any serious cost-benefit analysis must come to grips with these secondary effects—what the economists call "externalities"—if it is to carry any conviction. Unfortunately, the uncertainties of forecasting, the sheer economic difficulties and the necessity of incorporating disputable value judgments means that no analysis such as this can ever command general acceptance. The Roskill Commission made a brave attempt on the third London Airport problem. The debate revealed profound disagreement about the weighting of externalities and the Commission's assumptions about the future patterns of air traffic have probably already been falsified by subsequent economic events.

At the macro-level of public policy, therefore, it seems doubtful whether the actual sums that emerge from cost-benefit analysis are of any real value. The general approach, however, since it enforces hard thinking about, and listing of, both main effects and externalities may well be useful as an aid to informed judgment. Perhaps what we want in this sort of context is economic analysis without the economic arithmetic?

A technical point deserves comment here. The industrialist will decide, on business judgment, what value to give to the discount rate, r, when he comes to do his sums. For social studies no easy choice is available, and the answer may have to be arbitrary (such as, what the Treasury says is the "right" rate). Some economists argue that, sometimes, the "social discount rate" is approriate, that is the rate of growth of the economy as a whole. Since this rarely exceeds 3 per cent (and may be negative!) the point is important, though unresolved. The difference between, say, 2 and 10 per cent can have a dramatic effect on a long-continued cash flow.

Economic appraisal of R and D

The company can (and often does) regard research and development activity as an investment and more or less elaborate theories on how to do it have proliferated in recent years (Beattie and Reader, 1971). Essentially, all approaches seek to compare flows of R and D costs with flows of resultant profits; the elaborations chiefly concern the formidable problems of resource allocation and portfolio selection. The object is generally to maximise company profit and no account need be taken of social effects.

Public expenditure on R and D, however, must be aimed broadly at the public good; the object is not to make profits for individuals at the expense of others but rather to generate net benefits (which may, of course, be unequally distributed) to society at large. The proposition that public expenditure on R and D does indeed generate net social benefits is generally believed to be true; why else do we spend as much as we do? But the proposition has rarely been shown to be true and then only in isolated instances rather than over large areas of endeavour. The assumption has stood virtually unquestioned since the late war, and only recently have some doubts and discussion started to creep in. Lord Rothschild's emphasis on "accountability" sought to direct public R and D (or a part of it) along channels that were more directly identified with social needs. The ensuing debate was not so much about accountability (an obviously acceptable principle) but about the means of achieving it (which are not so obvious).

If economic appraisal has any place in thinking about publicly-supported R and D, the methods must clearly be those of cost-benefit analysis and the sums (if any) will take the usual DCF form. We saw above that large projects with complex externalities will probably remain inaccessible to formal treatment, and the same must be true in parts of the public R and D domain, conspicuously in defence (the costliest of all). Similarly, there must be areas of civil research (for example, public transport systems) where the only people who believe cost-benefit sums will be those who *want* to believe them (and, perhaps, those who did them). Large, complex projects with profound social implications are unlikely, therefore, to be amenable to formal analysis. Economics may provide a valuable guide on component issues but informed judgment must rule on the major ones.

Is cost-benefit analysis any use at all, then? I think it probably should be, especially on the less complex (but not small or trivial) issues which are relatively or completely free of evident externalities. Safer motor cars, improved domestic insulation, high yielding crop plants, industrial fuel economy, recycling of waste and many more spring to mind. Even at this fairly modest level there would certainly be formidable difficulties, but acceptable economic arithmetic should surely sometimes be possible. We will return later to the question of what can be done with an analysis of this kind when one has got it.

Agricultural R and D

There are but few published cost-benefit studies of agricultural R and D. The classic is that of Griliches (1958) on hybrid maize in the USA; there are two studies of machinery (a potato harvester—Grossfield and Heath, 1966; a tomato harvester—Schmitz and Seckler, 1970); one (using rather different methods) on poultry research (Peterson, 1967); one on plant breeding (Simmonds, 1974); and one on cattle breeding (Hill, 1971). All but the last are essentially retrospective, that is, they examine the economic history of established innovations. Collectively, their use is that they are beginning to provide a methodological basis, which is not yet, however, very secure (Wise, 1975). Certainly, prospective studies have not yet had any significant effect on decision making (which, in the absence of a secure methodology, may be no bad thing).

As a specific example, I will now summarize (necessarily very briefly) the analysis of Pentland Crown and Pentland Dell, bred at the Scottish Plant Breeding Station (Simmonds, 1974), concentrating on the arguments rather than on the sums.

The two varieties are maincrops which were aimed, successfully, at the " white ware " market and largely displaced Majestic from its leading position. The question of R and D costs leads straight into the first problem. The costs of running the Station are known accurately and reasonable estimates of the potato breeding component can easily be made. The raising of Crown and Dell occurred in the early years of the Station at Pentlandfield but the roots went back to the earlier phase, at Craig's House; conversely, by no means all the potato work of the time related to Crown and Dell. It is, in fact, impossible to identify precisely the R and D costs because (like all R and D) the potato work had its roots in the past and after-effects in the future. In practice, all one can do is to note that the earlier phase of the Station can be shown to be economically neutral (Simmonds, 1974) and treat the Pentlandfield costs conservatively.

The benefits of the two varieties resided mainly in their high yield, estimated as 10 per cent more than Majestic. For many years potato acreage has been falling, so that total crop has been more or less constant at rising yield. The yield benefit of Crown and Dell therefore lay in the resources saved by not growing potatoes; since the crop was more or less constant, nothing was saved in the harvesting. Analysis of costs of production put the saving at 10 £ (1970 prices) per acre grown. Note that it would have been quite wrong to say that the yield advantage was 1 ton/acre worth 15£/ton therefore 15£/acre. A gross return to the farmer is not the same as a benefit to society. Two other benefits could also be identified, namely: Dell's transient blight resistance, which saved some resources which would have otherwise gone into spraying (estimated to be 5£/acre); and Crown's virus resistance, which led to economy of resources in seed production (estimated to be 3 £/acre of ware grown).

We must now look for hidden costs and benefits. There appear to be none worth trying to count. The new varieties incurred no new costs that were not borne by their predecessor. There is no evidence of adverse effects on soil or environment. Consumer quality is unchanged. A very minor benefit was that, for a few years, Dell's blight resistance meant that less fungicide was used, a small environmental advantage.

Getting down to the sums, acreages were known from PMB statistics up to 1972 (when the analysis was done) and had to be forecast for the following years. Historical costs had to be adjusted for changes in the cost of money, for which purpose 1970 was arbitrarily chosen as base year. (There are, incidentally, considerable problems here as to what Index to use). Finally, for the DCF calculation itself, it was convenient to accumulate all costs and benefits up to 1972 as year t_0 and discount them thereafter. The discount rate was 10 per cent, not for any objective economic reason but because that's what the Government of the day said was the right rate for public expenditure.

TABLE 2

COST-BENEFIT ANALYSIS OF THE SPBS (M£)

		(1) 1951–72	(2) 1973–97	(3) 1951–97
COSTS		6·9	2·8	9·7
BENEFITS—	C. & D.	13·3	7·8	21·1
	Other	0	8·7	8·7
	Totals	13·3	16·5	29·8

Overall NPV = 29·8 — 9·7 = + 20·1 M£
Overall B/C = 29·8 ÷ 9·7 = 3·1
Internal rate of return = 22 per cent

BENEFITS FROM CROWN AND DELL

	(1)	(2)	(3)
Yield	11·0	6·9	17·9
Blight resistance	0·9	0	0·9
Seed economy	1·4	0·9	2·3
Totals	13·3	7·8	21·1

A highly condensed summary of the analysis is given in Table 2. This includes some breakdown of the benefits from Crown and Dell and also a figure for prospective benefits from other breeding projects. Since all the calculations were conservative and the benefits from Crown and Dell already largely realized, there can be no doubt that the Station as a whole looks economically very attractive against the arbitrary criterion of a 10 per cent return on expenditure. Even very unoptimistic assumptions about future achievements don't alter this conclusion. (Note in Table 2 that the realized 13·3 M£ exceeds the total cost of the Station, 9·7 M£). And this, in truth, is probably about as far as one can go. One can extract (and more or less justify) a whole crowd of benefit-cost ratios from Table 2 but these are of little value for comparison with other studies. Net present values are even less comparable because of changing money values and arbitrary time scales. There is a sense in which one can say that, in 1972, the SPBS was probably "worth" about 20 M£ to the UK economy; it is equally true (but just as little useful) to say that, in 1975, it is "worth" about 56 M£.

The study I have just described is, as cost-benefit studies go, small and simple but it still represents a lot of work. The conclusion—that the SPBS is economically well worth while—though limited, is useful. Precise comparisons with the other retrospective studies cited above are, for reasons given, not possible but one notes that the maize, chickens and tomato harvester examples all showed substantial net benefits. Since all these cases were picked for study because, presumptively, they seemed successful, collectively they provide no evidence as to the returns to agricultural R and D as a whole. As a personal view, I think it likely that agricultural R and D in the UK could, in principle, be justified on purely economic grounds, even though some R and D sectors could not be so justified. But this has not, in fact, been done. In the USA, fairly strong arguments have been advanced that publicly funded agricultural R and D as a whole has been economically successful (Peterson in Fishel, 1971); it would be interesting to see the American economic arguments, which were first developed by Schultz in 1953, applied to the UK situation.

In future, as land resources shrink, as populations swell and as food becomes ever more precious, the need for advanced agricultural technology will increase and the social value placed upon it must tend to rise. The economic attractions of agricultural R and D must tend to rise, too. In this context, plant breeding, which is remarkably free of adverse externalities and implementation costs, seems outstandingly attractive. The same will not be true of some other sectors where the cost of sophisticated machinery, the use of toxic chemicals, slurry disposal, welfare effects and so forth will need to be taken into the analyses. I believe, however, that food production will ultimately become so important that costs and externalities will simply have to be accepted, so will need to be identified and estimated.

In the light of the Crown-Dell analysis just outlined, it is worth enquiring whether there are implications for commercial potato breeding, since we saw above that commercial and social investment appraisal processes were very different. A partial answer may be obtained by considering the royalties that would have accrued if Crown and Dell had been subject to Rights under the Seeds Act. (In fact, they were not; they were bred too soon.) Using exactly the same procedures as above for discounting and for adjustment of money values, I calculate that the present value of royalties at 1972 would have been about 473 k£. This is equivalent to an annual expenditure of 6 k£ for the period 1951–97, the time scale over which Station costs were reckoned. On the face of it, therefore, royalties, even on very successful varieties, could not support much potato breeding. Probably, commercial justification for potato breeding would have to depend more on seed sales than on royalties. It should be noted that royalties, if Crown and Dell had earned them, would not have entered the social cost-benefit calculation: they are a kind of transfer payment that measure no change of real resources. Contrariwise, social benefits are irrelevant to the commercial calculations.

The place of economics

The agreed need for enhanced accountability means, I think, that economics should have a place in determining R and D programmes, but I hope this essay will have made clear that it neither could nor should be a dominant place. Economic arguments have nothing useful to say about fundamental research and they cannot hope to command general agreement on large, socially complex issues. Somewhere in between the trivial micro- and the impossible macro-scale, however, they must surely have their uses in helping to form rational decisions. Note that I say "helping to form"; a situation in which the economic view *determined* the decision is, I hope, inconceivable.

The most pressing need seems to me to be for more *ad hoc* historical studies so that the methodology may be established; prospective studies should follow but they cannot reveal the traps and pitfalls apparent in retrospect. As examples of this, Wise (1975) shows that there are three hitherto unrecognized kinds of benefit and that B/C ratios may be (indeed, have been) seriously distorted by inappropriate treatment of implementation costs. One would hope that further retrospective studies would not refer simply to presumptively successful R and D but would be spread across the field and chosen for probable methodological content.

Given the improved understanding that would surely follow, it should become possible to admit prospective economic studies as a component of decision making, as a means of helping to choose between competing demands for resources. There are, however, two very important areas of decision in which they are very unlikely to be of much help: we may call these the Budget Problem and the Portfolio Problem.

The Budget Problem is simply: "how much should the agricultural R and D budget be?', All attempted answers fail for want of knowledge of economic returns both to the R and D itself and to other, possibly competing, public expenditures and, still more important, because no objective answer is possible, even in principle. The Portfolio Problem is: "how to decide what to do within a predetermined budget." In principle, an answer could be given to this question, usually taking the form of a "linear programme" aimed at maximising social returns within the constraints of budget and other resources (*e.g.*, Beattie and Reader, 1971; Russell, 1973). In practice, the limitations of knowledge and the arbitrary nature of many of the assumptions disqualify the approach. On budgets and portfolios, therefore, there is no substitute for informed judgment.

The place of economics in determining R and D programmes will therefore be quite limited. It should be possible sometimes to disqualify projects as having no perceptible chance of yielding positive net benefits. There is an anecdote of a plant breeder who bred a certain crop all his working life and, near retirement, produced an excellent variety; at that moment his experimental plots exceeded in area the commercial acreage. Other, less dramatic, examples are not difficult to find. In such cases there ought surely to be very good alternative reasons for starting or continuing applied R and D. Again, choice between comparable projects in competition for resources will sometimes be aided by economic analysis, even though no simple rule-of-thumb based on NPV or B/C ratio is available. Once again we are back to informed judgment; economics should surely become part of the information underlying the judgment.

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4. *FIFTH SSRPB LECTURE*

SOME DEVELOPMENTS IN RESEARCH ON PLANT GROWTH AND PLANT DISEASE CONTROL

Professor R. L. Wain, CBE, DSc, FRS

Agricultural Research Council Unit of Plant Growth Substances and Systemic Fungicides, Wye College, University of London

There has been no more exciting and rapidly developing field of research in the last forty years than that concerned with the hormonal control of plant growth. There was already much evidence that the growth of plants was regulated by hormones when in 1934 Kögl isolated the auxin indole-3-acetic acid (IAA) from maize and human urine and showed it to have profound effects on plant growth. IAA was the first hormone to be discovered. Since that time other types of hormone have been recognised; there are the gibberellins which, like the auxins, promote cell enlargement and therefore extension growth, and the cytokinins, which play an important part in promoting cell division.

In addition, there are two naturally occurring chemicals, abscisic acid and xanthoxin which are able to inhibit the action of hormones. Xanthoxin, discovered in the ARC Unit at Wye, is produced when certain carotenoid pigments (xanthophyll epoxides) which occur in all green leaves, are exposed to light and its presence helps to explain why plants do not grow so tall in the light as they do in the dark. The chemical structure and steric configuration of xanthoxin have been determined.

Some of the synthetic auxins have found uses in practical agriculture, especially for selective weed control. The synthetic auxin 2,4-dichlorophenoxyacetic acid (2,4-D), for example, when applied to some broad leaved plants produce such drastic hormone effects that the plant outgrows itself and is destroyed. Cereals and grasses, however, can withstand higher doses of the chemical so that by choosing the right level of treatment it is possible to achieve a control of weed in crop.

Clover, lucerne and other legume crops are very susceptible to these hormone-type compounds but selective weed killers for use in these crops have been developed at Wye using a logical scientific approach which depends upon differences in the chemistry of the weed and the crop plant. The basic idea is as follows: a herbicide is chosen which will kill both weed and crop. This chemical (X) is then changed in the laboratory to a harmless derivative (Y). When Y is applied to the weed the weed's own chemistry changes it back, at cell level, to the original herbicide X so the weed dies, having brought about its own destruction by *lethal synthesis*. However, when Y is applied to a crop plant whose chemistry is unable to convert it into X no damage occurs.

This approach to selective weed control has been intensively studied in the ARC Unit and shown to operate with phenoxybutyric acids, phenoxyethylamines and other types of compound. In all cases the selective action depends on differences in the capacity of weed and crop to promote lethal synthesis. Such properties might well be worthy of consideration in a plant breeding programme.

Another area of hormone research of interest to the plant breeder is that related to physiological stress. It has been shown at Wye that, when water is withheld and the wilting syndrome commences, the plant responds by producing up to 50 times more abscisic acid in its leaves than occurs in a normal plant. One effect of this abscisic acid is to close the leaf stomata thereby reducing loss of water by transpiration; furthermore, by inhibiting the activity of the plant's hormones, the abscisic acid also arrests its growth. In this way energy is conserved during the stress period. By operating these defensive mechanisms the plant stands a better chance of surviving until water again becomes available.

From the foregoing it would appear that the more able a plant is to produce abscisic acid when subjected to drought conditions, the greater should be its chances of survival. The breeding in Mexico of a drought resistant line of maize (Latente) enabled these concepts to be examined. When compared with two other maize varieties which are not tolerant to drought, Latente plants were found to produce much higher levels of abscisic acid when subjected to water stress.

The other main line of research in the ARC Unit at Wye is concerned with the chemistry of plant disease resistance. An important concept of this work is that all growing plants in the field are continuously exposed to a wide range of fungi yet only a few of these actually cause disease. This widespread resistance can operate in many ways, one of which is through the protection afforded by fungicidal compounds present in the healthy plant. The tissues of broad bean (*Vicia faba*), for example, contain a potent fungicide whose presence can be demonstrated by standing a small segment of the seedling stem on an agar plate sown uniformly with the spores of *Aspergillus niger*. When the plate is incubated there is a pronounced zone of inhibited growth round the base of the segment which arises from diffusion of an antibiotic from the stem segment into the agar. This compound (Wyerone) has been isolated in the pure state and its chemical structure has been established. It is of interest that whilst it is fungicidal towards a wide range of fungal pathogens, it has little effect against *Botrytis fabae* and *B. cinerea*—the pathogens which cause chocolate spot disease of broad bean.

Other defensive chemicals (phytoalexins) are produced in plants in response to attempted infection by fungi and, as we have recently shown, by viruses also. All this research has moved forward rapidly following the discovery of a simple technique which enables these antifungal compounds to be isolated from plant tissues. Their chemical structures can then be established by ultra violet and infra red absorption spectroscopy, mass spectroscopy, nuclear magnetic resonance and other standard methods.

One interesting example of this type of investigation is provided by tobacco, the leaves of which contain two naturally occurring fungicides. When the plant is infected with tobacco mosaic virus, however, it responds by producing four more fungicidal compounds. All six of these chemicals have been identified.

The possibility that disease resistance in plants can be associated with such defensive chemicals present in their tissues provides a further tool for the plant breeder. Clearly any new plant variety having an appreciable level of an endogenous fungicide and which, when exposed to infection, can respond by the production of phytoalexins, is to be preferred and it is now easy to follow these desirable characteristics by the use of routine laboratory procedures.

Another research development in the ARC Unit arose from studies on why roots usually remain quite healthy when growing in soil or compost. Such roots are continuously exposed to numerous fungi and bacteria which, it would seem, cannot attack and destroy the living root tissue. Such considerations led to experiments in which seedlings of French bean (*Phaseolus vulgaris*) were grown with their roots in culture solution. Examination of this solution revealed the presence of four antifungal materials, all of which have now been identified.

Thus, useful progress is being made in studies on the chemical basis of plant disease resistance. Many new naturally occurring antifungal compounds are being isolated and identified and some of them may prove to be of value for disease control in agriculture and in medicine.

5. VARIETIES BRED BY THE STATION

The following varieties are on the market:—

Oats	Albyn Empress	Shearer
	Bell	Pentland Provender*
Swede	Pentland Harvester	
Grasses	Scotia Perennial Ryegrass	Scotia Cocksfoot
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*	Croft*

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.

A garden variety of *Brassica oleracea*, Pentland Brig, is a by-product of the Station's Brassica work. It is a horticultural kale used for producing succulent young leafy shoots and is marketed by the NSDO.

6. COLLABORATORS

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

(a) *Official bodies:*

Agricultural Development and Advisory Service (Gleadthorpe and Ely E.H.F.; Rosewarne E.H.S.; Swansea, Haverfordwest)
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Animal Diseases Research Association, Edinburgh.
Department of Agriculture and Fisheries for Scotland, Scientific Services, Edinburgh.
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JOHN ARBUCKLE, O.B.E., Barony Cottage, Newburgh, Fife KY14 6HL.

Vice-Chairman

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

Ordinary Directors

1972

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

1973

JOHN ARBUCKLE, O.B.E., Barony Cottage, Newburgh, Fife KY14 6HL
GEORGE CLAPPERTON, Sheriffhall Mains, Dalkeith EH22 1RX.
A. PATTULLO, M.C., J.P., Littleton of Airlie, Kirriemuir, Angus.
JAMES M. ROY (Gordon Innes Ltd.), 69 Bogie Street, Huntly, Aberdeenshire.
E. F. SHERRIFF (Sherriff & Sons Ltd.), The Mill, Great North Road, Hatfield, Herts.
W. STEVEN, The Brax Farm, by Arbroath, Angus.

1974

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

Directors Co-opted

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.

Directors nominated by the Secretary of State for Scotland

Professor ROBERT BROWN, D.Sc., F.R.S., Edinburgh University, Botany Department, King's Buildings, Mayfield Road, Edinburgh EH9 3JA.
Professor H. P. DONALD, C.B.E., Ph.D., D.Sc., F.R.S.E., 5 Glenorchy Road, North Berwick, East Lothian.
W. O. KINGHORN, B.Sc., Department of Agriculture and Fisheries for Scotland, St Andrew's House, Edinburgh EH1 3DA.
Sir MAURICE YONGE, C.B.E., D.Sc., F.R.S., F.R.S.E., 13 Cumin Place, Edinburgh EH9 21X.

Standing Committee—Finance

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

Research Committees

Brassicas

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

Cereals

O. T. GRIFFIN, *Convener*.
Sir DAVID LOWE.
D. MORRISON.
A. PATTULLO.
W. STEVEN.
H. A. WATERSON.
CHAIRMAN (*ex officio*).
VICE-CHAIRMAN (*ex officio*).

Grasses

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

Potatoes

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

Farm Advisory

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

9. ADMINISTRATION

Meetings

The Board met four times: on 11th April 1974; 6th June 1974; 18th July 1974; 7th November 1974.

The Finance Committee met on 6th June 1974.

The Cereals Research Committee met on 22nd August 1974.

The Grasses Research Committee met on 9th October 1974.

The Potatoes Research Committee met on 18th October 1974.

The Brassicas Research Committee met on 31st October 1974.

The Farm Advisory Committee met on 2nd May 1974, 20th June 1974 and 12th December 1974.

Board of Directors

The Board welcomed on election for the first time: Mr J. R. Marshall, Mr D. V. Rennie and Mr H. A. Waterson.

Finance

The abstract of audited accounts on pages 74 to 80 reveals the Society's financial position at 31st March 1975. The cost of the research programme at the Scottish Plant Breeding Station was met by a maintenance grant of £454,000 from the Department of Agriculture and Fisheries for Scotland. Sundry items of income at Pentlandfield amounted to £919. The unspent balance of the maintenance grant for the year amounted to £663. This sum has been added to unspent balances of grants from previous years, increasing them to £15,645.

Capital expenditure at Pentlandfield amounted to £38,924 on buildings and £18,669 on equipment for which DAFS grants were received. The Department had also approved the expenditure of £2,037 at The Murrays Farm on completing the new steading and associated roadworks. 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 1975 the total membership was 315, comprising 191 Life Members and 124 Annual Members. Six new members were elected during the year and eight died or resigned.

Election of Directors

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

HUGH C. DRUMMOND, The Currach, Girvan, Ayrshire.

W. H. M. GILL, Rosskeen, Invergordon, Ross-shire.

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

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

DOUGLAS MORRISON, B.Sc.(Agric.), Dip.Agric., M.S., School of Agriculture, 581 King Street, Aberdeen AB9 1UD.

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

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

G. B. R. GRAY, Smeaton, East Linton, East Lothian.

Mrs B. A. GORDON, B.Sc.(Agric.), Rosefarm, Cromarty.

JAMES MACFARLANE, Kames, East Mains, Duns, Berwickshire.

WILLIAM H. PORTER, West Scryne, Carnoustie, Angus.

DEREK RANDALL, The Miln Masters Group, Boughton, Chester.

Fifty-Third Annual General Meeting

MINUTE OF PROCEEDINGS AT THE FIFTY-THIRD 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, 18th July 1974.

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

Minute. The Minute of the 52nd Annual General Meeting, held at the Scottish Plant Breeding Station on Thursday, 26th July 1973, having been circulated prior to the meeting, was taken as read and was approved and signed.

Apologies. Apologies for absence were intimated by the Secretary.

Annual Report and Accounts. The 53rd Annual Report of the Directors embodying the audited accounts for the year ended 31st March 1974, 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 of Trustee. 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 Mr John Arbuckle, O.B.E., Barony Cottage, Newburgh, Fife, a Trustee of the Society in place of the late Sir James Denby Roberts, Bt., O.B.E., M.A., J.P.

Election to the Board of Directors. A motion by Mr G. Clapperton, Sheriffhall Mains, Dalkeith, supported by Sir David Lowe, C.B.E., D.Sc., F.R.S.E., F.R.Ag.S., Elvingston, Gladsmuir, East Lothian, was unanimously adopted to elect to the Board of Directors the following members:—

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

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

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

Douglas V. Rennie, South Belton, Dunbar, East Lothian.
G. A. Storrar, M.C., B.Sc., J.P., Rossie, Auchtermuchty, Fife.
H. A. Waterson, M.Sc., West of Scotland Agricultural College, Agronomy Department, Auchencruive, Ayr KA6 5HW.

Appointment of Auditors. On the motion of the Chairman, seconded by Mr J. Leslie Dawson, B.Sc. (S.A.I. Ltd.), West Mains of Ingliston, Newbridge, Midlothian, 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 Mr John Watson who, after many years of most helpful and constructive service as a Director of the Society, had decided to retire.

The Chairman intimated to the meeting that Mr R. J. L. Gallie had retired from the post of Secretary, and had been succeeded by Mr H. C. M. McLeod; Mr R. N. H. Whitehouse had been appointed head of the Forage Department and said he was sure that Mr Whitehouse would stimulate and encourage the staff of this department.

In his address on the Annual Report the Chairman said that he thought that the new format of the report was very good and that it gave a clear and concise picture of the work being done at the Station. 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, saying that, although it had not been a vintage year, there was some very promising material such as new varieties of blight resistant potatoes and very good barleys in the pipeline. He said that the Scottish Plant Breeding Station had no reason to fear comparison with similar institutes.

Mr Arbuckle said that he thought the Society's fourth lecture had been a great success.

Referring to the implementation of the Rothschild report, the Chairman assured fellow-Directors that they still had an important role to play in agricultural research. They had the duty to advise and support the Director of the Station and could influence the formation of future policy through the members of the various Boards of the Joint Consultative Organisation. He said that the preliminary reports, which had been a mammoth task, had been submitted by the five Boards, these would allow decisions to be made at the top level, and he hoped there would be no delay in making and implementing the decisions.

The Chairman acknowledged the Society's gratitude to the Department of Agriculture and Fisheries for Scotland for their continued support and said that The Murrays, although not yet a first-class experimental farm, was improving and would prove to be a gilt-edged investment for the Department.

Dr Simmonds then spoke on the work of the Station. He said that, of the four ARC categories of R and D (basic, strategic, applied and development), the work of the SPBS was virtually all strategic and applied, in a 50 : 50 mix which he thought productive. The strategic element was mostly cytogenetic and biochemical and he cited examples of the transition from strategic to applied, the exploitation of research findings for practical ends. Thus, Raphanobrassica and Neotuberosum work were in this state. Applied research, he said, was essential but it needed a continuing stimulus from strategic studies if it were to maintain impetus.

The application of applied and strategic research on a fifty-fifty basis created the balance necessary to run a successful plant breeding station, and one of the duties of the Director, with the support of his Board, was to maintain this balance against internal and external pressures.

Mr W. W. Gauld of the Department of Agriculture and Fisheries for Scotland, during his address to the meeting, said that the Department would continue to support the well-balanced programme of the Scottish Plant Breeding Station and, although the programme had not as yet been approved by the JCO, he was confident that this approval would be forthcoming. He also said that the Department hoped to finance the building of the new East Wing.

Mr Gauld then referred to the New Order, saying that although the system was complex, it would work provided that it did not seize-up or otherwise lose impetus and that it was given the proper support.

Mr Gauld said that the Scottish Society for Research in Plant Breeding should be congratulated on having Mr J. Arbuckle as its Chairman and Dr N. W. Simmonds as the Director, and he was sure that under their guidance the Station would continue to flourish.

Mr A. Pattullo then moved a vote of thanks to the Chairman and the meeting was closed.

Staff

The following appointments were made during the year:

SSO	R. L. Wastie, M.A., Ph.D.
Photographer	Mrs J. Sutherland
ASO	W. M. M. Eddie D. M. Farrer Miss K. W. Fraser

	Miss D. Gemmell
	R. S. Hird
	K. Ireson
	Mrs A. E. Leakey, B.Sc.
	Miss S. Mann
	Miss J. E. Middlefell
	Miss D. C. Page
	Miss H. E. Templeton
	Miss L. Thomson
	Mrs A. M. Watt, B.Sc.
	Miss L. A. Wilson
	Miss E. A. Young
LA	Miss F. M. Bruce
Experimental Workers	Mrs S. Bell
	R. Bruce
	Mrs M. H. McGuigan
	Mrs M. H. Tulloch
Field and Works	J. Hutchinson
	H. B. Jamieson
	A. Knox
	M. MacPartlan
	Mrs J. Turner
	W. Wilson
The Murrays	D. Ritchie
Administration	P. P. Bonnington
	Mrs M. M. Inglis
	Mrs E. K. Walley

The following staff left employment:—

HSO	D. A. Couzin, B.Sc., Ph.D.
	Mrs R. J. Low, B.Sc.
ASO	R. J. Begbie
	J. R. Curran
	Miss R. E. Edwards
	Miss K. M. Howe

	I. L. Howie, B.Sc.
	Miss E. A. Purves, H.N.C.
	Miss L. Thomson
	Mrs P. A. Toulin
	Miss J. D. Watt
Field and Works	S. Pirie
	G. D. Williams
Administration	Mrs D. M. Smith

Three members of staff made visits abroad during the year with the aid of travel grants from ARC. Dr J. H. W. Holden and Dr F. J. W. England attended the seventh Eucarpia Congress, on the theme of Heterosis, in Budapest, 24th-29th June 1974. Dr England read a paper on hybrid forage grasses. Dr I. H. McNaughton visited government and commercial plant breeding institutes in Sweden, Denmark, West Germany and The Netherlands, 15th-30th October 1974.

Dr Holden attended, and read a paper at a meeting of the Agronomy Section of the European Association for Potato Research (EAPR) at Arlon, Belgium, 9th-11th September 1974. The theme was " Improving the competitive position of the potato crop ". Miss R. M. Solomon attended a course on the identification of plant viruses at the Agricultural University, Wageningen, 20th January-28th February 1975.

Members of staff attended a number of meetings and conferences, formal and informal, within the UK during the year. Among them were the EAPR Pathology section meeting in Dundee, 19th-23rd March 1974, and the PMB conference on " Efficient potato production " in Coventry, 13th-14th November 1974, both attended by Dr Holden.

The Eucarpia Brassica Breeders' Conference, held at Scottish Horticultural Research Institute, Dundee, on 24th-27th September 1974, was attended by Mr R. N. H. Whitehouse, Dr I. H. McNaughton, Dr S. Gowers, Mr G. R. Mackay, Miss I. K. Munro and Miss C. L. Snell. Dr Gowers and Mr Mackay read papers, and a large party from the conference visited The Murrays after the meeting to see our Brassica work there.

Mr Fyfe again acted as external examiner for the M.Sc. course in agricultural botany at the University College of Wales, Aberystwyth. Dr Holden again, in February and March 1975, gave a course on " Genetics and plant breeding " to the fourth year honours botany class in the University of Edinburgh.

The Director gave six lectures/seminars to various audiences during the year. He continued to serve on SADC, on several committees connected with Research Councils' computing affairs, on the JCO Potato Committee, on the Potato Marketing Board Research and Development Committee, and on the Forestry Commission Research Advisory Committee. He visited Guyana and Barbados in November-December 1974 in connexion with sugar cane breeding, and was reappointed consultant to the Rubber Research Institute of Malaysia.

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.

One visitor made a more prolonged stay. Dr D. H. B. Sparrow of the Waite Institute, Adelaide, worked at the Station for three months, 3rd February-30th April, 1975. His visit was assisted by a grant from the Royal Society, Commonwealth Bursaries Scheme. Dr Sparrow, who is a barley breeder, was developing computer programs for canonical analysis of breeding data and management of breeding programmes.

10. PUBLICATIONS

ALLISON, M. J., ELLIS, R. P., and SWANSTON, J. S. (1974). Tissue distribution of α-amylase and phosphorylase in developing barley grain. *Journal of the Institute of Brewing*, **80**, 488–91.

ALLISON, M. J., and SWANSTON, J. S. (1974). Relationships between β-amylase polymorphisms in developing, mature and germinating grains of barley. *Journal of the Institute of Brewing*, **80**, 285–91.

CARROLL, C. P. (1975). The inheritance and expression of sterility in hybrids of dihaploid and cultivated diploid potatoes. *Genetica*, **45**, 149–62.

ENGLAND, F. (1974). A general approximate method for fitting additive and specific combining abilities to the diallel cross with unequal numbers of observations in the cells. *Theoretical and applied Genetics*, **44**, 378–80.

ENGLAND, F. (1975). Heritabilities and genetic correlations for yield in Italian ryegrass (*Lolium multiflorum* Lam) grown at different densities. *Journal of agricultural Science*, **84**, 153–58.

FYFE, J. L. (1974). A procedure for computer simulation of linkage with interference. *Theoretical and applied Genetics*, **44**, 270–71.

GILES, R. J., MCCONNELL, Gillian and FYFE, J. L. (1974). The frequency of natural cross-fertilization in a composite cross of barley grown in Scotland. *Journal of agricultural Science*, **83**, 447–50.

GOWERS, S. (1974). The production of F_1 swedes (*Brassica napus* ssp *rapifera*) by the utilisation of self-incompatibility. *Euphytica*, **23**, 205–8.

HOLDEN, J. H. W. (1974). Three new early potatoes from Pentlandfield. *Journal of the Royal Horticultural Society*, **99**, 109–13.

MCCONNELL, Gillian and FYFE, J. L. (1975). Mixed selfing and random mating with polysomic inheritance. *Heredity*, **34**, 271–72.

SIMMONDS, N. W. (1974). Costs and benefits of an agricultural research institute. *R & D Management*, **5**, 23–28.

SIMMONDS, N. W. (1974). Dry matter content of potatoes in relation to country of origin. *Potato Research*, **17**, 178–86.

Other papers by staff:

MEGGINSON, Fiona G. A., and PERSON, C. O. (1974). Somatic recombination in *Ustilago hordei* during the parasitic phase on barley. *Canadian Journal of Genetics and Cytology*, **16**, 851–55.

WILLIAMSON, Cynthia J., and BURCHILL, R. T. (1974). The perennation and control of pear scab (*Venturia pirina* Aderh.). *Plant Pathology*, **23**, 67–73.

11. ABSTRACT OF ACCOUNTS

ABSTRACT OF ACCOUNTS

For Year ended 31st March 1975

INCOME

1974			
£259	Sales of Produce		£494
191	Sale of Vehicle		—
139	Annual Subscriptions		118
316	Rents received		307
£905	*Total Ordinary Income*		£919
342,500	Maintenance grant from Department of Agriculture and Fisheries for Scotland—	£454,000	
	Less Appropriation from unexpended maintenance grants for previous years	600	
			453,400
£343,405	*Total Income*		£454,319
	Department of Agriculture and Fisheries for Scotland—		
23,885	Capital Grants—The Murrays Farm	£2,037	
8,253	Unexpended maintenance grants brought forward at 1st April 1974	15,582	
			17,619
£375,543			£471,938

EXPENDITURE

1974			
	Salaries:—		
£155,365	Scientific and Technical Staff	£215,106	
17,154	Administrative and Clerical Staff	19,701	
7,683	Pensions and Supplementation	7,634	
£180,202			£242,441
14,967	Superannuation		19,993
38,346	Wages		56,477
11,744	National Insurance and Graduated Contributions		18,244
8,765	Apparatus and Equipment		10,808
16,297	Chemicals and Materials		18,594
6,109	Travel and Subsistence		6,876
4,571	Rates and Rents		5,034
10,805	Power, Heat and Light		16,022
996	Library Books and Periodicals		787
4,442	Stationery, Postages and Telephones		6,213
1,055	Printing and Binding		1,284
—	Vehicles—Purchased £3,716		
3,768	Maintenance 5,917		9,633
385	Audit and Legal Expenses		1,198
2,218	Property Repairs		2,983
2,277	Property Alterations		—
690	Trial Centres		585
2,219	Edinburgh Centre of Rural Economy		2,790
4,143	Repairs and Servicing		6,531
661	Seed Testing		820
261	Transport		112
382	Staff Training		250
2,320	Advertising		1,842
367	Furniture and Fittings		1,188
827	Hire Charges and Rentals		1,265
35	Land improvement		409
16,190	The Murrays Farm—net operating costs		20,066
1,034	Miscellaneous		1,811
£336,076			£454,256
23,885	The Murrays Farm—improvements		2,037
15,582	Department of Agriculture and Fisheries for Scotland—unexpended maintenance grants carried forward on 31st March 1975		15,645
£375,543			£471,938

BALANCE SHEET

as at 31st March 1975

1974			
	I Funds—		
£443,446	1. Balance brought forward as at 1st April 1974	£466,406	
—	*Add:* Adjustments in respect of previous years	1,128	
	Grants received from Dept. of Agriculture and Fisheries for Scotland during year to date:—		
13,534	Capital Works	38,924	
9,426	Capital Equipment	18,669	
£466,406			£525,127
	II Current Liabilities:—		
926	1. Sundry Creditors	£3,089	
	2. Dept. of Agriculture and Fisheries for Scotland:—		
15,582	Unexpended Maintenance Grants	15,645	
			18,734
£482,914			£543,861

1974		Cost	Less Charged to Revenue	Nett
	I Fixed Assets:—			
£412,033	1. Heritable Property	£452,088	—	£452,088
53,871	2. Capital Equipment	72,550	—	72,550
£465,904		£524,638	—	£524,638
26,175	3. Implements and Tools	31,432	£31,432	
7,314	4. Vehicles	11,102	11,102	
55,119	5. Laboratory Apparatus	60,670	60,670	
13,489	6. Furniture and Fittings	14,677	14,677	
9,156	7. Library Books	9,943	9,943	
£577,157		£652,462	£127,824	£524,638
111,253	*Less:* Charged to Revenue to 31st March 1974			
£465,904				
	II Current Assets:—			
110	1. Sundry Debtors		£5,817	
16,900	2. Cash and Bank Balances		13,406	
				19,223
£482,914				£543,861

Edinburgh, *26th May, 1975.*—The undersigned, having had access to all the Books and Accounts of the Society and having examined the foregoing Statement of Accounts and verified the same with the Accounts and Vouchers relating thereto, now sign the same and 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 1975

1973/74	*Income*		
	Balances brought forward at 1st April 1974:—		
£11,565	Investments 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	
			£14,413
959	Dividends and Interest (gross)		1,016
50	Donations		50
60	Life Subscriptions		60
613	Profit on Sale of Investment		—
£14,718			£15,539

1973/74	*Expenditure*		
£75	SSRPB Lecture		£85
10	Retirement Gratuities		75
7	Insurance		—
121	Hospitality		133
3	Friendly Society Fee		3
58	Travelling Grants and Expenditure		146
—	Donation to Bawden Memorial Trust		52
31	Bank Fees and Charges		59
	Balances carried forward at 31st March 1975:—		
13,065	Investments (see Appendix) at Cost	£13,565	
290	Recoverable Income Tax	324	
65	Due from Bank of Scotland	—	
696	Cash in Bank—Current Account	269	
297	Savings Account	836	
		£14,994	
—	*Less:* Due to Bank of Scotland	8	
			14,986
£14,718			£15,539

W. J. REID AND JAMES MUNRO BEQUESTS

1973/74	*Income*		
	Balances brought forward at 1st April 1974:—		
£1,990	Investments at cost	£2,216	
42	Recoverable Income Tax	41	
235	Cash in Bank—Current Account	135	
			£2,392
130	Dividends and Interest (gross)		148
£2,397			£2,540

1973/74	*Expenditure*		
£5	Bank Fees and Charges		£7
	Balances carried forward at 31st March 1975:—		
2,216	Investments (see Appendix) at Cost	£2,216	
41	Recoverable Income Tax	48	
135	Cash in Bank—Current Account	20	
—	Savings Account	250	
		£2,534	
—	*Less:* Due to Bank of Scotland	1	
			2,533
£2,397			£2,540

DR. WILSON MEMORIAL FUND

1973/74	*Income*		
	Balances brought forward at 1st Aril 1974:—		
£566	Investments at cost	£566	
12	Recoverable Income Tax	10	
40	Cash in Bank—Current Account	74	
			£650
33	Dividends and Interest (gross)		34
£651			£684

1973/74	*Expenditure*		
£1	Bank Fees and Charges		£2
	Balances carried forward at 31st March 1975:—		
566	Investments (see Appendix) at Cost	£566	
10	Recoverable Income Tax	11	
74	Cash in Bank—Current Account	25	
—	Savings Account	80	
			682
£651			£684

J. C. THYNE BEQUEST

1973/74	*Income*	
—	Bequest from J. C. Thyne Trust	£2,119
—	Interest (gross)	108
—		£2,227

1973/74	*Expenditure*	
—	Balances carried forward at 31st March 1975:—	
—	Investment (see Appendix) at cost	£2,100
—	Recoverable Income Tax	24
—	Cash in Bank—Current Account	10
—	Savings Account	93
—		£2,227

APPENDIX

INVESTMENTS AS AT 31st MARCH 1975

Life Membership Subscriptions and Donations Fund

Book Value	Nominal Value		Gross Interest Dividends for Year to Date	Middle Price as at Date	Market Value as at Date
£1,508·39	£1,581·40	6½% Funding Stock 1985/87	£102·80	£69%	£1,091·17
1,099·96	1,153·00	Stirling County Council 7¾% Loan 1977/79	89·36	£82%	945·46
2,253·58	2,359·35	8¾% Treasury Loan 1997	206·44	£67½%	1,592·56
2,665·37	3,116·40	8½% Treasury Loan 1980/82	237·86	£90%	2,804·76
607·45	82·75	Guardian Royal Exchange Assurance Co. 331 Ordinary 25p shares	36·31	145p	479·95
864·09	495·00	National Commercial Banking Group 1980 Ordinary 25p shares	59·35	54½p	1,079·10
1,372·87	86·25	Shell Transport & Trading Co. Ltd. 345 Ordinary 25p shares	59·87	225p	776·25
608·82	345·00	Imperial Chemical Industries Ltd. 345 Ordinary Stock Units	57·05	215p	741·75
794·57	710·00	Claverhouse Investment Trust Ltd. 1,420 Ordinary 50p shares	55·10	41p	582·20
1,498·89	41·50	London & Manchester Assurance Co. Ltd. 830 Ordinary 5p shares	52·51	100p	830·00
290·99	290·25	Imperial Group 1,161 Ordinary 25p shares	30·33	58p	673·38
£13,564·98			£986·98		£11,596·58
	—	Bank of Scotland—"B" Savings Account Interest	29·42	—	—
£13,564·98			£1,016·40		£11,596·58

W. J. Reid and James Munro Bequests

Book Value	Nominal Value		Gross Interest Dividends for Year to Date	Middle Price as at Date	Market Value as at Date
£1,333·85	£1,359·29	6½ Funding Stock 1985/87	£88·36	£69%	£937·91
199·70	208·00	Stirling County Council 7¾% Loan 1977/79	16·12	£82%	170·56
517·45	430·00	English and International Trust Ltd. 7% Convertible Stock 1986	30·10	£85%	365·50
165·59	80·00	Imperial Chemical Industries Ltd. 80 Ordinary £1 Stock Units	13·22	215p	172·00
£2,216·59			£147·80		£1,645·97

Dr Wilson Memorial Fund

Book Value	Nominal Value		Gross Interest Dividends for Year to Date	Middle Price as at Date	Market Value as at Date
£265·77	£276·60	6½% Funding Stock 1985/87	£17·98	£69%	£190·85
102·40	70·00	English and International Trust Ltd. 7% Convertible Stock 1986	4·90	£85%	59·50
198·24	26·75	Guardian Royal Exchange Assurance Co. 107 Ordinary 25p shares	11·73	145p	155·15
£566·41			£34·61		£405·50

J. C. Thyne Trust

Book Value	Nominal Value		Gross Interest Dividends for Year to Date	Middle Price as at Date	Market Value as at Date
£2,100·00	£2,100·00	City of Birmingham Bonds (1 year) 13%	£73·79	£100½%	£2,110·50
—	—	Bank of Scotland—"E" Savings Account Interest	34·56	—	—
£2,100·00			£108·35		£2,110·50
£18,447·98		TOTALS	£1,307·16 (7·09% on invested capital)		£15,758·55

12. 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