# THE SCOTTISH HORTICULTURAL RESEARCH INSTITUTE

# NINTH

# ANNUAL REPORT



1961 - 1962

(April 1961 — March 1962)

MYLNEFIELD, INVERGOWRIE, DUNDEE
*Tel:* INVERGOWRIE 441

WEST OF SCOTLAND UNIT
AUCHINCRUIVE, AYR
*Tel:* ANNBANK 293

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PHOTOGRAPH BY J. SUNDERLAND

A view of the Glasshouse Unit at Mylnefield from the roof of the main laboratories.

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# THE SCOTTISH HORTICULTURAL RESEARCH INSTITUTE

*The Scottish Horticultural Research Institute was incorporated on 31st March, 1953, as a company limited by guarantee without share capital. The business of the Institute is managed by a Governing Body, the members of which are appointed by the Secretary of State for Scotland. The registered office is at Mylnefield, Invergowrie, Dundee. A West of Scotland Unit is located at Auchincruive, Ayr.*

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† Honorary Lecturer in the University of Glasgow.

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# THE DIRECTOR'S REPORT

For reasons of weather which are mentioned in detail elsewhere in this Report, 1961 was a most difficult year both for the outdoor work of the Institute and for financial administration. Spring frosts had a disastrous effect upon income, and the persistent rain from early July onwards made the costs of cultivation and harvesting unduly high. The position was rendered still more difficult by an unexpected cut in our maintenance grant.

In June the Institute received an A.R.C. Visiting Group under the chairmanship of Professor Alexander Robertson. This was the second such occasion since our foundation. At the time of the first one, six years previously, developments here were in their infancy, but we are now firmly established and policy and plans for the future can be envisaged more precisely. The main disappointment of the Group's visit was its unwillingness to recommend the formation of a Chemistry Department. The proposal for this will be reconsidered after a further five or six years; but until then the lack of this essential scientific discipline will undoubtedly retard progress, particularly in physiology where we are breaking new ground in connection with environmental effects on the development of plant growth-regulating substances. On the other hand the Group recommended that the Institute should be allowed to purchase for its virology investigations a new electron microscope, a U.V. spectrophotometer and the equipment necessary for fluorescence microscopy. We appreciate very much this powerful backing, for although we are recognized leaders in this field it is also true that we are a relatively small unit.

An unexpected recommendation of the Group concerns the future of the Institute's strawberry breeding work, conducted under Mr. R. D. Reid at the West of Scotland Unit at Auchincruive, Ayr. Mr. Reid and his staff have pioneered the breeding of strawberries for resistance to red core root rot and have in recent years provided the industry with the varieties Auchincruive Climax, Talisman and Redgauntlet. Looking to the future, however, the Group felt that this small unit was suffering from scientific isolation, and recommended that all the scientific officers of the Institute should be concentrated at Mylnefield and the Auchincruive facilities maintained as a field station. The Institute's Staff and Research Committee subsequently discussed with great care both this proposal and the alternative course of increasing the number of scientific officers at Auchincruive. It finally decided to implement the Group's recommendation, provided however that this is not done precipitately or before suitable additional laboratory and glasshouse facilities have been provided at Mylnefield.

It is appropriate at this point to refer to two notable honours which were conferred upon Mr. R. D. Reid during the year, in recognition of his outstanding contribution to the strawberry growing industry during nearly thirty years of work in plant breeding. Her Majesty the Queen in her Birthday Honours List bestowed upon Mr. Reid the honour of Officer of the Order of the British Empire; and in February the University of Glasgow announced that it had awarded him its honorary degree of Master of Science. It is a pleasure to

all of us to congratulate Mr. Reid upon these tributes to meritorious achievement in his chosen field of work.

A development of potential value to the future work of the Institute was the introduction in Scotland during 1961 of the new scientific journal 'Horticultural Research', the first number of which appeared in November. Although this venture is closely associated with certain of the Institute's own senior staff, the journal will be available to serve as an English-language medium of publication for research findings in horticulture from centres anywhere in the world. It will seek to maintain a balance between the more basic and the more practical types of research contribution and will aim to publish from time to time review papers by workers of international repute in various fields of horticultural science. The Director of the Institute is Chairman of the editorial board, and the editorship is shared by Dr. C. A. Wood (Head of the Institute's Pomology Department) and Professor W. W. Fletcher, until recently Head of the Botany Department of The West of Scotland Agricultural College. The journal is owned and published by Messrs. Oliver and Boyd Ltd., of Edinburgh and London.

The present time—the farming year of 1961-62—is a turning point in the Institute's use of its land. Hitherto more than half of the land has been under ordinary agricultural cropping, pending its use for field experiments, but from now onwards the staff will be using more than half of the total acreage for experiments. It will now be only a few years before two-thirds of all the available land is under planned experiments, leaving a reserve of about 70 acres which will be brought into the same use as a similar area is released.

## RESEARCH PROGRESS

In the year of an A.R.C. Visiting Group a considerable part of the effort of the research staff was naturally directed to the consolidation of appropriate current work and the preparation and discussion of future programmes. Against this background the general activity of the Institute went forward and useful progress was maintained.

The Mycology Department confirmed that infection of the opening flower-buds of strawberry by *Botrytis cinerea* can result in the establishment of a latent mycelium in the very young developing fruits, and that this can afterwards cause rotting of the berries as they ripen. These findings, and the further discovery that the same pattern of infection is even more prevalent in raspberries, may explain the inadequacy of present spraying and dusting programmes used against grey mould disease, and should help to make possible the development of improved control measures.

Of equal importance is the demonstration that spores of *B. cinerea* can be drawn into the ends of the xylem vessels in the petiole stubs when tomato plants are de-leafed, and can there give rise to latent mycelium which is apparently capable of rapid development when the plants become susceptible at a later stage of growth. This finding suggests that the generally accepted view that infection of tomato stems by the grey mould fungus is largely dependent upon high humidity (consequent upon poor ventilation) may not be entirely true, and that control measures, again, will have to be reconsidered.

The maintenance of supplies of cabbage for market throughout the winter is notoriously difficult, because even the hardiest varieties are frequently

damaged by frost. The Vegetable Crops Department has shown that in Scotland certain types of cabbage can be cut in November and stored in clamps until required. The produce from several acres has now been treated in this way at Mylnefield in two successive years, with results which are highly encouraging. In the winter of 1961/62 the clamped crop made a handsome profit in face of the scarcity of fresh vegetables. There now seems little doubt that cabbages for storing in clamps could be a useful crop in Scotland.

The Genetics Department has been able during the past year to report a considerable improvement in its ability to carry out cytological examinations of the small chromosomes of fruit plants, thanks to the installation and use of a phase-contrast microscope.

The Physiology Department continued its work on the production of parthenocarpic strawberry fruits through the application of growth substance treatments. It also reports the inhibition of flower initiation in apple, without obvious bud abnormality, as a result of treatment with gibberellic acid.

**STAFF**

Dr. C. H. Cadman was promoted to Senior Principal Scientific Officer on merit as from July 1961. Mr. H. J. V. Gledhill, a graduate of Glasgow University, was appointed as Scientific Officer to a newly created post in the Vegetable Crops Department. Mr. M. M. Anderson (Pomology Department) was appointed to the new post of Fruit Trials Officer and Senior Recorder, and Mr. W. Fordyce was promoted to the Experimental Officer vacancy which this change created. Mrs. J. A. Myles (Genetics), Miss K. S. Forbes (Mycology) and Mr. E. D. McCabe (Laboratory Service) resigned their appointments as Scientific Assistants and were replaced respectively by Miss H. Campbell, Mr. H. M. Wilson and Mr. J. S. Lornie.

Miss E. H. Prain (Pomology), Miss R. N. Macdonald (Physiology) and Miss A. M. Jobbins (West of Scotland Unit), all Scientific Assistants, married and became respectively Mrs. Haughey, Mrs. Smith and Mrs. Millar. All three are continuing in their posts. Miss P. A. Duncan (Assistant Experimental Officer, Virology) left to be married, and Mrs. F. W. Gow (Administration) resigned and was succeeded by Miss J. McLeish.

In March 1962 Dr. G. M. L. Haskell was awarded the degree of Doctor of Science of the University of London for his work in the fields of genetics and plant breeding during the years 1942-1962; and in January Mr. P. A. Thompson was awarded the degree of Master of Science of the University of London for a thesis entitled 'Studies of the effect of applications of maleic hydrazide on growth and reproduction in the cultivated strawberry'.

Also in January, Mr. L. S. Gray became Vice-President of the Dundee branch of the National Farmers' Union of Scotland.

Mr. R. J. Stephens was appointed to the Horticultural sub-Committee of the British Weed Control Council's Herbicide Recommendations Committee. Dr. Wood served as an Examiner in the Royal Horticultural Society's Final Examination for the National Diploma in Horticulture.

**VISITS ABROAD**

Mr. P. A. Thompson was awarded an O.E.E.C. Senior Visiting Fellowship to work for two months under Dr. J. P. Nitsch at the Laboratoire

du Phytotron, Centre Nationale de Recherche Scientifique, Gif-sur-Yvette, France. There he studied the methods of plant growth-hormone assay used by Dr. Nitsch, which will be adapted for use at Mylnefield. Dr. A. R. Wilson in April attended a Council meeting of the European Association for Potato Research at Wageningen, Netherlands, and took the opportunity that this provided of visiting fellow-mycologists at the Institute for Phytopathological Research (I.P.O.). Dr. C. North obtained an A.R.C. overseas travel grant to visit research stations and horticultural centres in Belgium, Holland, Italy and France: in this tour the emphasis was placed on centres where vegetable breeding was in progress, particularly where it was closely linked with the canning and freezing of vegetables.

One valuable sequel of the Symposium on Soil-borne Viruses held at Mylnefield in the summer of 1960 was an invitation to the Institute to send one of its staff to occupy a research post in the Agricultural Experiment Station of the University of California, at Davis. The work to be undertaken was a study of nematodes as vectors of soil-borne viruses. Dr. C. E. Taylor was offered this opportunity and left to take up the post at the beginning of May, 1962. He is due to return here in May 1963. The Institute is exceedingly grateful to the University of California, and in particular to Dr. D. J. Raski, for the offer of this visit and for the substantial dollar grant which made it possible.

### OVERSEAS VISITORS

Special mention must be made of a three-day stay spent at the Institute in September by a party of three visitors from the Soviet Union, accompanied by a Russian official interpreter and a second one provided by the British Council. With only one interpreter very little would have been accomplished. A major criticism of the official arrangements made to receive these visitors is the scant information we had of their individual interests. One of the two working scientists, Dr. S. N. Stepanov, was the Director of a Plant Breeding Institute, and the other, Mr. D. D. Kovalenko, was primarily interested in agricultural machinery and cultivation procedures. To make the best use of the available time our arrangements to show the party round as a group had to be reorganized at very short notice, and it was here that the two interpreters were so useful. The visitors were particularly interested in the production of soft fruit stocks of high health status and in our certification procedures, and spent one day of their visit in viewing the commercial production of certified raspberries, strawberries and black currants on neighbouring farms.

Dr. G. Barabino, of the Institute of Plant Pathology, University of Milan, came to the Virology Department for almost the whole of the year to work on problems of viruses affecting grape vines. Mr. C. J. Asjes (Netherlands) and Mrs. E. Tapio (Finland) worked in the same department for periods of some weeks. The Institute was also glad to welcome as visitors Mr. Salim Amir (Sudan), Mr. Lloyd Spangelo (Ottawa), Professor P. Chouard with a party of other visitors from France, Professor Säkö (Finland), Mr. E. Kvaale (Norway), Dr. Misić (Yugoslavia), Dr. Sanger (Germany), Dr. Bovey (Switzerland), Dr. Kristensen and Mr. B. Jacobsen (Denmark), Mr. van der Meer (Netherlands), Dr. Rejman (Poland), Professor Sen (Calcutta) and Dr. Schmelzer (Germany).

Dr. Breakey, of the Washington State University, U.S.A., and Mrs. Breakey, based themselves at the Institute for a period of work and travel during the summer.

The number of visitors, particularly those coming as organized parties of fruit-growers and others, continues to increase, and although the appointment of someone with special responsibility to receive them and show them round may not yet be justified, the reception of these guests—welcome though they always are—now takes up a considerable amount of time of the research staff.

OTHER ACTIVITIES

The Royal Society of London invited Dr. Cadman to contribute a short paper at a symposium on 'Mechanisms of Virus Infection', which took place in London on 2 November. At a meeting mainly of medical scientists Dr. Cadman was able to present such knowledge as is available for plant viruses. Lectures to scientific societies, advisory officers' meetings and similar bodies were given during the year by most of the senior members of staff, and the Director and others also addressed Growers' Conferences and local meetings of horticulturists.

A highly successful Open Day for fruit-growers was held on 22 July. The weather was much better than had prevailed on corresponding occasions for at least two years, and there was an attendance of more than 150 visitors.

Dr. North and Mr. L. H. Frith judged the commercial vegetable exhibits at the Royal Caledonian Horticultural Society's Autumn Show at Edinburgh on 6-8 September. An exhibit to demonstrate the growing and clamping of winter cabbage was staged at the Scottish Food Exhibition held at Dundee on 4-5 April, and a stand displaying a large range of unusual vegetables grown at Mylnefield was exhibited at the Dundee Horticultural Society's annual Flower Show on 1-2 September.

ACKNOWLEDGMENTS

Gifts of chemicals for experimental use as herbicides, fungicides, nematicides or plant growth substances continued to be received by the Institute, as well as gifts of seeds and plants. It is now impracticable to list these in full, but some are mentioned in the departmental reports which follow and we endeavour to make due acknowledgment whenever donated materials are named in research publications. We thank all who again assisted the Institute's work in this way.

Grateful acknowledgment is also made of a further gift of £25 from Scottish Agricultural Industries Ltd., in support of staff amenities.

For providing land or other facilities for experimental work we are indebted to Sir James Denby Roberts, Bt., Mr. T. R. Dale, Colonel A. S. Nelson, Messrs. R. Niven and Son, Mr. W. D. Soutar, Messrs. J. & A. Henderson, Ltd., and Messrs. John Morrell and Co. Ltd. Most departments at Mylnefield again benefited from the advice and assistance so readily provided by the A.R.C. Unit of Statistics at Aberdeen, and fruitful collaboration continued with several other research stations and organizations in the United Kingdom and with many individual scientists at home and overseas. The staff of the Chief Surveyor of the Department of Agriculture and Fisheries for Scotland again reproduced the year's plan of experimental plantations at Mylnefield (see pp. 44-45).

Finally, acknowledgment is due to Dr. Wood, Mr. Jennings and Dr. Taylor for undertaking the editorial work connected with this Report.

# FARM, PLANTATIONS AND GLASSHOUSES

L. S. GRAY

Apart from a short period in the spring, weather conditions during the 1961 season were mainly unfavourable. Late frosts in April, May and June caused widespread damage to fruit blossom, and a wet autumn provided difficult harvesting conditions for most farm crops. Winter came early, with severe frosts and two snowstorms in December.

Outdoor work went forward well in the spring, and although the remainder of the season was largely cool and wet the yields of hay and grain crops were at least up to average. Carrots were grown on a field scale for the first time, using the 'bed' method. Management was easy prior to harvest, but at that point considerably more hand labour was required than for lifting potatoes. Yields, however, were excellent, averaging more than 13 tons of canning carrots and 2 tons of ware per acre. The potato crop itself escaped spring frost damage and gave a satisfactory yield of large, good-quality tubers; but sugar beet was disappointing, with a yield of only 11·35 tons per acre and a sugar content of 14·53 per cent. All root crops had been harvested and some ploughing done by the end of November. Livestock policy remained unchanged, and 52 bullocks were fattened and sold during the year.

Soft fruit crops were considerably reduced by frost damage. The losses of yield were estimated at 50 per cent. in strawberries and 20 per cent. in raspberries. The actual sales were 9½ tons of strawberries and 29½ tons of raspberries, together with about 5 tons of black currants. Compared with 1960, the output of soft fruit was lower by about 25 per cent. Top fruit also suffered badly: plums and apples were much reduced in quantity and to some extent in quality, and the gales in September increased the losses. Somewhat better prices, notably for raspberries, helped to redress the income position.

Brussels sprouts were again the main vegetable crop. Four tons of these were sold, together with lesser quantities of other vegetables. A small area was planted with cabbage for further studies on clamp storage (see p. 31).

A crop of tomatoes (partly from a variety trial) was again produced in the glasshouse unit at Carselea. New constructional work in the main glasshouse area at Mylnefield included the erection of a second propagating house and a special structure for vegetable pollination work, and a start was made on the erection of a small heated glasshouse for herbicide studies. The volume of work connected with the glasshouses remained about the same as in recent years.

During periods of adverse weather several small but useful improvements were made in the farm buildings area by our own farm and plantations staff. This work included the construction of a small chemical store and a small room to rehouse the heat-therapy equipment of the Virology Department.

# POMOLOGY

C. A. WOOD

Fruit crops in 1961 suffered chiefly by spring frosts and high winds. The growing season was quite remarkable for the sustained prevalence of wind, which damaged raspberry plantations in spring and summer and culminated in September and October gales which depleted the orchard crops and caused damage and losses among trees. After early mild weather in February which accelerated spring growth, very harmful frosts occurred on several nights in April, May and June.

The periods of picking of standard soft fruit varieties were from 26 June to 26 July for strawberries and from 3 July to 14 August for raspberries. The black currant crop came largely from breeding material, the picking dates of which varied widely and are not of general interest.

Four lines of work continue to form the main programme of this department. These are fruit breeding (in raspberries and currants), the study of cultural factors affecting the performance of raspberry plantations, the action and practical use of chemical weedkillers, and the performance of apple varieties and rootstocks. In addition, collections of soft fruit varieties and tree fruits are maintained and we participate in the regional work of the Scottish Fruit Trials.

I was re-appointed during the year a member of the Scottish Fruit Trials Committee, and Mr. M. M. Anderson was appointed to the Institute post of Fruit Trials Officer and Senior Recorder. Mr. G. G. Hutchison joined the staff as a Scientific Assistant.

## RASPBERRY BREEDING

The general objective of the raspberry breeding work is to combine the high cropping capacity shown by such varieties as Malling Promise and Malling Jewel with improved features of quality, particularly those of good fruit texture and size, and with disease resistance. Selection for fruit quality was made difficult in 1961 by frost damage, but in general the seedlings which had been selected in 1960 again showed reasonably good quality: they were all inferior, however, in either flavour or productivity. Most of the breeding work is now concerned with families derived from crossing Malling Jewel with either Burnetholm Seedling or Baumforth's Seedling B, and the second inbred generations from these crosses were planted in early June. Possibilities of still further improvement in fruit texture are being studied in material derived from crosses between red raspberry and black raspberry (*Rubus occidentalis*), followed by backcrosses to red raspberry. The selections so far made from this material are inferior in fruit colour and flavour, and further backcrosses have been made to correct these faults.

*Differentiation of Fruiting Laterals in the Raspberry*

Several kinds of variation appear to affect the growth form of raspberry fruiting laterals. Firstly, there is variation in the ratio between the diameter

of the laterals and that of the main stem, and this has been found to be correlated with size variations in individual lateral parts. Secondly, variation occurs in the response shown to environmental factors which induce flower-bud initiation, and this appears to influence lateral length also. Thirdly, each individual lateral part is capable of independent variation. Variation of the first kind is shown by the progeny of the Malling Jewel mutant described in the 1960-61 Report. This family apparently segregates for a gene which causes an increase in the diameter of the fruiting laterals relative to that of the main stem, a reduction in the length of the laterals relative to their diameter, and an increase in the size of all flower and fruit parts. The expression of the gene in the heterozygotes appears to be so influenced by the segregation of minor genes, acting as dominance modifiers, that the variability of the lateral characters studied was much greater than in the normal (homozygous) seedlings: furthermore, variations in the effect of the gene on lateral thickness were positively correlated with variations in its effect on other characters, such as sepal size. A similar type of gene action was shown by a recessive gene which segregated in two families obtained by selfing Norfolk Giant and Baumforth's Seedling B. This gene caused an overall reduction in the growth of the seedlings in which it was present; but the reduction appeared to increase progressively with each order of branching, the growth of the main stems in the Norfolk Giant family being reduced to about 80% of that in normal seedlings, the growth of the fruiting laterals to about 67% of the normal, and the size of the seeds, which can be regarded as the ultimate branches, to about 47% of the normal. With only a slight reduction in the number of drupelets formed per fruit, the effect of this considerable decrease in the size of the individual drupelets and seeds was to give the appearance of a miniature fruit. With regard to the second form of variation mentioned, it was found that the total number of nodes differentiated along fruiting laterals could be influenced by variables which are known to affect the flower-initiating stimulus. An early onset of initiation in the terminal meristem of the lateral apparently limited the total number of nodes differentiated, thereby reducing the length of the lateral. This suggests that, under uniform conditions, observation of the number of lateral nodes present might serve to indicate the response of a plant to the autumn environment. Knowledge of the relative importance of these two postulated forms of lateral variation would help in the choice of raspberry seedlings for use as parents, particularly the parents to be used in crosses with closely related species such as *Rubus phoeniculatus* (see below), which produce undesirably excessive vegetative growth and very long, rather thin fruiting laterals.

*Disease Resistance*

Further grafts were made during the year to obtain more information on the genetics of immunity to three soil-borne viruses which affect the raspberry. Protection against these viruses is being sought by breeding for immunity from the viruses themselves, while for protection against aphid-borne viruses reliance is being placed on two major genes which confer resistance to the main insect vector concerned (*Amphorophora rubi*). A possible alternative in the latter case might again be to breed for resistance to the viruses themselves, but

an experiment designed to assess field resistance to 'veinbanding' disease in progenies derived from Norfolk Giant and Malling Exploit—two varieties known to possess direct resistance to this aphid-borne virus disease—has given so little disease-spread that progress in selection and breeding by this method would probably be exceedingly difficult. However, two years' results have now shown that the resistance of Norfolk Giant and some of its progeny may be attributed to a considerable extent to aphid resistance, conferred apparently by minor genes.

Protection against fungal diseases of the canes is being sought by selecting for cane types which appear to escape, rather than to resist, infection. Some further evidence was obtained during the year on possible factors involved in this protection, and a synopsis of a paper dealing with the subject appears below. (D. L. Jennings, B. M. Tulloch.)

*Resistance to Raspberry Beetle* (Byturus tomentosus)

An experiment was begun to investigate further some evidence that *Rubus phoeniculatus*, *R. innominatus* and *R. kuntzeanus* are resistant to raspberry beetle, and to see if resistance can be found in progenies obtained by crossing these species with the raspberry. (C. E. Taylor, D. L. Jennings.)

*Fertility in Diploid and Tetraploid Raspberries*

The fruits of many seedlings derived from crosses involving Burnetholm Seedling have shown evidence of a reduced seed-set, with a resultant reduction in the cohesion between the drupelets. Three independently segregating genes from this variety have each shown aberrant segregation ratios. Further crosses were therefore made to examine the possible causes of this and to see if the same causes could be responsible for the observed reduction in fertility. Results are available so far only for the segregation of the gene-difference *S*:*s* (spiny: non-spiny canes, and glandular: eglandular cotyledons). It was found that there was a considerable deficiency of *s* forms in the self of Burnetholm Seedling and in reciprocal crosses between this variety and parents of *ss* genotype. This suggests that in this variety the gene *s* is linked with a semi-lethal gene which reduces the viability of either the gametes or the young embryos or both. The extent of the deficiency in these crosses was affected by environmental conditions at the time of pollination, and was improved only slightly by the inclusion of seedlings from late-germinating seeds. When seedling 3B/45—a derivative of Burnetholm Seedling—was either selfed or used as the male parent in a backcross to Burnetholm Seedling, there was no significant deficiency of either phenotype in the progenies; but the *ss* genotypes tended to germinate so much earlier than the *S* forms that a 2:1 ratio was at first obtained, and this became modified to the expected 3:1 ratio only towards the end of the germination period. In this parent, therefore, the postulated linked gene affected the alternative genotype to that affected in Burnetholm Seedling, and reduced the vitality rather than the viability of the zygotes. The reasons for these differences are not understood.

It was stated in the 1960-61 Report that seed-set in tetraploid raspberries appeared not to be related to the viability of their pollen. Some further crosses have shown that the ploidy and genotype of the pollen used can

greatly influence the numbers of seeds set, however, and that the results are markedly affected by the direction in which crosses are made. The best pollen parent and the best direction of crossing for the tetraploid of the East Malling Seedling 69/139 were not the same as for the tetraploid of Malling Jewel. This suggests that the number of seeds set is determined by the existence of some form of balance between the embryo and either the endosperm or the maternal tissues.

*Out-of-Season Fruits*

Experiments have been done on the physiology of the raspberry with a view to expediting breeding work by the production of fruits out of season. A full year is saved if parents which are selected in the field in the summer can be used to obtain a winter crop of seed, and if the latter can then be induced to germinate in time for the seedlings to be planted in early June. The results of this work suggest that dormancy both of canes and of seeds is caused at first by the presence of a growth inhibitor, and later by an insufficient supply of a growth promoter. The postulated inhibitor appeared to be lost from canes which were left outside until about mid-December, while in seeds it was apparently lost or much reduced during six weeks of moist chilling, provided that the seeds were first given an appropriate pre-treatment with chemicals such as concentrated sulphuric acid or the hypochlorites of sodium or calcium. The efficiency of the hypochlorite treatments was considerably improved by adding calcium hydroxide to the solutions. After a minimum period of moist chilling, germination was improved by adding gibberellic acid at appropriate strength, by exposure to a long photoperiod, or by prolonging the chilling treatment, but neither gibberellic acid nor a long photoperiod had any effect unless the preliminary moist chilling had been adequate. This was presumably because an inhibitor had not been removed. A similar situation appears to apply in the case of dormant canes, though the effect of long daylengths following exposure to cold has not yet been determined. The difficulty of removing the growth inhibitor postulated as being in canes has hitherto been the obstacle to the production of a winter fruit crop which would ripen early enough for the seeds to germinate in time for spring planting. Work elsewhere, however, has shown that although the inhibitor is normally formed in response to the same environments which promote flower-bud initiation (short daylengths, and mean temperatures of about 50°F), the two processes can be varied independently of each other. For example, it has been shown that fully-grown raspberry canes will initiate flower-buds in the dark at a temperature (38°F) too low to permit the onset of dormancy. When these conditions of treatment were tested at Mylnefield it was found that flowering was subsequently delayed by a prolonged production of vegetative nodes on the laterals, presumably because initiation under such conditions had occurred only slowly. If, however, the plants were kept for six weeks at an intermediate temperature (45°F) and in a 9-hour daylength, flowering was not delayed in this way and development was not impeded by the onset of dormancy. This method was used successfully for the first time during the past year, ripe fruits being harvested in January from seedlings selected and removed from

the field in August. The seeds obtained were given treatment which induced them to germinate in late March. (D. L. Jennings, B. M. Tulloch.)

### BLACK CURRANT BREEDING

The extensive range of seedling families planted out into fruiting rows in the period from 1958 to 1960 continues to form the main basis for further development of the black currant breeding programme. The material fruiting in 1961 included 43 major families, containing altogether nearly 6,000 individual bushes.

Selection was continued mainly in the large families of intervarietal black currant crosses planted in 1959, special attention being paid to the crosses involving the Finnish variety Brödtorp. The crosses between this parent and Silvergieter's Black and Baldwin cropped less well than in 1960, and only about a quarter of the seedlings selected from them in that year were reselected. Extreme variation in habit and productivity was to be seen within the families Brödtorp × Silvergieter's Black and Brödtorp × Janslunda, with the most vigorous and erect-growing seedlings almost barren and the very spreading, weak-growing types generally carrying good crops of large berries. This variation was much less evident in some other Brödtorp crosses.

Eight crosses between species within the *Eucoreosma* sub-genus of *Ribes* (see 1960-61 Report) fruited for the first time, but were very unproductive. Those of Baldwin × *R. dikuscha* and Mendip Cross × *R. dikuscha* made moderately vigorous growth and contained large proportions of seedlings apparently immune from *Pseudopeziza Ribis*. Seedlings from the crosses Baldwin × *R. fuscescans*, Baldwin × *R. bracteosum* and Seabrook's Black × *R. bracteosum* were of very vigorous growth and carried long racemes with small berries. Selections from these will probably be used for breeding for improved strig length.

Nineteen new crosses were made between seedlings selected from seven families. The propagation of selections for extended trial and for use as breeding material was continued. (M. M. Anderson, W. Fordyce.)

### THE CULTIVATION OF RASPBERRIES

*Experiments planted in 1954*

The earlier series of raspberry cultural experiments, concerned with non-manurial factors, was concluded after the picking of a final crop from the experiment comparing 'stooling' and 'non-stooling' ('hedgerow') systems of row management (see 1960-61 and earlier Reports). In this experiment three varieties (Malling Promise, Lloyd George and Norfolk Giant) and two original planting distances within rows (1½ft. and 2½ft.) were combined factorially with the two management systems to give twelve treatments, which were replicated in six randomized blocks. In 1961 the stooled rows gave the higher yield in Lloyd George while the non-stooled rows led by small margins in the other varieties; but over the whole seven-year cropping period of the experiment the stooling system gave the better performance, with advantages in total yield per acre which ranged from a few hundredweights in Norfolk Giant to nearly two tons in Lloyd George. In all three varieties the treatments originally planted with canes 1½ft. apart usefully outyielded those planted at

the 2½ft. spacing. The results of this and other experiments of the series will be published in full elsewhere.

*Experiments planted since 1956*

The last Report described in some detail a large factorial experiment to compare the effects upon growth and yield of three levels each of nitrogen, phosphorus and potassium, applied annually as inorganic fertilizers, and three levels of farmyard manure applied biennially. The main effect in 1961 was again that of nitrogen, although the differences in yield at different levels of application were less marked than in previous years, probably because of general frost damage and disproportionately heavy damage by rain and wind on the better plots. A large body of information is being accumulated from this experiment as different types of season are successively encountered.

Also described last year was an experiment on six systems of soil management—a permanent straw mulch, a grass and clover cover crop and four variants of the usual clean-cultivation system—each under high and low levels of nitrogen. The variety grown is Malling Exploit. In 1961 the straw mulch system gave the highest fruit yield and the cover crop system the lowest, but the difference between these extremes was not great. However, two trends first noted in 1960 were maintained. These were that the two systems of very shallow surface cultivation showed evidence of superiority over the two which employ deeper, more conventional methods; and that the effect of the nitrogen differential continued to decrease. As would be expected, the effect of higher nitrogen remained greatest under the cover crop system. Further continuation of the experiment should show whether these trends are genuinely established.

Mention was made in the Report for 1959-60 of an experiment established in 1958 to compare eight possible ways of preparing ground manurially for raspberry planting, followed later by eight different post-planting systems of manuring. The combinations of pre- and post-planting treatments were chosen with a view to providing interesting comparisons which might point the way to profitable lines of future work—for example, on the value of green manure crops and mulches and on the effects of organic as opposed to inorganic nitrogenous fertilizers. After only three cropping seasons it is still early to draw conclusions from the results. There are suggestions of the value —under our particular soil conditions—of incorporating an annual dressing of horticultural peat along the rows, and of the usefulness of green manuring (the system used was April-sown tick beans followed by July-sown rye) as a preparatory treatment: but growth and cropping so far have been good under all the treatments, with most of the differences small.

The past three Reports have contained comments on the progress of an experiment planted in 1957 to compare the performance of virus-free raspberry stocks with that of the mildly virus-affected material released by the Institute for nuclear stock purposes prior to 1958. This experiment—which contains the varieties Lloyd George and Malling Jewel—has been a comparison not between poor and good stocks but between good and better, for the lower-grade stocks represent the best material of these two widely grown varieties that fruit-growers could obtain through the official certification schemes at

any time before the autumn of 1960. In 1961 the originally virus-free stocks again slightly outyielded the older stocks, although, as noted in the last Report, some degree of virus infection is now present throughout the experiment. In the first three cropping seasons (1958-60) the superior productivity of the healthier stocks was clearly sufficient to establish their value.

Other experiments of this series were also continued. (C. A. Wood, M. M. Anderson.)

## WEED CONTROL

### *Raspberries*

The three long-term residual herbicide experiments described in earlier Reports were continued. The trial planted in 1959 with the variety Lloyd George, to which overall applications are made each spring of simazine (2·5 lb.),[1] monuron (3·5 lb.) and mixtures of 2,4-DES (4·6 lb.) with propham (4·0 lb.) or with fenuron (0·5 lb.), was picked and recorded for the third year. Previously the control (i.e., mechanically-cultivated) plots had suffered a severe check in 1959 through a delay in hoeing, and had cropped poorly in comparison with the herbicide-treated plots. Following good cane growth in 1960, however, none of the treatments differed significantly in yield in 1961. Young suckers in the simazine-treated plots showed transient signs of damage by this herbicide in the spring, but no subsequent reduction in cane vigour was seen. The control of annual weeds was again good in the simazine- and monuron-treated plots, where hoeing was required only to control unwanted suckers between the stools. The inter-row alleyways throughout the experiment were shallowly rotavated when those in the control plots required it, but this did not result in any apparent diminution of weed control on the simazine and monuron plots. A trial with the variety Malling Jewel, to evaluate simazine (1·5 lb.), monuron (3·0 lb.), diuron (3·0 lb.), an alternation of simazine (1·5 lb.) with monuron (3·0 lb.), and a hand and mechanically cleaned control, received its first annual application of herbicides in April 1961. None of the plots were entirely weed free after July, but simazine (1·5 lb.) was superior to the other treatments. The diuron treatment resulted in a severe, though temporary, chlorosis in some of the small suckers. Crop yields recorded in 1961 showed no differences attributable to the chemical treatments. An older experiment to test mixtures containing 2,4-DES, propham, fenuron and TCA was continued in 1961 for a final year. None of the treatments gave a control of annual weeds that lasted beyond the picking season.

In a new 'screening' trial, treatments of 2,6-DBN, simazine, atrazine, prometryne, diuron, monuron and fenuron were applied at various rates and in various formulations between rows of newly planted raspberries in March. Simazine, atrazine and 2,6-DBN were applied as wettable powders and as granules. 2,6-DBN applied to the surface in either of these forms at rates below 4·0 lb. per acre, and not incorporated, failed to reduce the growth of annual weeds. Simazine and atrazine granules at 2·0 and 4·0 lb. were relatively ineffective compared with wettable powder formulations, which at 2·0 lb. or more controlled almost all annual weeds until December. Pro-

[1]Rates are given in pounds of active ingredient per acre.

metryne at 2·0, 4·0 and 6·0 lb. was as good as simazine until September, when some weeds began to grow. Diuron, fenuron and monuron, each at 4·0 lb., were all much less effective than simazine at 2·0 lb. No damage to raspberry growth was observed during the summer and autumn as a result of any of these treatments.

An experiment in which small raspberry plants raised from root cuttings, and growing in small pots of ordinary potting compost, were potted-on into turf loam containing various concentrations of simazine, demonstrated no differences in susceptibility between the varieties Lloyd George, Malling Jewel, Malling Promise and Norfolk Giant. There was little difference in the leaf symptoms produced following either an application of the simazine powder (diluted in talc) to the soil surface or the incorporation of an equivalent amount of simazine in the soil used for potting-on. Almost all the plants survived in soil containing up to 10 p.p.m. of active simazine, although severe leaf symptoms were produced.

Soil samples taken from the Malling Exploit cane nursery experiment described in previous Reports were kept under conditions suitable for weed seed germination, and weed counts were made at intervals for nine months. Larger numbers of seedlings were recorded on the samples from the control and unsuccessful herbicide treatments than on those from plots treated with simazine (1·0, 2·0 or 3·0 lb.) or monuron (3·0 lb.). (R. J. Stephens, E. H. Haughey.)

*Strawberries*

A trial planted in 1960 with Cambridge Vigour and Talisman was sprayed with herbicides in spring 1961 after a thorough cleaning by hand. The three treatments, again in rates per acre, were 1·5 lb. of simazine, 12 lb. of dacthal (dimethyl ester of tetrachloroterephthalic acid) and 10 lb. of neburon. The dacthal and neburon provided some temporary weed control, but by July all the plots treated with these two materials were infested with annual weeds (mainly annual nettle). The simazine-treated plots were still moderately clean. The crop yields showed no significant differences associated with the treatments, nor were there any signs of herbicide damage to the plants. Future applications of the treatments, beginning in autumn 1961, are to be split equally between autumn and spring.

Other herbicides were applied in autumn 1961 to a second-year plantation of the varieties Talisman, Cambridge Favourite and Redgauntlet. The treatments included simazine at 2·0 and 4·0 lb. per acre, Du Pont 326 (3-(3,4-dichlorophenyl)-l-methoxy-l-methylurea) at 2·0 lb., amiben (3-amino-2,5-dichlorobenzoic acid) at 2·0 and 4·0 lb., both as wettable powder and as granules, 2,6-DBN (2,6-dichlorobenzonitrile) at 2·0, 4·0 and 6·0 lb., and solan (N-(3-chloro-4-methylphenyl)-2 methylpentanamide) at 2·0 and 4·0 lb. Except for the Du Pont 326 and solan, which were applied after the appearance of a flush of growth of groundsel, annual meadow grass and chickweed seedlings, the treatments were sprayed onto damp soil after a shallow Dutch hoeing. Records will be kept of weed and crop growth and of crop yields. (R. J. Stephens, E. H. Haughey.)

Following preliminary trials in 1960 of diquat for the post-harvest desiccation of strawberry leaves—as an alternative to hand or mechanical defoliation—several plant desiccant chemicals were tested in August 1961 on one-year-old plots of Talisman and Redgauntlet. The materials used were diquat at 1·0 and 2·0 lb. per acre, pentachlorophenol at 9·6 lb., sodium monochloroacetate at 30 lb., 'Crestol' (a proprietory mixture containing phenols) at 8 gallons, 'Stemmex D' (a proprietory potato haulm desiccant based on dinoseb and mineral oils), and a concentrated solution of ammonium sulphate. 'Shellestol' in a proportion of up to 1% was added to the ammonium sulphate, and 'Agral 90' at up to 0·5% to the diquat sprays. Crestol and ammonium sulphate had little effect on the strawberry foliage, but the other treatments achieved varying degrees of foliage desiccation. Crown samples have been taken for examination for flower-buds by the Physiology Department, and fruit yields will be recorded in 1962. (R. J. Stephens, D. T. Mason.)

*Potatoes*

Results in 1961 again confirmed our experience that mixtures of dinoseb amine with either TCA or dalapon can be used with safety and success against annual weeds in potato crops. This was partly shown in a replicated trial with the variety Redskin, in which the following treatments were tested: dinoseb amine (3·0 lb.), dinoseb amine (6·0 lb.) + dalapon (2·5 lb.), trietazine (2·0 lb.), mechanical cultivation, and a treatment in which the rows were left completely untouched after planting and ridging. The trietazine was applied immediately after planting and the two dinoseb treatments were given at the earliest stage of crop emergence. Of the large number of other chemicals tested in screening trials at Mylnefield and at Mill of Gask, Perthshire, the materials solan (see above) and diquat were as good as dinoseb for killing weeds which had grown between planting and emergence of the potatoes, but neither was as persistent. Prometryne at 2 lb. and dinoseb amine at 6 lb. were equally effective both for immediate 'knockdown' of weeds and for residual weed control. Trietazine at 2 lb. and 4 lb., applied immediately after planting, killed almost all weeds except orache (*Atriplex patula*), which, though a minor weed elsewhere in the trials, soon covered the bare ground between the potato plants in the plots of these treatments. Dinoseb amine was almost as effective at 3 lb. as at 6 lb. Other herbicides tested, including 2,6-DBN at up to 2·0 lb., simazine at 2·0 lb. and diuron at 1·0 lb., were much less effective.

Samples of tubers from the potato herbicide trials of 1960 were sent to the laboratory of the British Food Manufacturing Industries Research Association at Leatherhead, Surrey, for taint tests, but there was again no consistent evidence of tainting associated with chemical treatments.

*Windbreaks*

A granular form of 2,6-DBN was applied on 18 April at rates of 4, 8 and 12 lb. per acre to plots in a mixed spinney of beech, sycamore, maple, Sitka spruce and Corsican pine. The trees were young and in their third growing season on the site. The area was roughly cleaned by hand and by rotary cultivation shortly before treatment, and still carried some small plants of annual meadow grass. The untreated control plots soon afterwards became

choked with creeping thistle and other weeds to a height of up to 4 feet. During the remainder of the year, however, very few weeds grew on the plots treated with 8 lb. and 12 lb. rates of 2,6-DBN, and weed growth on the 4 lb. plots was greatly reduced. No herbicide damage to the trees was seen.

*Chemical Pre-sowing Treatments*

Clean plots of ground were treated during the autumn with various rates of 2,6-DBN in the wettable powder and granular forms, and with another coded compound chemically similar to 2,6-DBN. Some of the applications were raked into the surface zone and others incorporated by rotary cultivation to a depth of about 4 inches. An attempt will be made in 1962 to grow a range of annual crops on these plots, and observations will be made on crop and weed growth throughout the season. (R. J. Stephens, E. H. Haughey.)

STRAWBERRY INVESTIGATIONS

Past Reports have mentioned an experiment planted in 1957 with Redgauntlet strawberry, in which comparisons have been made of the effects of post-harvest defoliation on three dates in August in combination with spring and autumn applications of nitrogen. This cropped for the fourth and last time in 1961. The defoliated plots had been mown on either 2, 12 or 22 August, 1960: ammonium sulphate at 2 cwt. per acre had been applied during the first week of that month to one-half of the plots mown on the first date and to one-half of the unmown control plots, and one-half of the later-mown plots were similarly treated shortly after their respective defoliation dates. The experiment received no autumn dressing of potash. In spring 1961 the plots were halved and the same half-plots as in previous years received dressings of ammonium sulphate at 2 cwt. per acre.

Inflorescence numbers in 1961 were considerably higher than in 1960, and also slightly lower on the mown plants than on the controls. The mown plots, however, cropped more heavily than the unmown, and inflorescence numbers and fruit yields on the mown plots both increased with earliness of mowing. The effects of nitrogen were less clear, and conclusions must await the completion of analyses. The cropping of the experiment was probably more than halved by spring frost damage.

The summary of three years' records from this experiment shows that defoliation in early August increased the numbers of inflorescences by about 12% and the annual output of sound fruit by about a ton per acre. Late defoliation had no effect on total inflorescence numbers or fruit yield. The application of ammonium sulphate seemed generally to depress flowering and fruiting, most markedly in the half-plots which received this treatment in both autumn and spring.

For the final cropping year of a Scottish Fruit Trials strawberry trial of eight varieties, planted in 1958, the unit plots were again halved and one half-plot of each pair was defoliated on 11 August 1960. Inflorescences in 1961 were in general much more numerous than in 1960 and were increased eight- or ten-fold on the unmown plants of Talisman and Cambridge Rearguard, which had been markedly vegetative in the previous year. Differences

in inflorescence numbers between mown and unmown plots were smaller than in 1960, but increases associated with mowing ranged from 5% to 44% in seven of the varieties. Only in Senga 54 were the unmown plots the more floriferous. The mown plots of Talisman and Redgauntlet gave increases of yield equivalent to 37 and 12 cwt. per acre respectively, and those of Cambridge Vigour and Senga Sengana showed increases of about a ton. As expected from the inflorescence records, the yield of Senga 54 was depressed by mowing.

During the two cropping years for which the treatment was applied, six of the varieties in this trial showed a clear response to defoliation. Total crop increases per acre ranged from 31 cwt. in Cambridge Vigour to about 2 tons in Senga Sengana and Merton Princess, 3 tons in Redgauntlet, 5¼ tons in Cambridge Rearguard and 9 tons in Talisman. Defoliation depressed the yield of Senga 54 and little affected that of Royal Sovereign. (M. M. Anderson.)

Eleven advanced strawberry seedling selections were received from the West of Scotland Unit and propagated for field trials to be planted in spring 1962. Twenty-nine selections were received for smaller-scale trial. (C. A. Wood, M. M. Anderson.)

APPLE VARIETY-ROOTSTOCK TRIALS

The apple crop in 1961 was badly hit by a succession of adverse weather conditions. Frosts in April and a very damaging frost on 27 May seriously reduced the fruit-set, the May frost being particularly severe on early-maturing varieties which had reached the fruitlet stage. The combination of spring frost damage with a dry May and June and a wet July and August led to very much cracking and russeting in dessert varieties. A gale on 16 September damaged many trees and blew down much of the surviving crop, which might otherwise have been about one-half of that of the preceding year.

The best yields in this series of trials, which date from 1954, were from the trial (IIIB) of four culinary varieties on rootstocks M.VII and M.IX. This trial, which alone showed a yield increase over 1960, is also the only one not yet grassed down. Since there was no parallel increase in cropping from the same varieties (though on different rootstocks) in trial I, it seems that the absence of a grass cover may have afforded some protection against frost. The two weaker-growing varieties in IIIB, Grenadier and Royal Jubilee, are now cropping much more heavily on M.VII than on M.IX, whereas Bramley's Seedling continues to crop more heavily on M.IX: in 1961 the latter combination was in fact the most productive in the trial, giving 1¾ bushels per tree. Also interesting was the absence of cracking in the late-flowering Edward VII, a variety which had cracked badly in previous years.

In the corresponding trial of dessert varieties (IIIA), Winston, Cox's Orange Pippin and Wagener cropped better on M.IX than on M.VII. Cox cracked very badly, but Winston, especially on M.IX, was of quite nice quality and noticeably improved in size. Red Melba so far shows the greatest difference in accumulated yield between the two rootstocks, having been the heaviest cropper on M.VII but the lightest on M.IX. It is the weakest variety in the trial and makes a very dwarf tree on M.IX.

In the other trial of dessert varieties wholly on rootstocks of the Malling series (trial II), the differences in accumulated crop weights between the rootstocks are still very small. Pruning weights and cross-sectional diameter records show that so far the trees on M.IV are similar in vigour to those on M.I, while those on M.II are slightly more vigorous than those on M.VII. Laxton's Superb gave the best crop in 1961. In the Worcester Pearmain section of the trial of four Malling and four Malling-Merton rootstocks (trial IIA), the trees on M.M.111 are leading slightly in total crop while those on M.IV have cropped least. The trees on M.M.109 are by far the most vigorous, followed by those on M.M.104, M.I and M.M.106. The trees on M.M.111 and M.IV are slightly less vigorous, and the weakest are those on M.II and M.VII. The 72 trees of Laxton's Fortune added to this trial in 1959 have not yet cropped. To complete the trial a third set of 72 trees on the same eight rootstocks—this time all of the scion variety Exeter Cross—will be planted in the winter of 1962-63.

In trial I—of four culinary varieties on four Malling rootstocks—Bramley's Seedling and Edward VII are now making large trees, especially on M.XVI. Grenadier and Royal Jubilee are much smaller. Bramley, Edward VII and Royal Jubilee have all cropped best so far on M.II, but Grenadier has been better on M.I and Crab C. The trees on Crab C are intermediate in vigour between those on M.I and on M.XVI, and have cropped better so far than the ones on M.XVI. The cropping of the varieties to date is in the following descending order: Grenadier, Edward VII, Bramley's Seedling, Royal Jubilee.

In the trials of dwarf pyramid trees planted in 1959, the alternative treatments of normal summer pruning and 'festooning' were applied for the second time. Both varieties (Worcester Pearmain and Sunset) continued to make good growth. In trial 'A' the trees on M.XXVI are now distinctly smaller than those on either M.VII or M.M.106, whilst in trial 'B' those on M.M.104 seem likely to become too large for dwarf pyramids.

Growth in 1961 was generally satisfactory in all these trials. Nitrogen dressings applied in the autumn and winter of 1960-61 apparently counteracted the adverse effect of grassing-down which was noted in the last Report. Canker continued to spread in trial IIIA, causing the loss of four trees on M.VII and two on M.IX. The only variety not yet affected is Winston. Some scab also occurred in this trial, on the variety Red Melba. (W. Fordyce.)

## OTHER VARIETY TRIALS

### *Apples*

For reasons already given, both the number of apple varieties cropping and the individual yields recorded were much reduced in 1961. In the Variety Collection 417 varieties cropped, as compared with 668 in 1960. Sixty cropped for the first time. A further 13 varieties were added in the spring to bring the total number of trees (which includes some duplicates and synonyms) to 826: but the gale on 16 September caused serious damage and 29 trees were lost.

All of the varieties in the 1953 variety 'elimination' trial cropped except Melba and Crystal, but yields were considerably below expectation. The

early varieties Lodi and George Cave (Cave's Seedling) were very badly cracked. James Grieve was again one of the most successful varieties, with the crop a little reduced but size and quality well maintained. Among the Canadian varieties, Hume and Lobo finished well with very good size and a noticeable freedom from cracking. This trial has been exceedingly useful as a first assessment of the performance of most of the leading apples of the present day, the majority of which had not previously been planted in Scotland. Some of the more successful ones will be included in a new trial to be planted in 1962-63. (W. Fordyce.)

*Plums*

By 1961 so many trees in the 1953 'elimination' trial of plum varieties had been killed by bacterial canker that there seemed little reason to retain the trial any longer. It was therefore cleared in March 1962. Of the 229 trees of the original planting, plus subsequent replacements, 71 had been lost through canker. These comprised 21 on Myrobolan B rootstock, 23 on Common Plum and 27 on Brompton. In the final year 34 varieties cropped, though many of them only lightly. Two consistently good bearers in previous years, Blue Rock and Laxton's Cropper, were disappointing, Blue Rock as a result of frost damage and Laxton's Cropper perhaps because of the tremendous crop it carried in 1960. Czar and Thames Cross gave reasonable yields and the best of the gages were Jefferson's Gage, Apricot Gage and Bryanston Gage. (W. Fordyce.)

*Pears and Cherries*

No additions have been made to the Pear Collection since the spring of 1958, but the existing trees are growing well and becoming of increasing interest. The majority of the varieties are just beginning to reach bearing age. The 1961 crop was very light, with Bristol Cross and Cheltenham Cross the two best varieties. Altogether 52 varieties cropped, 14 of them for the first time.

In the cherry trial the trees are continuing to make good growth and are benefiting from the protection of the shelter belt planted in 1953. Despite ample blossom in 1961 there was a poor fruit-set. Protection from birds—especially in the case of the early varieties Early Rivers and Merton Heart—remains the chief practical problem with this trial. (W. Fordyce.)

*Red Currants*

The two variety trials of red currants planted in 1955 were continued. In the smaller trial of five varieties the cropping was in the following order: Ayrshire Queen, Earliest of Fourlands, Laxton's No. 1, Red Lake, Jonkheer van Tets. In the trial of fifteen varieties the highest yielder was Victoria, followed by New Red Dutch and Red Dutch. (M. M. Anderson.)

*Scottish Regional Fruit Trials*

The first two pairs of blocks of a new experiment on the effects of post-harvest defoliation of strawberries were planted at the Scottish Fruit Trials centres, including Mylnefield, in the spring of 1961. This experiment, which contains the varieties Talisman and Cambridge Vigour, is designed to compare

a number of systems of management ranging from repeated annual defoliation to biennial defoliation and complete lack of defoliation. It will also be planted in successive sections over a period of three years, and concluded in similar stages, with the aim of spreading the testing of defoliation over a reasonably varied range of seasons.

In the 1958 trial of eight strawberry varieties the post-harvest defoliation treatment first tested in 1959-1960 was repeated in 1960-1961 (see p. 22). Although yields were affected by the spring frosts, crops equivalent to more than 4 tons of sound fruit per acre were obtained from the defoliated sub-plots of Talisman, Cambridge Vigour, Senga Sengana and Merton Princess and the non-defoliated sub-plots of Merton Princess.

The crop of the 1954 trial of bush plums was also much reduced by frost and by cold winds in April. Twenty-six varieties on Common Plum rootstock fruited and sixteen on Myrobolan B, but many of the yields were of less than 10 lb. of sound fruit per tree. For the third successive year Laxton's Cropper and Cox's Emperor were the most productive varieties on both rootstocks, and Warwickshire Drooper again cropped well on Myrobolan B. For the first time Thames Cross cropped well on both rootstocks. The fruit quality of most varieties was good, with less splitting than usual. Thames Cross was affected by brown rot, and this variety and Early Transparent Gage both shed an undue amount of their fruit. Two trees in the trial were killed by bacterial canker.

Despite the adverse spring conditions, yields in the 1960 trial of virus-free stocks of seven raspberry varieties were good. Lloyd George cropped best with more than 2½ tons per acre, followed by Malling Promise and Malling Exploit each with more than 2 tons. The East Malling Seedling 69/139 was poorest with 34 cwt. per acre. In the 'health demonstration plot' of different grades of certified nursery stocks of raspberry, also planted in 1960 (see 1960-61 Report), the virus-free stocks of the three varieties—Malling Promise, Malling Jewel and Lloyd George—outyielded the lower-grade stocks. The cropping of the virus-free Malling Jewel was particularly good following its large production of new canes in the previous year.

In the 1952 trial of six raspberry varieties, now discarded at the other trial centres, the original plots were halved and a high nitrogen treatment was applied to one half-plot of each. No effect of the extra nitrogen appeared in the 1961 fruit crop but slight increases of cane growth were recorded at the end of the year. Three of the varieties—Malling Promise, Malling Jewel and Malling Exploit—cropped at more than 4 tons per acre, and Norfolk Giant, Malling Enterprise and Lloyd George (the last much affected by frost) each at more than 3 tons. (M. M. Anderson.)

### MISCELLANEOUS

Co-operative work on plum bacterial canker was continued with Dr. A. M. Paton of the University of Aberdeen and Dr. A. E. W. Boyd of the Edinburgh and East of Scotland College of Agriculture (see also p. 77). Recording was continued on the plantation of Victoria plum planted in March 1960 and further work on field aspects of the investigation was initiated.

## PUBLICATIONS

### Research Papers

JENNINGS, D. L. (1962). Some evidence on the influence of the morphology of raspberry canes upon their liability to be attacked by certain fungi. *Hort. Res.*, **1**, 100-11.
[The incidence of certain cane diseases in families of raspberry seedlings was found to be influenced by cane morphology. Spur blight (*Didymella applanata*) was less frequent on seedlings with hairy, spine-free, wax-free or non-pigmented canes, and also on seedlings whose canes had a moderately dense wax covering. The incidence of grey mould (*Botrytis cinerea*) was influenced in a similar way except that it was slightly greater on the wax-free canes; and the incidence of cane spot (*Elsinoe veneta*) was also similar to that of spur blight in its relationship to spininess, wax thickness and pigmentation, but was greater on hairy and on wax-free canes. It is concluded that the characters mentioned confer properties on the cane surfaces which enable them to avoid infection by the fungal pathogens, and some evidence is given on the possible nature of these properties. The significance of these findings for the breeding of improved varieties is discussed.]

JENNINGS, D. L. (1962). Variation in pollen and ovule fertility in varieties of cassava, and the effect of interspecific crossing on fertility. *Euphytica*, **11**. (In press.)
[This paper describes work done by the writer while on the staff of the East African Agriculture and Forestry Research Organization. The capacity of cassava varieties (*Manihot esculenta*) to set seeds has been reduced during their evolution from non-tuberous wild forms into tuberous forms which are propagated vegetatively by stem cuttings. The reductions in pollen and ovule fertilities appear to have occurred independently of each other. Additional causes of sterility, probably including meiotic irregularities, appeared to operate in $F_1$ interspecific hybrids but were not important after the first backcross generation. *Manihot melanobasis*, a wild form which normally establishes itself from seed, contributed factors which enhanced the fertility of its hybrids with cassava.]

STEPHENS, R. J. (1962). The control of weeds in potatoes by pre-emergence application of herbicides. *Weed Res.*, **2**. (In press.)
[Trials in 1959, 1960 and 1961 failed to show significant yield differences between potatoes of three varieties receiving from 7-9 separate tractor cultivations and similar potatoes in which the weeds were well controlled by the pre-emergence application of mixtures of dinoseb (6·0 lb.[1]) and dalapon (2·5-5·0 lb.). Under less effective herbicide treatments, including simazine and mixtures containing 2,4-DES, there were significant reductions in yield.
Preliminary taint tests in 1959 on cooked tubers suggested that slight tainting might have been caused by one of the treatments, but tests on potato crisps made from the 1959 and 1960 crops were completely inconclusive. Tubers from all the treatments in the 1959 and 1960 trials sprouted normally in the spring after harvest.]

STEPHENS, R. J., and SUTHERLAND, J. P. (1962). Effects of some herbicides on the weeds and crop in a raspberry cane nursery. *Hort. Res.*, **1**, 112-19.
[After earlier trials of herbicides in raspberry cane nurseries from 1955 to 1958, a three-year trial of monuron (at rates of 1·0, 2·0 and 3·0 lb. per acre[1]), of simazine (1·0, 2·0 and 3·0 lb.) and of a mixture of 2,4-DES (3·6 lb.) with propham (5·0 lb.) was conducted in a nursery planted in 1958 with the variety Malling Exploit. The treatments were applied annually in late winter or spring. Hand cultivation for weed control was unnecessary on the 2·0 lb. and 3·0 lb. simazine plots and scarcely needed on the 3·0 lb. monuron plots, but the 1·0 lb. simazine, 1·0 lb. and 2·0 lb. monuron and 2,4-DES/propham treatments were less effective. The plots on which chemical weed control was effective were superior to the others in the numbers and quality of the canes which they produced. Seed germination tests on soil samples taken twelve months after the final applications of the herbicides revealed much smaller numbers of weed seeds in the topmost 2 in. zone of soil under the successful treatments than under those which were less successful.

[1]Herbicide rates are given in pounds of active ingredient per acre.

On the basis of this trial and collateral experience, simazine at 2·0-3·0 lb. per acre is considered to be an effective and satisfactorily safe herbicide treatment for raspberry cane nurseries; but there may be value in the occasional use of alternative materials to prevent the build-up of resistant weed species.]

WOOD, C. A., ANDERSON, M. M., and SMITH, A. M.[1] (1962). Quantities and composition of crop materials removed from an established raspberry plantation. *Hort. Res.*, **1**, 85-94.

[A record was kept in 1957 and 1958 of the quantities of waste vegetative material—mainly spent fruiting canes and surplus new canes—removed from a 5-6 year old raspberry plantation containing plots of six varieties. The average weight of waste material was about 57 cwt. per acre per annum. The amounts of dry matter and of the nutrients N, P, K, Ca and Mg removed in the waste were greater than the amounts either in the fruit harvested or (except possibly for potassium) in the leaves returned to the soil. The results are discussed in relation to manurial practice.

From the data for the individual varieties, factors relating annual fruit yield to annual removal of vegetative waste have been calculated and found to reflect closely the general experience of 'manageability' among varieties.]

[1]Dr. A. M. Smith, of the Chemistry Dept., Edinburgh School of Agriculture, who carried out the analyses of the materials.

## GENERAL PAPERS

STEPHENS, R. J. (1961). Modern herbicides: accuracy ensures safety and success. *Grower*, **55**, 1, 124. (3 June.)

STEPHENS, R. J. (1961). Chemical weed control in soft fruit crops. *Gdnrs' Chron.*, **149**, 546. (24 June.)

STEPHENS, R. J. (1962). Using herbicides to control weeds in vegetables. *Gdnrs' Chron.*, **151**, 142, 161. (24 February and 3 March.)

# VEGETABLE CROPS

## C. North

The main efforts of the department were again directed to work on the cultivation and breeding of brussels sprouts and cabbage. However, more attention was given to studies on carrots than in previous years, and work on this crop will be still further expanded in the future by Mr. H. J. V. Gledhill, who joined the department in August 1961.

Unusually cold wet summer and autumn weather delayed the maturation of many vegetable crops, and the growth of brassicas was poor. As a result of the delayed maturation and the severe frosts which followed in January and February, most cabbage crops overwintering in the field were severely damaged; but those stored experimentally in clamps were unharmed. The hard weather conditions, however, made it possible to select cabbage breeding material critically for winter hardiness.

Another unusual phenomenon was the prevalence of motley dwarf virus in carrot crops grown in Perthshire and Angus. This disease, which was previously of no apparent consequence in Scotland, caused widespread damage to crops grown for canning. The outbreak has prompted the Virology Department to study the disease, and it is hoped, with their co-operation, to examine the possibility of breeding resistant strains of carrots for Scottish conditions.

### VARIETY TRIALS

*Broad Beans*

Twenty-two seed stocks of broad bean were compared in a yield trial for the third consecutive year. Some strains of the varieties Bunyard's Exhibition, Extra Lange Afhangers and Green Masterpiece, which were productive in earlier trials, again gave good yields of shelled beans. Of the varieties suitable for canning, Threefold White strains gave the highest yields though none of them were as productive as the varieties mentioned above. The other canning varieties tested, including Sugar and Lux, gave low or very low yields.

Variety trials with this crop are being discontinued, and a paper describing the results of the trials from 1956 to 1961 is in preparation.

*Leek*

The series of leek trials started in 1958 has been concluded and a paper describing the results will shortly be published. A new series, which forms part of a joint project between the Institute and the N.A.A.S. Experimental Horticulture Station, Stockbridge House, Cawood, Yorks., was started in 1961. Twenty-six varieties, chosen for their performance in the Institute trials from 1958 to 1960 and in previous trials at Cawood, are now being compared in yield trials at both centres and at a station in Lanarkshire. At both Scottish centres high yields were obtained in 1961 from Winter Ruizen,

Cullen's Giant (dark selection), Sutton's Prizetaker and a strain of Elefant. All these varieties were rated as having a fairly good, or good, appearance when bunched for marketing.

*Jerusalem Artichoke*

The eight varieties of this vegetable tested in a yield trial at Mylnefield in 1960 were compared again in 1961. As in the previous trial, the varieties showed considerable differences in productivity. Bianke again gave a significantly higher yield than any of the other varieties, but its tubers were irregularly shaped and consequently difficult to clean or peel. The variety Traube was the best compromise for productivity and quality of tubers. Its tubers had pale yellow skins and relatively few thick side-roots. (L. H. Frith, H. Taylor.)

## CULTURAL EXPERIMENTS

*Brussels Sprouts*

Many growers claim that brussels sprouts must be planted firmly, and a series of experiments was started at Mylnefield in 1959 to see if any justification could be found for this belief. In a small preliminary experiment that year, plants of the variety Cambridge No. 1 were transplanted from the seed bed into soil either (a) consolidated with a tractor and roller or (b) loosened by rotary hoeing shortly before planting. Five weeks after transplanting, half of the plants in each soil consolidation treatment were given a top dressing of nitrate of lime (21% N) at a rate equivalent to 6 cwt. per acre. Neither this experiment nor a more extensive one conducted in 1960 showed significant differences in yield or quality of the sprouts which could be attributed to soil consolidation, either with or without the nitrogenous fertilizer. In 1961, however, plants transplanted to loose soil gave nearly twice the yield of those grown in firm soil, and the sprouts were also firmer and included a smaller proportion of 'blowers.' The addition of nitrogen also increased the yields of marketable sprouts, but it induced higher proportions of 'blowers' under both soil treatments. There was no significant interaction between the soil consolidation and fertilizer treatments. The effects of soil consolidation may well be influenced by seasonal climatic conditions, but the experiments so far conducted do not support the contention that planting in loose soil is disadvantageous.

An experiment was carried out to assess the effects of different rates of application of a nitrogenous top-dressing on the yield and quality of the brussels sprout varieties Irish Elegance and Cambridge Special. Applications of nitrate of lime (21% N) were given at rates equivalent to 2, 6 and 10 cwt. per acre, each rate both as a single application at planting time and also divided into two equal doses, one applied at planting time and the other during the growing season. Half of the total plants were planted at a spacing of $2\frac{1}{2}$ ft. $\times 2\frac{1}{2}$ ft.—the customary planting distance in Scotland—and half at the close spacing of $1\frac{1}{4}$ ft. $\times$ $2\frac{1}{2}$ ft.

Increases in the amount of fertilizer applied did not always lead to increases in the yield of marketable sprouts or even in total yield. At the

normal spacing, Cambridge Special gave its highest marketable yields with the 2 cwt. dressings and Irish Elegance with the 6 cwt. dressings, whilst at the close spacing both varieties yielded best with either the 6 or 10 cwt. dressings. Cambridge Special outyielded Irish Elegance in nearly all of the treatments, but there was a significant interaction of fertilizer level with variety, Irish Elegance responding more than Cambridge Special to higher rates of fertilizer. This effect was partly due to the production of larger proportions of unmarketable waste in Cambridge Special as higher rates of fertilizer were applied. Slightly higher yields were recorded where the fertilizer was given in two applications instead of one, but the differences were not always significant. Normal spacing gave higher yields than close spacing at all rates of nitrogen application and with both varieties.

The effect of the fertilizer on sprout quality was to decrease firmness, increase the proportion of 'blowers' and darken the colour, in proportion to the amounts applied.

In some parts of England brussels sprouts are 'topped'—i.e., the growing point is broken out by hand—but this is not often practised in Scotland. In an experiment at Mylnefield in 1961 spring-sown plants topped on 7 September gave a significant 25% increase in yield of marketable sprouts harvested in November, with no effect on firmness or average size. This result suggests that the 'topping' practice may be advantageous for the production of early sprouts in Scotland, but further experiments will have to be conducted before it can be confidently recommended.

In 1960 an experiment was conducted to investigate the effects of different sowing rates in the seed bed and of transplanting at different dates (see 1960-61 Report). The results clearly showed the importance of thin sowing and early transplanting, and a similar experiment in 1961 confirmed these findings. Plants raised from seed sown in the open on 23 March and planted on 1 June gave more than twice the yield of others planted two weeks later, and twelve times the yield of those planted four weeks later. Significantly higher yields were also given by plants raised from seed sown at rates equivalent to $\frac{1}{2}$ oz. per 100 ft. of row than by plants from sowings of 3 oz. or more per 100 ft. The percentage of plantable seedlings obtained was higher where the seed was sown at low rates—a result which further emphasizes the importance of thin sowing, most especially when using valuable or expensive seed, such as that of an $F_1$ hybrid. (C. North, L. H. Frith.)

*Clamp Storage of Cabbage*

A preliminary experiment in 1960 on cabbage clamping having indicated the importance of adequate ventilation of the clamps, a larger-scale experiment was set up in November 1961 in the hope of confirming and extending these findings. Clamps of two different sizes containing altogether $6\frac{1}{4}$ tons of each of the varieties Amager and Winter Pride (a Langendijker type) were prepared, half of them with slatted wooden ventilators running along the base and half without this additional ventilation. The cabbage heads will be examined and weighed towards the end of March 1962. A paper describing some of the work at Mylnefield on clamp storage of cabbage has been published. (C. North, L. H. Frith.)

*Carrot*

A further experiment was done to assess the optimum sowing rate for the production of carrots for canning whole. Seed of a strain of Chantenay was sown on 22 April, and again on 7 June, in rows 6 in. apart at rates equivalent to 6, 8, 10 and 12 lb. per acre, and the roots were harvested on 10 October. Several unforeseen circumstances combined to make the results more variable than those of the 1960 trial. Wet weather prevented the timely control of weeds, many of which grew to such a large size that the stand of carrots was unavoidably reduced during weeding. Furthermore, some of the carrot plants showed symptoms similar to those caused by motley dwarf virus: this trouble was rife in the area in 1961 (see p. 70), but it is possible that the plants at Mylnefield were infected at a late stage of growth, for the yields were not substantially less than for an average year.

Although the results of this experiment were less precise than those of the 1960 trial, they showed a similar trend. The highest yield of canning-sized carrots for each date of sowing was given by the highest sowing rate. This rate was equivalent to about 8 lb. of seed per acre sown on spaced beds of six rows 6 in. apart with 26-inch spaces between the outside rows of adjacent beds, but owing to the destruction of a relatively large number of carrot seedlings when the crop was weeded, the plant stand was thinner than is usual with such a high sowing rate. Even at the highest rate of sowing in April, 20% of the roots—50% of them by weight—were too large for canning, suggesting that still higher sowing rates might have increased the yield of canning-sized roots. These results therefore support those of the 1960 experiment in showing that high sowing rates should be used when carrots grown primarily for canning are sown in April to be harvested in October-November.

A preliminary experiment in 1960 indicated that carrots which had reached a size suitable for canning could be left in the field until required by the factory, further increase in size being prevented by cutting down the foliage close to the roots. An experiment was conducted in 1961 to examine further the effects of this treatment. Seed of a Chantenay type was sown on 24 April at a relatively low rate (equivalent to about 4 lb. per acre on the bed system), and the resultant plants were subjected to two different top-removal treatments. The foliage of some was cut at ground level on 15 August and again on 18 September, and that of others on 18 September only: still other plants were left untopped as controls. In the control plots the number of roots of a size suitable for canning fell by about 35% between 15 August and 15 November, but during this period there was very little change of root size in the plots which had been topped twice, and a reduction of only 22% in the number of roots of canning size in the plots which had been topped only on 18 September. At harvest time the roots which had been topped twice were narrower, paler in colour and poorer in flavour than those of similar length from the control plots. The roots topped only once did not differ from the controls in any of these respects. (H. Taylor, H. J. V. Gledhill.)

*Peat as a Soil Additive*

Composted straw is used at Mylnefield to raise the humus content of field soil for vegetable crops. It is preferred to farmyard manure for this purpose

because there is so much less risk of its carrying the club-root disease organism. However, the preparation of well-rotted compost involves much labour, and it would be convenient if a source of humus could be found which required no such preparation on the farm.

In 1960 an experiment was started to compare the effects on the growth of leeks and cabbage of the addition to the soil of black peat, brown peat and compost, each together with a normal top-dressing of a complete fertilizer. In 1960 none of the yields from the treated plots differed significantly from those of the control plots which had received no organic matter. In 1961 the same plots were each given a further application of the appropriate form of organic matter and replanted in a similar way with leeks and cabbage, except that the siting of the two crops was reversed. The yields of leeks on plots treated with either form of peat were increased by 20% over those of the control plots, a difference which was significant at the 5% level and comparable with that produced by treatment with compost. The yield of cabbage was not significantly affected by the treatments. (L. H. Frith, H. Taylor.)

### WEED CONTROL IN CARROTS

Trials of herbicides were made in carrots in collaboration with the Pomology Department. They included replicated yield trials at Mylnefield and North Berwick in which the chemical treatments (in terms of active ingredients per acre) were: pre-emergence applications of propazine (0·5 lb.), amiben (4 lb.) and HS/55/4 (3 pints—equivalent to about 0.5 lb. cycloocytyl-dimethyl urea and 0·4 lb. m-chlorophenyl-butinyl-carbamate); and a post-emergence application of Shell 'W' at 80 gal. per acre. There was also a hand-weeded control treatment. At Mylnefield each of the three pre-emergence treatments gave a good control of weeds, and the yield of roots from them was higher than from the plots treated with Shell 'W' or hand-weeded. However, too much importance should not be attached to these yield effects since the unfavourable weather conditions made it difficult either to apply the Shell 'W' at the optimum time or to hand-weed without severely checking the seedlings. Of the pre-emergence treatments, the plots treated with HS/55/4 gave a significantly higher yield than those treated with either of the other chemicals. At North Berwick the growth of the carrots was extremely poor owing to the dry conditions there early in the season, and no yield records were obtained; but it was noted that HS/55/4 gave a more effective control of weeds than either propazine or amiben.

Small-scale screening trials were conducted at Mylnefield to test the efficacy, at various rates of application, of dicryl (N-(3,4-dichlorophenyl) methacrylamide), karsil (N-(3,4-dichlorophenyl)-2-methylpentanamide), solan (N-(3-chloro-4-methylphenyl)-2-methylpentanamide), chlorpropham, chlorpropham + diuron, and amiben. Treatments with the last three of these materials gave good weed control. (R. J. Stephens, H. Taylor.)

### MECHANICAL HARVESTING OF BRUSSELS SPROUTS

Brussels sprouts are nearly always harvested by being picked by hand from the stalks, which are left standing in the field. Since this operation usually

accounts for 40-50% of the total cost of production of the crop, a less expensive method of harvesting should be of advantage to many growers. A prototype machine for harvesting sprouts has recently been designed and built at Mylnefield and covered by an application (No. 46244/61) for a patent.

This apparatus is essentially designed to strip sprouts from stems which have been cut at ground level in the field. The stems are introduced by hand to the machine, which grips them by two shaped and ribbed rollers contra-rotated through a train of gears by a ⅓ h.p. electric motor. These rollers pull the stem through an aperture of 2 in. diameter in a board, and the sprouts are broken off against the board as the stem passes through. No appreciable damage occurs to the sprouts.

The machine obviously can only be used once on a given section of a crop of sprouts, since it destroys the plants. However, it does not follow that its use would necessarily result in a reduction of total yield. If combined with a judicious system of hand picking, and possibly also with the topping of plants to induce a more uniform maturation of the sprouts, a single mechanical stripping might give yields as good as those resulting from the conventional method of hand harvesting. Experiments are being planned to find the best routine for growing brussels sprouts which are to be harvested by this mechanical method. (C. North, J. H. Couttie.)

## BREEDING OF BRUSSELS SPROUTS

### *Production of a Composite Variety*

Seed of an experimental 'composite' variety was obtained in 1960 by isolating plants selected from three inbred lines in an insect-proof glasshouse and permitting them to mass-seed, using a small hive of bees as pollinators. This seed was sown in 1961 and produced very uniform plants bearing sprouts of good quality. Unfortunately, the production of this material cannot be exactly repeated, since clonal material of only one of the original plants is available. It proved impossible to propagate the others vegetatively from root cuttings—the method which had been relied upon for maintaining the parent material.

An attempt will be made to establish a number of clones which can be readily propagated from root cuttings, and these will be used to produce more experimental composite varieties.

### *Environmental Modification of Genetic Male-Sterility*

An experiment conducted in 1960 showed that the phenotypic expression of male-sterility could be influenced by environmental conditions. The results suggested that plants carrying genes for male-sterility were more likely to produce male-sterile flowers under high than under low temperature conditions.

A second, similar experiment was conducted in 1961. Ramets from clones which had a previous history of complete or partial male-sterility were grown in pots stood outside during the summer. On 23 December, fourteen were transferred to each of the following treatments: (a) glasshouse at 20-27°C; (b) glasshouse at 13-18°C; (c) unheated glasshouse; and fourteen were left outside (treatment d). Under treatment (a) flowering was sup-

pressed, but under all the other treatments the clones which were previously classified as fully male-sterile gave over 90% of male-sterile flowers. Plants previously classified as partially male-sterile gave 62, 12 and 66% of male-sterile flowers under treatments (b), (c) and (d) respectively. The results under glasshouse conditions were therefore in agreement with those of the previous experiment (see 1960-61 Report), in that there were more male-sterile flowers under a higher than under a lower temperature treatment; but the plants left outside produced as many male-sterile flowers as those kept in the moderately heated glasshouse (treatment b). It seems, therefore, that whereas temperature may be important, it is not the only environmental factor which modifies the expression of male-sterility. (W. G. Priestley.)

'*Glossy Foliage*'

$F_1$ plants, obtained by crossing 'glossy' plants with unrelated normal plants, were self-pollinated and also backcrossed to the 'glossy' type. Segregation of the seedlings in the $F_2$ and backcross populations did not deviate significantly from the ratios 3 : 1 and 1 : 1 respectively, thus indicating that in this material the glossy character is inherited as a simple recessive. A paper describing this work has been published.

Seed of a collard variety reputed to have 'glossy' leaves produced not only 'glossy' and normal types but also plants which were intermediate for the 'glossy' condition. It seems therefore that the condition is not always simply inherited, but may be more complex in some forms of *Brassica oleracea*. Controlled pollinations of the collard plants were made with a view to further studies on the inheritance of the 'glossy' condition.

Work has commenced on the introduction of the 'glossy' condition to some of the more promising of our inbred lines of brussels sprout, with a view to producing glossy-leaved strains which might be used as mother parents in the production of commercial $F_1$ seed. The glossy condition would make it possible to detect any undesirable sib-crosses within the progeny of the mother parents. (C. North, W. G. Priestley.)

*Other Genetic Markers*

Among 87 brussels sprout plants of an inbred family, 15 had very 'crinkly' petals which failed to unfold normally. Controlled pollinations were made with these abnormal types to study the inheritance of this character. The plants with crinkly petals developed viable seed.

Work has been started on the introduction of a gene for white flowers into lines also carrying the gene for 'glossy foliage.'

*The Inheritance of Internal Browning*

Further studies on the inheritance of the disorder of brussels sprouts known as 'internal browning' have confirmed that a tendency to this condition is inherited. A brief report on the work has been published. (W. G. Priestley, C. North.)

BREEDING OF WINTER CABBAGE

Thirty families resulting from sib-crosses within material derived from Cambridge Drumhead x Blåtopp, January King x Danish Keeping and January King x Ormskirk Savoy were grown in the field. Material from the last-mentioned cross resembled a Savoy cabbage but had much firmer heads than the usual commercial varieties of that type, and was very uniform. The plants tended to mature earlier than those of January King, with the result that many had become over-mature and rotten by January. A trial will be conducted to see whether, by sowing it relatively late in the year, this strain can be induced to produce heads for cutting in the field from January to March.

Work is progressing on the transference to cabbage of the gene for white flowers. Four backcross generations have been raised, but all from plants grown as annuals in pots. The material will shortly be grown in the field so that its agronomic qualities can be examined. (W. G. Priestley.)

BREEDING OF DWARF BEAN

Phaseolus vulgaris

The reserve seed of the selections from Record x Fullcrop which outyielded Record in trials at Mylnefield in 1960 was sown in isolated multiplication plots to produce more seed for trials. Two lines of this material are being included in a series of trials in 1962 at Invergowrie, Efford (Hampshire), Rosewarne (Cornwall), Sprowston (Norfolk) and Cambridge, organized by the National Institute of Agricultural Botany. To improve the pod quality of some of the early-maturing lines selected from the above cross, they were crossed with material of a dwarf form derived from the variety Blue Lake, kindly provided by Professor W. A. Frazier, of Oregon State College, Corvallis, Oregon. Seed developed only when the Mylnefield material was used as the female parent.

Eighty-eight lines of the $F_4$ generations from the crosses Record x Contender and Contender x Zenevski Trznii were grown in the field. None of this material is very promising and only a few single-plant selections were made.

Plants of the segregating $F_2$ families from the crosses Record x Prelude, Record x Slavia and Record x Early Blue Lake (a climbing variety) were grown in an unheated glasshouse. Three per cent. of those derived from the last-named cross combined the determinate habit and earliness of Record with the white flower and white seed colour of Early Blue Lake. Seed saved from the best plants of this material will be sown in the field in 1962.

Phaseolus vulgaris x P. coccineus

A wide range of dwarf selections, developed from crosses between varieties of *Phaseolus vulgaris* and *P. coccineus*, were again grown in the field. Most of the lines became infected with anthracnose and very few plants were selected.

A white-seeded dwarf form, selected from the variety Tschermak Multigaris, more closely resembles a dwarf form of *P. coccineus*, although it is

reputed to have been derived from a cross between this species and *P. vulgaris*. It might be a useful dwarf form for the processing industry but it does not give high yields in Scotland. To improve productivity, it was crossed with the climbing, white-seeded variety of runner bean named Czar. Thirty-four per cent. of the flower-buds pollinated developed pods, which gave altogether more than 100 $F_1$ seeds—a relatively high proportion of successful pollinations. Successive generations of this material will be selected for dwarf habit, productivity and seed colour. (W. G. Priestley.)

## PUBLICATIONS

### Research Papers

North, C. (1961). Relationship between leaf shape and head formation in cabbage. *Proc. 15th int. hort. Congr.*, **1**, 487-92.[1]

(The leaves of non-heading rogue plants of January King cabbage were found to be narrower than those of headed plants sampled from the same crop. This led to an examination of the shape of the leaves of five varieties, and a positive correlation was discovered between the length/width ratio of the 7th-12th oldest leaves of a variety and the time needed to form a head. Results from a trial of 33 varieties showed that it might be possible to forecast varietal rates of maturation from measurements made on the 7th oldest leaf at transplanting time.)

[1]This paper, listed in the 1958-59 Report as in the press, is now re-listed on publication.

North, C., Frith, L. H., and Taylor, H. (1962). Variety trials of vegetables in Scotland. X. Stringless dwarf French beans, 1954-1960. *Hort. Res.*, **1**, 76-80.

(Two hundred and one stocks of French bean from a wide range of sources were grown at Mylnefield in the hope of finding dwarf, green, stringless-podded varieties suitable for Scottish conditions. Twelve of these stocks were compared in yield trials. The new Dutch variety Prelude was the only productive variety with stringless pods of good quality and of a type suitable for processing whole; but it was tested only for two years, and further trials are necessary before it can be confidently recommended for commercial production in Scotland. There is a need for improved varieties of French bean, and work on the breeding of this crop is in progress at Mylnefield.)

North, C., and Gray, L. S. (1962). Cabbages stored in clamps—a possible new crop for Scotland. *Scot. Agric.*, **41**, 145-7.

(Substantial quantities of cabbages which have been stored in sheds during the winter are imported by the United Kingdom from Holland. Experiments at Mylnefield have shown that similar cabbages can be grown and stored successfully in clamps—a method which may commend itself to growers because no capital outlay is required. Heads of the Dutch Langendijker and Danish Amager types were cut, without retaining any loose outer leaves, and made into low, narrow clamps in November. These were covered with a layer of straw and an outer layer of soil. Heads were removed from the clamps at fortnightly intervals from early January to the end of March, and were trimmed and then marketed locally. In January the weight of marketable cabbage was 67-70% of that put into the clamps, and by the end of March this proportion had fallen to 40%. These results were sufficiently encouraging to suggest that growers might themselves profitably experiment with the method.)

North, C., and Priestley, W. Greta (1962). A glossy-leaved mutant of brussels sprout. *Hort. Res.*, **1**, 95-99.

(Brussels sprout plants with glossy leaves, lacking the normal waxy bloom, were found in the variety 'The Cluseed.' When these plants were self-pollinated they gave progenies which were entirely of the 'glossy' type, and when pollinated with unrelated normal plants they gave progenies which were entirely normal for this character. When the $F_1$ plants were selfed, or backcrossed to glossy types, the families nearly all showed segregation ratios which did not significantly differ from 3:1 and 1:1 respectively.

In this material the 'glossy' condition is therefore controlled by a single recessive gene. Since the condition can be recognized at a very early stage of growth of the seedling, it may be useful as a genetic marker to detect non-hybrid seedlings among $F_1$ hybrid stocks.)

NORTH, C., and COUTTIE, J. H. (1962). A machine for stripping brussels sprouts from the stalk. *Hort. Res.*, **2.** (In press.)
[A machine for stripping brussels sprouts from the stalk has been designed and built at Mylnefield. The prototype consists essentially of a metal framework carrying a vertically-held board in which there is a circular aperture of 2 inches diameter. Stems, which have been prepared by removing all the leaves and also the immature sprouts from the top 2 inches, are inserted by hand, top first and one at a time, through the aperture. They are gripped and pulled through this aperture by a pair of power-operated rollers, and while the stem passes through the sprouts are broken off against the board. A provisional specification for a patent (No. 46224/61) has been filed for this machine.]

PRIESTLEY, W. GRETA, and NORTH, C. (1962). Inheritance of susceptibility to Internal Browning of brussels sprouts. *Nature, Lond.*, **193,** 801.
[Plants with high (50-60% of the sprouts) and low (0-6% of the sprouts) levels of incidence of 'internal browning' were self-pollinated, and twenty-eight $S_1$ plants from each parent were examined for the presence of this disorder. Plants with high incidence and low incidence gave progenies in which 89-96% and 25-61% respectively of the plants had some sprouts with internal browning. This indicates that proneness to internal browning is inherited, and suggests that practical difficulties with internal browning might be overcome by breeding resistant strains.]

### GENERAL PAPERS

NORTH, C. (1961). Cabbages and Brussels Sprouts. (Based on a lecture given to the Royal Caledonian Horticultural Society on 7 February 1961.) *J. R. Caledonian hort. Soc., 1961,* 11.

# PHYSIOLOGY

C. G. GUTTRIDGE

Strawberry growers have long recognized that over-vigorous vegetative growth of the strawberry plant is often associated with poor cropping, and that there is an appearance of antagonism between vegetative development and flower truss formation. This view is strongly supported by results of experiments on the regulation of growth by environment. In work at Mylnefield over a number of years, changes in environment which have promoted vegetative development have always (except in special circumstances) tended to decrease flower truss formation, and *vice versa*. These opposed effects can be observed whenever vegetative development is promoted or restrained by changes in daylength, temperature or chilling history, and probably also by changes in nutrient status, although in this case the evidence is incomplete (see below). These are probably the chief factors of environment which regulate plant development.

In horticultural practice the apparent antagonism between vegetative development and truss formation can be seen when vegetative growth is checked by transplanting, defoliation, drought, virus infection, 'June Yellows' or delayed repotting. It is well known that such checks often induce truss formation or increase the number of trusses formed.

The results of recent experiments on post-harvest defoliation agree with these observations and suggest that the balance between vegetative development and truss formation can be a factor of much practical importance in the culture of maincrop strawberries. In several experiments conducted here jointly with the Pomology Department, post-harvest defoliation increased the numbers of trusses formed, sometimes substantially, with consequent increases in fruit yield in the following summer. Measurements of plant height showed that defoliation reduced vigour, and it would seem that without such treatment the plants became too vigorous for maximum fruit production.

It appears that maximum yields from mature plantations will be obtained only when the right balance is struck between vegetative development and truss formation. Vegetative development must be sufficient to encourage the formation of large, strong plants with well developed fruit trusses and a large leaf area, but must not be excessive to the point of depressing flower initiation and causing the crop to be reduced by a deficiency of trusses. It is probable that high yields of 6-8 tons per acre will be obtained consistently only if the degree of vigour can be maintained close to the critical level for truss formation: hence an awareness of the fundamental antagonism between the two phases of development of the plant is highly important.

## PHYSIOLOGICAL INVESTIGATIONS ON THE STRAWBERRY

### *Gibberellic Acid*

The application of gibberellic acid to strawberry plants increases their vegetative development, causing increases in petiole length, leaf area, fruit

truss size and numbers of runners, but inhibiting fruit truss initiation. It also causes elongation of the main crown stems, a phenomenon which does not occur with ordinary photoperiodic stimulation of vegetative development. An experiment was set up to test whether such elongation of the main stems could be reduced, or even eliminated, by applying gibberellic acid in small daily doses rather than in less frequent large doses which, by raising the concentration in the plant temporarily to high levels, might be the cause of this particular response. It was a condition of the experiment, however, that all the levels of application used should be sufficiently high to induce leaf and runner responses of the same order as those normally induced by long day-lengths. Accordingly, spray applications containing 3·5, 7, 14 or 28 p.p.m. of the growth substance were given weekly, and were compared with daily applications of one-seventh of each of these concentrations. Two further treatments consisted of single applications of 28 and 224 p.p.m., and untreated controls were also provided. The spray treatments continued for 8 weeks and the plants were harvested after a further period of 5 weeks.

At harvest, records were made of stem, petiole and inflorescence lengths, and of weights of stems, petioles, laminae, runners, inflorescences and branch crowns. The buds were dissected for records of inflorescence initiation.

Elongation of the crown stems, sufficient to separate clearly the consecutive nodes, occurred with both daily and weekly applications equivalent to 14 and 28 p.p.m. per week. At lower rates only slight elongation occurred. Weekly applications gave slightly greater responses than the equivalent daily ones; but this slight difference could not be taken to support the hypothesis, because apart from one exception all the other responses recorded were also relatively greater following the weekly applications. The exception was the weight of inflorescences, where the response is complicated by special factors involved in fruit set.

It is not known whether the generally greater response obtained from weekly as compared with daily applications is of physiological significance. It may have been due to physical causes concerned with surface spreading on the leaf and uptake through the surface.

The results with single applications suggested that petioles are at their most responsive stage to gibberellic acid at the time of emergence.

In another experiment a study was made of the interaction between day-length and gibberellic acid, primarily to see whether this substance can replace completely or only partially the promoting effect of long days on vegetative development. To test this, very high levels of application were required, fully saturating the reponse. Single applications were therefore made in aqueous solution at rates of 20, 200, 1,000 or 2,000 $\mu$g. per plant, and in order to ensure complete uptake of these large doses the solution was applied to each plant through the stump of a cut petiole. Glass tubes approximately 10 cm. long were heated and drawn to make a single, narrow constriction part-way along their length. The cut stump of a severed petiole was then fitted with a small rubber sleeve, and one of the tubes was pushed onto it until the sleeve formed a watertight joint with the constriction. Solutions of appropriate concentration were applied in 1 ml. quantities to the open ends of the

tubes, and uptake was usually complete within 48 hours, often sooner. Control plants received no applications but the corresponding petioles on them were severed. This experiment was set up in the glasshouse in November with dormant plants of the varieties Talisman and Redgauntlet. The short-day treatment consisted of natural daylength, which was extended by the use of tungsten filament lamps to 24 hours of continuous light for the long-day treatment.

In a careful study of the subsequent growth of the petioles, the following were the main conclusions reached: (i) applications of gibberellic acid and increase of daylength both increased the rate of elongation of individual petioles, without affecting the duration of elongation: this result fully confirmed an earlier observation by P. A. Thompson, and shows that final length can be used as an estimate of rate of growth; (ii) the response of petioles to gibberellic acid was saturated by a dosage of 200 $\mu$g; (iii) in spite of such a saturated response, further increments of growth were obtained by extending the daylength to 24 hours; and (iv) these further increments were clearly increments in rate of growth. It seems from these results that extended daylength provides other growth factors besides those substituted for by gibberellic acid. It may nevertheless still be true that the main stimulus to vegetative development in long daylengths comes from a native gibberellin-like substance.

In view of P. A. Thompson's observations on the effect of gibberellic acid on fruit set, reported in the next section, records of truss size, flowering and fruit set were also taken on the plants of the above experiment. Gibberellic acid increased the total length of the trusses: at 20 $\mu$g. per plant the increase was beneficial, but at the higher dosage rates the trusses became so long as to be unacceptable horticulturally. The number of flowers per truss was also increased, but at the higher dosages the fruits did not set. The highest fruit yields were from the plants treated at 20 $\mu$g. At this dosage the mean number of fruits under short days was increased to 12·2 per plant as compared with 0·8 per plant in the controls, and under long days the corresponding increase was from 4·2 to 9·2 fruits per plant.

These increases in fruit yield were the result of the stimulating effect of gibberellic acid on the general growth of unchilled plants. Chilled plants would have been expected to show a smaller response. Careful timing of gibberellic acid treatments might minimize the undesirable effect on fruit set and open the way for a practical use of this substance in the culture of strawberries by forcing. (C. G. Guttridge.)

*Development of the Flower Truss*

The treatment of strawberry plants with gibberellic acid has a pronounced effect on the flower truss. In treated plants the truss emerges earlier and grows taller and more upright than in untreated plants. Experiments were designed to study this response and to provide information on the number of flowers per truss and on subsequent fruit development.

Plants of Talisman with inflorescences already present in the bud were brought into the glasshouse in late September. They were then treated with gibberellic acid twice weekly at 6·25 or 3·12 p.p.m. for four weeks, beginning

a week after their introduction to the glasshouse. The time of appearance of the first flowers was not recorded, but counts were made of the numbers of flowers produced per truss and the numbers of fruits set. These showed that treatment with the growth substance approximately doubled the number of flowers per truss at the lower treatment level (14 increased to 27) and trebled it at the higher level (14 increased to 42). However, none of these extra flowers set, and the number of fruits formed per truss was lower after the chemical treatments than in the controls.

In another experiment, plants of the same variety were placed in the glasshouse in early January and treated with gibberellic acid at 5, 2·5 or 1·25 p.p.m., twice weekly for a month from one week after their introduction. The flowers opened earlier after treatment: at the highest dosage level the difference in flowering date between the treated and untreated plants was about fourteen days. The number of flowers per truss, however, was not affected. The percentage set of fruit was increased by treatment with gibberellic acid at 1·25 p.p.m. (45% to 69%) but drastically reduced at the highest treatment level (45% to 4%), and it seemed clear from this and from the experiment described above that dosages above a certain level produced some form of infertility in the flowers. To examine this probability, all flowers opening on some of the treated and untreated plants in the second experiment were emasculated and bagged to prevent chance pollination, and pollinations were then attempted from treated to untreated plants and *vice versa*. Flowers on plants which had been treated with gibberellic acid set only 4·2% of fruits in response to pollen from untreated plants; but the flowers on the latter set 25% of fruits with pollen from the treated plants. Pollen in the treated plants was abundant and appeared normal, and it seems likely that the sterility induced by gibberellic acid resulted from infertility of the carpels.

In the first of these experiments very large increases in flower numbers per truss resulted from gibberellic acid treatment. The strawberry inflorescence is a dichasial cyme, and therefore potentially of unlimited size. It seems possible, therefore, that a useful increase in crop might be obtained if a practical method could be found of increasing the number of flowers on each truss. To gain information on this point, a preliminary study was made of the weights of successive fruits in the truss and of the effects of one fruit upon another. Talisman was found very suitable for this work, as it produces a very regularly-shaped truss with fruits which are easily designated as primary, secondary, tertiary, etc. It was found that the average weight of primary fruits was approximately twice that of secondaries, and that these in turn were approximately twice the weight of tertiary fruits. From this it would appear that increases in the complexity of the cyme are likely to be of only marginal value for increasing crop weight, and much less effective than increases in total numbers of inflorescences.

In Talisman the first two branches of the inflorescence do not arise at the same point. This means that the upper branch is more closely associated with the primary flower than the lower branch. It was found in these experiments that this association of the primary flower with the superior branch

system of the cyme regularly reduced the extent of branching and also the size of the secondary and tertiary flowers, and delayed the date of emergence of succeeding flowers on the side of the truss carrying the primary flower. These seem likely to be direct competitive effects of the primary flower on the development of subsequent flowers. (P. A. Thompson.)

*Nutrition*

In a series of nutritional experiments started during the year, strawberry plants were grown in a mixture of one part peat and three parts sand in 5-inch 'Whalehide' pots. The pots were watered twice weekly with a complete nutrient solution (prepared to a formula kindly supplied by Dr. C. Bould, of Long Ashton Research Station) used at the recommended strength and at one-ninth, one-third and three times this concentration.

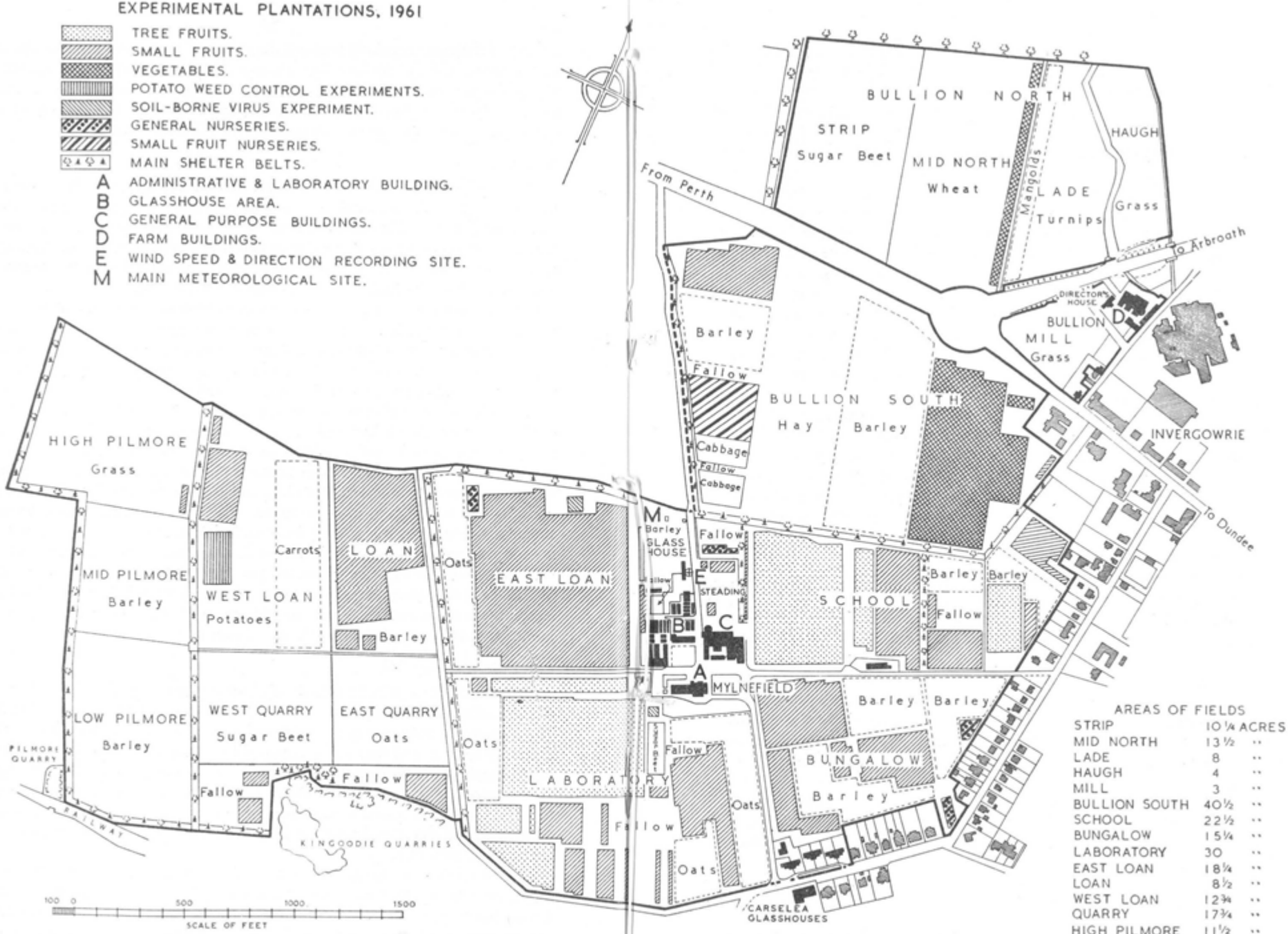
In an experiment with *Fragaria vesca*, vegetative development was proportional to the nutrient level. This was clearly apparent from the numbers of runners emerging and of leaves produced. In contrast, the number of fruit trusses initiated decreased with increasing nutrient level, especially when this was raised from normal to three times the normal.

Two further experiments, using the same four levels of nutrition, were carried out with the variety Talisman, one in a glasshouse in the autumn and the other in a growth cabinet with a constant daylength of 14 hours. In the glasshouse experiment, in addition to the expected vegetative responses, there was a slight, probably insignificant increase in the number of trusses initiated per crown as the nutrient levels increased. In the growth cabinet experiment vegetative development markedly increased with increasing levels of nutrition, and, in contrast with the experiment on *F. vesca*, increasing nutrition did not reduce the number of trusses initiated per crown, although it caused a delay in the onset of flower initiation. The effect on flower induction is still not clear, however, as this delay was roughly proportional to the increase in the number of leaves produced. (D. T. Mason.)

*Bio-assay of Gibberellins*

Most of the recognized methods of bio-assaying gibberellins depend on the ready availability of test plants, such as dwarf pea or dwarf mutants of maize. These require a preparatory growing period of about three weeks before they are ready for use, and frequent successional sowings must be made to ensure a ready supply of test material. Even when this is done it is not always easy to synchronize the time when one wants to do a bio-assay with the time when test material is in an optimum condition. To overcome these difficulties an assay has been developed which makes use of dry seeds, which are of course available at any time.

Initial trials were made with seeds of the dwarf pea variety Meteor, a large number of other dwarf pea varieties and the $F_1$ brussels sprout Jade Cross, but none of these were very satisfactory. The peas responded well to concentrations of gibberellic acid between 1 and 10 p.p.m. but required a large volume of liquid for soaking and were very variable in growth. The brussels sprout seeds grew well and needed only a little liquid, but were insufficiently sensitive to be useful. Seeds of the lettuce variety Grand Rapids,




# SCOTTISH HORTICULTURAL RESEARCH INSTITUTE
## MYLNEFIELD AND BULLION
## INVERGOWRIE

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however, were found to germinate well on pads of paper tissue soaked in gibberellic acid, and required only a small amount of liquid for the test. They also showed a high level of sensitivity to the chemical and were particularly suitable for the bio-assay of chromatograms. The technique finally used was a modification of one described earlier by Frankland and Wareing (*Nature, Lond.* (1959), **185,** 255).

Twelve lettuce seeds were sown on pads of paper tissue in small glass or perspex dishes of 1¼ in. diameter. The pad was moistened with 0·5 ml. of a solution of buffer, or of gibberellic acid in buffer, and the dishes were then placed in germinating trays in a saturated atmosphere in growth cabinets, at 60°F. Measurements of the hypocotyl length of the best ten seedlings were made four to five days after sowing. These measurements indicated a linear response to gibberellic acid between 0·025 and 0·5 p.p.m., and a significant response at 0·01 p.p.m. When chromatograms were assayed the strips were cut into small sections at equal intervals and the sections were placed in the glass dishes, covered with tissue and moistened with 0·5 ml. of buffer. Usually the dishes were left overnight to allow the material in the chromatogram to diffuse fully before the lettuce seeds were sown.

This test appears to be specific for gibberellins. There was no response to indole acetic acid or to kinetin, nor was there any synergistic effect between these substances and gibberellic acid when they were applied together over a range of concentrations. No response was found to the following growth substances, at concentrations between 0·01 and 100 p.p.m.: 2, 3, 5-tri-iodobenzoic acid, $\beta$-(3-indolyl) propionic acid, 1-naphthylacetic acid, phenylacetic acid, naphthalene acetic acid, 2-naphthoxy acetic acid, $\gamma$-(3-indolyl) butyric acid, 2, 4, 5-trichlorophenoxy acetic acid.

The activity of a number of gibberellins was examined, and it was found that $A_3$ and $A_7$ were the most active, that $A_4$, $A_1$ and $A_9$ showed less and $A_5$ very much less activity, and that $A_8$ was practically inactive. An experiment to investigate the possibility that $A_8$ might act as a competitive inhibitor to $A_3$ gave negative results.

The lettuce-seed test was also used to determine the $R_F$ values of the different gibberellins in six different solvents. It was found that in solvent systems of *iso*-propanol or *n*-propanol, water and ammonia, all the gibberellins examined had approximately the same $R_F$ values. The best spread of values was obtained with a solvent system containing *n*-butanol, ethyl acetate and ammonia.

It is believed that this test will be very suitable for the chromatographic examination of extracts of strawberry plants for gibberellins, and that it should be possible, where necessary, to separate different gibberellins in such extracts. (P. A. Thompson.)

*Development of the Strawberry Fruit*

Workers elsewhere have obtained evidence which indicates that the development of the strawberry receptacle is closely correlated with the presence of fertilized achenes. Experiments designed to test the validity of this concept and to investigate the nature of the control are described below.

In one experiment all the secondary flowers of a batch of Talisman plants were tagged at anthesis with labels recording the dates of opening. The flowers were hand pollinated, and then at intervals of 4, 6, 8, 10 or 12 days after anthesis all the achenes were removed by scraping with a plastic label. The surface of each receptacle was then covered either with a lanolin/water emulsion (50/50 w/w) or with a solution of 2-naphthoxy acetic acid in a lanolin/water emulsion at concentrations of 0·1, 0·03, 0·01, 0·003 or 0·001%. The size of the receptacles was measured at the time of achene removal, and again at maturity, with a pair of vernier calipers, by measuring two diameters at right angles at the broadest part. Measurements of the fresh weight and volume of each receptacle were also made at maturity. It was found that removal of the achenes resulted in the immediate cessation of receptacle growth unless 2-naphthoxy acetic acid was applied. The effectiveness of this chemical as a substitute for the achenes varied with the length of time for which the latter had been retained after pollination. No concentration produced effective stimulation when the achenes were removed as early as four or six days after pollination. When they were retained for eight days the minimum concentration of the growth substance required for effective stimulation was 0·1%; but after ten days the minimum requirement dropped to 0·03%, and after twelve days to 0·003%. This suggests an increased effectiveness of 2-naphthoxy acetic acid of approximately 30-fold during the four-day period 8-12 days after anthesis.

Attempts were also made to produce parthenocarpic fruits of the male-sterile variety Tardive de Leopold by applying various growth substances to plants growing in the glasshouse during the winter, when there was little risk of pollination. All flowers opening over a period of about three weeks were treated with one of the following compounds at either $10^{-1\cdot5}$M, $10^{-2}$M or $10^{-3}$M: $\gamma$-(3-indolyl) butyric acid, 3-indolyl acetic acid, 2-naphthoxy acetic acid, $\beta$-(3-indolyl) propionic acid, $\alpha$-naphthalene acetic acid, phenyl acetic acid.

At the highest treatment level practically all the receptacles were killed whichever growth substance was used. $\gamma$-(3-indolyl) butyric acid at $10^{-2}$M was the only treatment which produced any fruits comparable to control fruits produced after hand pollinations. In this treatment five out of fifteen fruits matured, four of them on one plant. Slight initial stimulation of growth in a few fruits was produced by treatment with $\alpha$-naphthalene acetic acid at $10^{-3}$M and by 3-indolyl acetic acid at $10^{-2}$M. It was noted that whenever the receptacle responded even slightly to a treatment, the carpels also increased in size.

It had been found previously that if plants bearing developing fruits were treated with maleic hydrazide at 1,500 p.p.m. the further development of the achenes was sometimes prevented, with or without a corresponding effect on receptable development, depending on the time of spraying. In a further experiment in 1961 the maleic hydrazide was applied either before anthesis or 3, 6, 9 or 12 days after anthesis of the primary flower. These treatments, together with an untreated set of controls, were combined factorially with twice-weekly spray applications of 2-naphthoxy acetic acid at 0, 50, 100, 200

or 500 p.p.m. Records were made of the date of opening of every flower in the experiment, the weight of each individual primary and secondary fruit when ripe, and the numbers of viable and aborted achenes on representative samples of the fruits.

Maleic hydrazide applied before anthesis or 3, 6 or 9 days after it clearly modified the appearance of all the fruits. When application was delayed until the twelfth day no effect was recorded in the appearance or weight of the great majority of the ripe fruits. Application made before anthesis almost entirely prevented receptacle development, and with the 3-day treatment also the final size was very restricted; but where the maleic hydrazide was applied 9 days after anthesis the final size of the fruits, though on average less than that on the controls or on the plants treated 12 days after anthesis, was within the normal range for the variety. Treatment with 2-naphthoxy acetic acid increased the size of the fruits on the plants which received maleic hydrazide 9 days after anthesis, but apart from this it was of marginal efficiency in reversing the effect of maleic hydrazide. At 200 or 500 p.p.m. it tended to restrict development severely, especially in plants not treated with maleic hydrazide.

The counts of achenes showed that the maleic hydrazide treatments applied either before anthesis or 3, 6 or 9 days after it almost entirely prevented the formation of viable achenes; but treatment 12 days after anthesis had little or no effect on achene viability. These results confirmed those of the previous year, in which a marked change in the response of both the achene and the receptacle to maleic hydrazide was found to occur about ten days after anthesis. Treatment with increasing levels of 2-naphthoxy acetic acid progressively reduced achene viability in plants not treated with maleic hydrazide.

Sections were made of immature fruits from plants treated with maleic hydrazide at various intervals after anthesis. These showed that maleic hydrazide applied at or very soon after anthesis prevented development both of the embryo and of the endosperm, but that if application was delayed for a few days the endosperm appeared to develop normally, even though the embryo was still inhibited.

Sections were also made of receptacles taken from normally developing flowers from about six days before until twelve days after pollination. These showed that the embryo-sac is fully developed by about two days before anthesis, and that after pollination the fusion nucleus starts to divide sooner than the embryo nucleus and forms within six days a free-nuclear endosperm with numerous nuclei. After ten days the endosperm starts to become cellular and forms a layer one cell deep around the periphery of the embryo sac. The embryo at first divides very slowly but starts to grow rapidly between the seventh and tenth days, by which time it is clearly visible on a well-developed suspensor. (P. A. Thompson.)

*AMO 1618—a Growth Retardant*

AMO 1618, when applied to Chrysanthemums, Climbing French beans and a few other species, has the effect of shortening internode lengths, thus reducing

plant height. Morphologically, this is the opposite effect to that induced by applications of gibberellic acid. Chiefly because the latter substance inhibits fruit truss initiation in the strawberry, it seemed worth while to test the effect of AMO 1618 on this plant. Two experiments were carried out. In the first, the roots of lifted plants were soaked for 24 hours in AMO 1618 solutions at concentrations of up to 1000 p.p.m., after which the plants were potted. Observations on growth were made at intervals but no effects of the chemical were seen. In the second experiment, AMO 1618 solutions were sprayed onto established plants (var. Talisman) growing in pots in the glasshouse. After seven applications on alternate days at concentrations of up to 500 p.p.m., again no responses were observed. Moreover, AMO 1618 did not suppress the effect of gibberellic acid on the strawberry. Newer chemicals, effective on a wide range of species, have recently become available and are being tested. (C. G. Guttridge.)

## PHYSIOLOGICAL INVESTIGATIONS WITH OTHER SPECIES

### *Gibberellic Acid on Apples*

Gibberellic acid has on several occasions been reported to act as an inhibitor of flower-bud formation in tree fruits, including cherry, plum and peach but not apple. In the summer of 1960, branches on trees of six varieties of apple (Bénédictin, Delicious, Madresfield Court, McIntosh Red, Lord Derby and Laxton's Superb) were selected, and treatments allocated at random to the branches on each tree. Sprays of gibberellic acid at 10 and 50 p.p.m. were applied at approximately weekly intervals from 31/5/60 to 29/8/60, a total of fourteen application dates. Control branches were untreated. The trees used were dwarf bushes on M.IX, approximately eight years old.

Spur counts made on 11 May 1961 showed that the treatments had reduced flower-bud formation in all six varieties. Of 160 spurs counted on the unsprayed control branches, 64 (40%) had flower buds, whereas of the 197 spurs on the sprayed branches (taking the two levels of treatment together) only 29 (14·7%) had flower buds. There was also a very pronounced inhibition of flower-bud formation on the new wood of Laxton's Superb. In contrast to reports on *Prunus*, bud-burst in spring was not delayed. It remains conjectural whether a natural inhibitor system based on the presence of gibberellin-like substances influences flower formation in apples.

### *Poinsettias*

Poinsettia (*Euphorbia pulcherrima*) is a short-day perennial plant, forming flowers, and the associated coloured bracts, under conditions of short day-length. Its photoperiodic responses are similar to those of strawberry, but unlike those of most short-day annuals, in that flower formation occurs more freely as the growing temperature is lowered. Because of this, a pilot experiment was set up to test whether flower formation was inhibited, as in the strawberry, by gibberellic acid. Plants were sprayed twice a week with solutions of 10, 5 or 2·5 p.p.m. of gibberellic acid together with 0·5% Shellestol. For the duration of the treatments (13 applications covering 6½ weeks)

the plants were kept under short days, and were then returned to long day-lengths. The unsprayed control plants subsequently flowered about 6 weeks after the cessation of treatment. The plants treated with gibberellic acid at 2·5 and 5 p.p.m. levels were considerably delayed in flowering, and flowering in those treated at the 10 p.p.m. level was almost completely inhibited, although they did produce a few flowers several months later.

In a second experiment gibberellic acid was applied weekly by spray from 25 October until 23 November, at concentrations of 2·5, 5, 10, 20 or 40 p.p.m., control plants being left unsprayed. During this time the plants were in natural short days. On 30 November they were returned to a long photoperiod, consisting of natural day extended to 24 hours of continuous light by the use of incandescent lamps. A further set of controls was kept in continuous light throughout the duration of the experiment. These latter plants did not flower. Again, gibberellic acid delayed flowering and reduced the density of bract coloration, although even with a dose of 40 p.p.m. per week some of the plants produced a few flower buds and some weak coloration. In both experiments gibberellic acid increased the elongation of internodes.

Although complete inhibition was not obtained, it seems possible that this species may be grouped with strawberry and *Kalanchoe bloesfeldiana* as a short-day plant in which flower induction is inhibited by gibberellic acid. The failure completely to inhibit flower formation by the treatments may have been due to metabolic changes induced by the short-day exposure before the level of gibberellic acid in the plant had been built up to an inhibitory concentration. (C. G. Guttridge.)

## FIELD INVESTIGATIONS ON STRAWBERRY

The frost on 26-27 May caused serious damage to strawberry flowers in Laboratory and South Bullion fields. Redgauntlet was the most seriously affected, with about 50% of the flowers partially or completely killed.

About three acres of strawberries for experiments and runner beds were planted in the north-west part of Bungalow Field in spring 1961. Their growth has been exceptionally good, and it is obvious that this site is much more suitable for strawberries than the South Bullion site where the 1960 plantings were made. The increased strawberry acreage at Mylnefield has led to the regular use of the Ferguson steerage hoe for inter-row cultivations, and when fitted with 'spiders' (Reekie weeders) this implement has proved superior both to rotary cultivators and to a mechanized tool frame. On 3 November the strawberries (excluding runner beds) in Bungalow Field were sprayed with simazine at 1 lb. active ingredient per acre, which prevented the growth of chickweed during the winter.

### *Seasonal Growth Pattern*

Records collected from May 1960 until November 1961 are being used to build up a composite picture of the growth and development of Talisman strawberry plants under field conditions over two growing seasons. It appears that leaf initiation and emergence are both retarded by the development of the fruit. Petiole length in the cropping year, 1961, reached its

maximum in mid-May and then decreased rapidly, whereas the deblossomed maiden plants in 1960 showed no decline in petiole length until the end of August. This work is being extended. (D. T. Mason.)

*Temperature and Flowering*

Cloches were again used, this time with the varieties Talisman and Cambridge Rearguard, to study the effect of temperature on the flower initiation of strawberries in the field. At night, the air temperature under the cloches averaged about 3°F higher than that outside. Dissections of Talisman showed that cloching from 8 September until 6 October doubled the number of trusses initiated, a result in contrast with that of the previous year, when cloching reduced truss initiation. The explanation of this apparent contradiction may be that maximum flower initiation in non-defoliated plants is obtained only under narrow temperature limits. It is now proposed to examine accumulated temperature records for the past eight years in an attempt to elucidate further the role of temperature in flower initiation in the field.

The crown samples of Cambridge Rearguard have still to be dissected. Since it is apparently not well adapted to the Scottish climate, this variety may prove to be a sensitive indicator of temperature effects on flower initiation. The records for both varieties will be extended by flower counts in summer 1962. (D. T. Mason.)

*Defoliation*

During the winter of 1961-62 dissections were again made of sample crowns taken from defoliated and intact plots of the eight varieties in a Scottish Fruit Trials variety trial at Mylnefield. Defoliation on 11 August 1961 was found to have considerably increased the average numbers of inflorescences per crown in Talisman and Redgauntlet, the increase in Redgauntlet being from one per crown to two per crown. The latter figure is the highest average number of trusses found here in crowns from the field during six years of study. Defoliation in 1961 had little or no effect on flower initiation in Cambridge Vigour, Cambridge Rearguard or Merton Princess, and actually depressed it in Royal Sovereign, Senga 54 and Senga Sengana. In general the numbers of trusses initiated at Mylnefield in autumn 1961 were exceptionally high. Yields of fruit recorded in 1962 should provide more data for assessing the relationship between yield and truss number.

Five varieties—Cambridge Favourite, Cambridge Rearguard, Redgauntlet, Royal Sovereign and Talisman—planted in South Bullion Field in spring 1960 were defoliated for the first time in the autumn of 1961. The treatments included complete defoliation on either 29 July, 14 August or 5 September, and partial defoliation (removal of old leaves only) on 14 August. The dissection results are not yet complete, but the partial defoliation of Talisman seems to have been as effective as complete defoliation. This, if confirmed, will be a result of considerable physiological interest. In the other varieties the differences due to defoliation were not large, because flower initiation in the intact plants was good.

Defoliation by means of various chemicals instead of by the usual method of mowing was carried out in co-operation with the Pomology Department. Details of the chemicals used appear on page 21. A general study is being made of the physiological effects of these chemicals in relation to the degree of defoliation. (D. T. Mason.)

*Cold Storage*

In the past, runners have been lifted for cold storage at any time during the period from November to February, taking care only to avoid storing plants which had commenced spring growth. To extend information, an experiment was set up in 1959-60 to test the effect of lifting and storing plants in the autumn rather than in early spring. Whilst autumn lifting involves a longer storage period, which increases the costs, a certain amount of winter damage is avoided and more green leaves may survive to help the establishment of the plants in the following summer. In this experiment, runners of Talisman and Redgauntlet formed in 1959 were lifted in either November or early March and stored at 28-30°F in 200-guage polythene bags until they were planted in the field in 1960, on either 20 April, 18 June, or 15-16 July.

The lifting date had little effect on later vegetative growth, although the autumn-lifted plants grew slightly more vigorously than the spring-lifted ones when planting was delayed until July. Flower truss counts in 1961 showed no differences. Unfortunately the crop was severely reduced by frost damage to the flowers, so that any small yield differences possibly due to plant vigour were masked. In view of the extra cost, storage over the longer period would not on present evidence appear to be worth while, although it has the merit of completely avoiding the danger of storing plants which have commenced spring growth. (D. T. Mason, C. G. Guttridge.)

The possibility of obtaining a small out-of-season crop in late summer by means of cold storage has aroused much interest in parts of England. Because this crop is carried on trusses already present in the plants during storage, picking can be timed at will by varying the planting date. To try out this technique, cold-stored runners of Cambridge Favourite, Cambridge Rearguard, Cambridge Vigour, Merton Princess, Redgauntlet and Talisman were planted out in Bungalow Field in 1961 on 12 and 26 May. Establishment was good despite the exposed nature of the site. Total yields per plant following the planting on 12 May varied from 2·4 oz. for Redgauntlet to 0·7 oz. for Cambridge Rearguard, and the yields from the later planting were lower. Merton Princess was characterized by very large first fruits (mean 0·9 oz.) followed by very small fruits from the secondary and tertiary flowers. The bulk of the fruit from the planting on 12 May was picked between 24 July and 15 August, and that from the planting on 26 May from 2 to 19 August. From the standpoints of yield and the size and quality of fruit, Redgauntlet appeared to be the most suitable of the six varieties for this type of cropping. A late summer crop of the size described would probably not in itself justify the trouble and expense of cold-storing the plants, but as the beds can be retained for normal cropping in the following year the system may still have economic possibilities.

Since it is considered that strawberries will not ripen satisfactorily in the open in Scotland after the end of August, cold-stored runners intended for cropping in September and October were planted on 20 June and 13 July under Dutch lights. The varieties used in this case were Merton Princess, Redgauntlet and Talisman. Overhead irrigation was used during the early stages, and the growth of the first planting was so good that most of the leaves had later to be removed to improve the air circulation around the developing fruits. The plants of the second planting grew less vigorously and did not need this treatment. All the plants were covered with the lights when the fruits started to swell, but despite copious ventilation mildew was a serious problem. Total yields per plant from the planting on 20 June were 2·2 oz. for Redgauntlet, 1·6 oz. for Talisman and 1·4 oz. for Merton Princess, and the yields from the planting on 13 July were lower.

Approximately 44,000 strawberry runners were placed into cold storage at Mylnefield early in 1962, partly for experiments here and at the Scottish Agricultural Colleges and partly on behalf of growers, for trials under commercial conditions on their own holdings. (D. T. Mason.)

*Maleic Hydrazide for Runner Control*

The 1960-1961 Report described an experiment on the use of maleic hydrazide to control runner production in the strawberry varieties Talisman, Redgauntlet, Cambridge Favourite and Cambridge Vigour. The plants were sprayed in 1960, their maiden year, with solutions of maleic hydrazide at a standard rate of approximately 60 gal. per acre, at the following concentrations and times: (i) 0·3% on 22 June; or (ii) 0·2% on 22 June and 0·15% on 25 July; or (iii) 0·15% on both 22 June and 25 July. The first crop of fruit was picked and recorded in the summer of 1961. This crop was reduced by spring frost damage to the flowers, and only small yield differences were found between the various treatments. No effects could be attributed to the applications of maleic hydrazide. Counts of the flower trusses, however, showed that these were in all cases fewer, and sometimes markedly so, after treatment with maleic hydrazide. In the most extreme case, Talisman plants which had received treatment (ii) produced only 5·8 flower trusses per plant, compared with 9·6 trusses on control plants whose runners in 1960 were removed by hand. Reductions in several other treatments varied from 20-25%. In past years the numbers of trusses in strawberry experiments have been found to be closely correlated with yield, and it seems very likely that in the absence of frost damage substantial reductions in crop weights would have been recorded as a result of the maleic hydrazide treatments of the previous year. This is the first time in four years of trials that maleic hydrazide has produced a general reduction in flower truss numbers at application levels which caused little or no damage to the parent plants. (P. A. Thompson.)

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# GENETICS

G. HASKELL

## *RUBUS* INVESTIGATIONS

### *Variability of Local Wild Blackberries*

The 33 families of blackberry reported last year as having been field planted have not yet flowered and fruited, and so it has not been possible to identify them. In 1961 the individual families were highly uniform for major morphological characters. Height measurements were made on the 10 plants of each so that the intra-family variation for this characteristic could be calculated: coefficients of variation were determined and were found to range in value widely, from 9 to 51%. These data, it is hoped, will help to reveal the type of apomictic breeding system present. It is postulated that a breeding system based almost completely on apospory would give rise to families having very low coefficients of variation, the lack of crossing-over making them highly stable from one generation to another. When arranged according to increasing variability, the families should reflect increases in the frequency of diplospory, since this system involves cytological crossing-over and so provides for increased, though limited, variability among the offspring; although the variability, in turn, may be influenced by the degree of heterozygosity. This should be the general position with apomictic progenies, since apomictic polyploid Rubi 'throw' true sexual seedlings only occasionally. Some of the variability could, however, be due to such occasional occurrence of true sexual reproduction *within* the species, the actual extent of which is as yet unknown.

Two other wild blackberry families, from seed harvested in West Middlesex, had low coefficients of variation, which indicates that a high variability is not necessarily obtained in apomictic progenies grown in a more northerly environment than that of their mother plant.

It is postulated that, of a total of 344 wild blackberry forms recorded in Great Britain, those which have the widest distributions and are recognized by botanists as being stable species will eventually be found to include the ones which have the lowest coefficients of variation and a predominantly aposporous breeding system. Aspects of distribution, speciation and variability are to be further investigated, and it is hoped eventually to link the biometrical data not only with the taxonomy and general distribution of species but also with the cytology of their gamete formation.

### *Seed Size and Population Vigour*

Seeds from each of several *Rubus* species were divided into three size groups (largest, smallest and the remainder) and sown, and the resultant seedlings planted into the field. In selfed progenies of the loganberry (a hexaploid hybrid of blackberry-raspberry parentage) 4% of the seedlings died in the population derived from large seeds and 7% in that derived from the

smallest seeds. The proportions of small-sized plants were 12% and 18% in the two populations respectively. First-year growth was generally only slightly greater in plants derived from large seeds than in those from small seeds. The possibility of a relationship between reduced vigour and possible changes in chromosome number associated with extreme seed size selection has yet to be investigated.

In families obtained by selfing five commercial raspberry varieties, 30% of the seedlings died in the populations derived from large seeds and 25% in those derived from small seeds, while the proportions of small seedlings were 5% and 4% in the respective classes. These differences were considered attributable mainly to the absence of dead or small seedlings in the population derived from small seeds of Malling Landmark, a variety which had 36% of these in populations derived from its large seeds. In contrast to loganberry (in which the percentages of dead seedlings and weak seedlings were highest in the populations derived from small seeds) the primary species *R. idaeus* suffers immediate depression from inbreeding and segregates for genetic lethals or semi-lethals. This difference between the behaviour of raspberry and loganberry may have occurred, therefore, because the types carrying lethals and semi-lethals among small seeds of *R. idaeus* fail to germinate, whereas among larger seeds they manage to germinate but die after planting out. Further morphological and cytological studies will be made on these progenies.

*Breeding Thornless Tetraploid Blackberries*

The thornless segregants of the cross Merton Thornless (4*x*) x Himalaya Giant (4*x*) commenced to flower and fruit for the first time in 1961. Many of the plants were highly vigorous vegetatively despite their lack of spines, although absence of the latter was at one time held to be detrimental to plant growth in the blackberry. Of the 81 thornless seedlings, all of which overwintered satisfactorily in the field, 55 flowered and 38 also fruited. The fruit qualities were scored and 14 plants (two with fruits of markedly good quality) were noted as possible selections.

The same thornless plants were found to be segregating also for hairy and sub-glabrous stem types (65 sub-glabrous : 18 hairy). This a close fit to a 3:1 ratio, i.e., segregation for a simplex state with chromosome assortment. Crane and Darlington in 1927 reported a tetraploid *Rubus* hybrid in which one character showed polyploid segregation and the other apparently did not; but this they attributed to differences in the pairing relationships of chromosomes of different parental types. Other examples of apparently different ploidy segregations have been recorded within polyploid *Gossypium* and *Gillia*. It is proposed to test the gene in blackberry for homology with that controlling the sub-glabrous/hairy difference in raspberry.

*Sex-differentiation in* Rubus

Although most true blackberries and raspberries are hermaphrodite, genes are known which convert plants into males, females or even neuters. The north-west American polyploid trailing blackberry, *R. macropetalus*, which is of potential value for *Rubus* improvement in Britain, occurs regularly

in two forms: female plants having small flowers with small petals, and male plants with large petals. Rudiments of the other sexual organs are present in each. There is a tendency for the female plants to commence flowering before the males. A population raised at Mylnefield comprised 27 females and 19 males: as the female is the heterozygous sex and each generation is genetically a backcross, this was close to the expectation of 23 females and 23 males.

Biometrical studies were started on the relationship between leaf shape and sex-type. Using lengths and breadths measured on 5-leaf samples from each plant of this population, the figures for mean leaf index (mean length/mean breadth x 100) clearly indicated that the leaves of the female plants were relatively broader than those of the males. Furthermore, the frequency distribution of the indices indicated two peaks in both sex-type populations. As two chromosome-races of *R. macropetalus* have been recorded ($2n=56$ or 84), an attempt will be made to see whether leaf index is influenced by chromosome number as well as by sex. The biometrical data show that the female plants correspond to the 'foliolus obtusis' and the male plants to the 'foliolus acutis' types of the taxonomists. How such morphological differences have evolved, and their relationship to the outbreeding system of *R. macropetalus*, are questions as yet unanswered.

The female plants of *R. macropetalus* segregated for shape and quality of fruits. They were all very early and ripened only slightly later than raspberries. It is proposed to breed from the best-fruited selections and to investigate the possibility of selecting for an hermaphrodite strain. (G. Haskell.)

## *RIBES* INVESTIGATIONS

### *Variation in Yield Components in Black and Red Currants*

Red currants yield more reliably at Mylnefield than black currants. Differences between and within the species concern frost susceptibility of the flowers, numbers of flowers per inflorescence, proneness to running-off, fruit size and many other characters, all of which affect the final yield. Flower and fruit development have been followed in six varieties of black and six of red currant to assess the extent of such differences. Measurements were made from the time of bud opening until the fruit was ripe.

Red currants, as expected, produced almost twice as many flowers per strig as black currants. Red currants also showed much wider variation between varieties, from 11·7 flowers per strig in Raby Castle to 19·2 in Prince Albert and Red Dutch: black currants varied only from 8·7 in Janslunda to 11·2 in Rosenthal's Black.

Frost damage before pollination results in failure of flowers to open or in injury to the stigmas of opened flowers. It is thus reflected in the proportion of flowers showing successful pollination. An average of 71% of red currant flowers survived to this stage, compared with 56% in black currants.

A surprising feature revealed by the survey was that whilst a quarter of the pollinated flowers of black currant dropped before the fruit ripened, the proportion which did so in red currants was as much as a half. Most of the loss in black currants occurred soon after pollination, but in red currants the

drop proceeded steadily throughout the period of swelling, with a sharp increase before colouring. Part of this apparent difference may have been due to the longer period over which the red currant flowers opened.

Both kinds of fruit also showed intervarietal differences in all the characters studied, but the survey has at present covered only one season and the importance of these differences cannot yet be adequately assessed.

Similar studies are being made on families of black currant seedlings obtained by self- and cross-pollination of standard varieties.

*Growth Analysis*

Ideograms, obtained by pictorially plotting internode length against internode number, have been valuable for distinguishing between sweet corn types of varied origin (see p. 59).

To discover if this method could be of similar value in taxonomic and evolutionary studies of woody fruit plants, measurements were made on three plants of each of six varieties of black currant. Intra-plant variations were first compared for three types of one-year-old shoot: basal, terminal and axillary. Terminal and axillary shoots each gave consistent patterns, but the strongly growing basal shoots showed no such consistency. The latter were therefore omitted from the subsequent analysis.

Intra-varietal ideograms showed good agreement. Where one plant in the variety Goliath differed markedly from the others, subsequent examination confirmed that it was not true to varietal type. The six varieties tested showed a continuous progression from types like Seabrook's Black (with rapid spring growth, long and relatively few internodes and early cessation of growth) to the other extreme represented by Goliath (with slower spring growth, shorter and more abundant internodes and a second, late flush of growth). As this method of analysis is proving to be of practical value for black currant classification, it is proposed to extend the investigation to other varieties and to further *Ribes* species and their hybrids.

*The Breeding System in* Ribes

A survey is being made of pollen characters in several *Ribes* species. Large differences have been observed between the pollen grain size of different species and in the sculpturing of the sexine. Pollen grains of all species examined have germinated well in 15% glucose solution. An attempt will be made to relate the differences observed to other differences concerned with the breeding system. (A. B. Wills.)

## STRAWBERRY INVESTIGATIONS

*June Yellows*

Studies in progress since 1955 on the inheritance of June Yellows have confirmed that the casual agent is non-chromosomal. General conclusions from the investigation were summarized briefly in the 1960-61 Report and a full account is in course of publication.

The inheritance study is now concluded, but a minor study has been made of chloroplast distribution in the mesophyll of affected leaves. This has

shown that the chloroplast complement varies in different cells, some at one extreme having an apparently normal complement while others are completely devoid of chloroplasts: the majority of cells examined showed intermediate numbers. Little difference in colour was observed among the chloroplasts in expanded leaves. Extreme types of cell tended to occur in random patches, with gradients in chloroplast number occurring through the adjacent cells. Comparison of young and old affected leaves indicated that an increase in chloroplast number accompanied the disappearance of symptoms, although all the plastids observed appeared to be about equal in size. By contrast with these results, the mesophyll of a strawberry seedling which was a mixochimaera of green and mutant-yellow cells contained patches, variable in size, of each cell type, but no intermediate cell types were found. The chloroplasts of affected cells were yellow, and progressively became smaller from the time of leaf expansion until they finally disintegrated.

*Biometrical Analyses*

Studies were made on the variation of biometrical characters in a series of strawberry plants possessing 2 (diploid), 3, 4, 5, 6 or 8 (octoploid) complements of chromosomes. The types were separated graphically by plotting the breadth:length ratio of the stomata against the breadth:length ratio of the terminal leaflet, using measurements from ten leaves of each plant. A triploid plant occurring in the progeny from an $8x$ x $2x$ cross was found by this method to lie between the areas occupied by diploid and tetraploid types, and away from the area occupied by the octoploid putative parent. This finding confirmed other indications that the triploid seedling was erroneously labelled as to family origin.

Plants of the octoploid variety Talisman raised in a greenhouse differed markedly in terminal leaflet breadth:length ratio from plants of the same variety grown in the open, but there was no difference in the corresponding ratio for stomata. For plants to be successfully compared, therefore, a common environment is required.

Numerous and rapid stomatal measurements were made possible by the development of a technique enabling portions of the abaxial leaf epidermis to be stripped off by means of Scotch Tape. This method works well with plants from a wide range of genera. (A. B. Wills.)

SWEET CORN INVESTIGATIONS

*Adaptation at the Northern Limit of Maize Cultivation*

Sweet corn is the sugary-seeded form of maize, and may be found in cultivation on a limited garden scale in Perthshire as elsewhere in northern parts of Britain. It is very sensitive to such external factors as daylength, light intensity, soil temperature during germination and temperature prior to flowering, and is also readily attacked by the frit-fly (*Oscinella frit*). Hence the growing of sweet corn in eastern Scotland—approximately at its northerly limit of cultivation by man—affords interesting opportunities for investigating problems of environmental and genetical adaptation in an outbreeding species.

The detrimental environmental factors can be controlled to some extent by improvements in culture. Sowing in artificial heat reduces failures at

germination, and the use of soil blocks or 'Whalehide' pots in heated closed frames reduces the risk of damage by frit-flies. Hybrid vigour plays an important role in improving cold tolerance; and hybridity can also confer stability, or homeostasis, on the development and functioning of male and female inflorescences exposed to the contrasting conditions of long days and short nights. Hence, to be successful in Scotland a variety must have a high degree of heterozygosity and must also show heterosis. Two varieties previously recommended for growing in England—the $F_1$ hybrid North Star from New York State, and Canada Cross—a top-cross of C.13 (an inbred) with the variety Canada Gold—were considered the most likely to be adaptable to conditions at Mylnefield. A 'first-early' $F_1$ hybrid, Earliking from Minnesota, which performs well over a wide range of conditions in northern parts of North America, was also regarded as a potentiality. It is recognized that any strains selected must be early-maturing: this means that they must have originated—as the above three varieties have—as *su* mutations in the North American Flint (*Su*) maize types, rather than in Southern Dent types (cf. Haskell, G., *Genetica*, **28,** 308-44).

*Selection of a variety for Scotland*

Canada Cross, North Star and Earliking were included in a replicated trial in which the spacing was 2 ft. between the rows and 1 ft. between the plants within each row. Seeds were sown singly on 16 May in whalehide pots, which were transferred to open frames nine days later. The mean germination for all varieties exceeded 96%, and the seedlings were planted out on 13 June. A single harvesting was made on 27 September, when the percentages of plants which yielded marketable ears were North Star 75%, Canada Cross 68% and Earliking 59%. The low yield of Earliking was mainly attributable to severe frit-fly damage. It is not possible to predict a variety's reaction to this pest, since the insect does not occur in North America and selection against it has therefore not been made. All the varieties had relatively poor tassels, but there was sufficient pollination to provide adequate setting of seed. The quality of Earliking was excellent, and that of Canada Cross very good; but North Star, which had the most uniform ears, rather lacked sweetness.

Ears from open-pollinated silks of eight good plants selected for earliness were saved for seed. Six of these ears were from North Star and one each from Canada Cross and Earliking, and their seeds have been mixed to form a new composite variety of polycross origin. This represents an initial selection for our local conditions, and it will be further selected in 1962. The work here described is being done in collaboration with the Vegetable Crops Department. (G. Haskell.)

**TOMATO INVESTIGATIONS**

*Adaptation of Cultivated Tomatoes in Scotland*

As the cultivated tomato is inbred, variation within a variety can largely be attributed to environmental effects, with mutation playing a minor role. Yet varieties may show differences in the degree of correlation which occurs between characters—such as times of flowering and of ripening—which are regarded as being under polygenic control. Some analyses have therefore been started

to ascertain the degree of correlation between such characters when plants are grown in the northerly environment of Mylnefield, with daylengths and sunlight intensities which differ from those of southern Britain.

The number of leaves below the first truss was recorded for all the plants of seven varieties growing in a trial under commercial glasshouse conditions at Mylnefield in 1961 (see 1960-61 Report, p. 52). The flowering dates of the first trusses were also recorded. This was to determine whether a relationship existed between the two characters: if this should be so, then a discrete character like leaf number might be more useful than a continuously varying one like flowering time as an aid to the selection of earlier fruiting plants. It is already known that a correlation exists between times of flowering and fruiting. It was found, however, that all the varieties had an average of eight leaves below the first truss, except for Discovery, which had nine or more. Moreover there was no regular relationship within any one variety between the number of leaves below the first truss and the mean time of opening of the flowers on the truss. Flowering time itself, therefore, still seems the better criterion to use when selecting for earliness.

*Selection for an Early, High-yielding Variety Adapted to Scottish Conditions*

Three $F_3$ families, totalling 869 seedlings derived from the three best $F_2$ seedlings selected in 1960 (see 1960-61 Report, p. 52), were grown and reselected in 1961. The first elimination was for lateness in first flowering: whereas the plants of the $F_2$ generation had shown an overall range of 54 days in first flowering time, the $F_3$ plants came into flower within 14 days of each other, indicating that selection for early flowering in the $F_2$ had been effective, at least in reducing the range of time taken for the plants to commence flowering. At the fruiting stage plants were discarded if they had irregularly-shaped fruits, fruits with too many loculi or fruits that split easily. Final selection was made for the following characters: high total number of ripe fruits on the first three trusses; double second trusses, if segregating; absence of conspicuous 'green-back' during ripening, and its total absence on ripe fruits; absence of nipples at the tips of the fruits; and high grading and bright colour. Ultimately there remained only the plants—30 in number—which were selected as breeding parents for the $F_4$ generation. Of these the eight best lines have since been included in a trial with four Dutch $F_1$ hybrids, four standard varieties popular in Scotland and a 'potato-leaf' variety carrying a gene for uniform ripening.

*Segregation for Single and Double Second Truss*

Although the first trusses in two of the families selected were always single, the second ones were either single or double (bifurcated). Fourteen plants of family 1 had single second trusses and twenty had bifurcated ones. This does not differ significantly from the expectation of a 2:1 ratio of double to single, but differs from that of a ratio of 3:1. There was, however, a fit for a 3:1 ratio for double to single trusses in family 2. The anomalous ratio recorded from family 1 is interpreted tentatively as indicating that plants with a dominant gene for double truss were carrying also a linked recessive lethal; but that the

postulated lethal did not occur in family 2. It may here be noted that a recessive gene *bi* ('bifurcate inflorescence') is already known in tomato.

The bifurcated second trusses of potted plants produced on average four more ripe fruits than single ones in family 1 and two more in family 2. Therefore only plants with this type of truss have been selected for future breeding.

*Performance of Cultivated Tomatoes at Mylnefield*

In 1961 an initial variety performance trial was carried out in order to gain some knowledge of the behaviour of standard varieties used in Scotland, and with the further object of selecting the best of these for later comparison with our own selections. Particular attention was paid to grading. The results, summarized in Table 1, show that E.S.1 was outstanding and that Moneymaker and Ware Cross were also very good. Two Glasshouse Crops Research Institute varieties (G.C.R. 6 and 21) were apparently not well adapted to the growing conditions.

TABLE I

*Tomato variety trial, 1961: mean yield of ripe fruit per plant (grades A and B combined). (Data for 8 trusses only.)*

| Variety | Yield (lb.) | Variety | Yield (lb.) |
|---|---|---|---|
| E.S.1 | 7·9 | Dutch Victory | 5·8 |
| Ware Cross | 6·9 | Aldourie | 5·7 |
| Moneymaker | 6·9 | G.C.R. 21 | 5·1 |
| Discovery | 6·3 | G.C.R. 6 | 4·7 |
| J.R. 6 | 6·2 | | |

A further trial in 1962 will include Dutch $F_1$ varieties, Scottish standard varieties and the best of our own selections.

*Polygenic Selections within Inbred Lines*

A further generation of 'pleiocot' tomato seedlings was raised (see 1960-61 Report, p. 53). Plants from monocotyledonous seedlings produced offspring which were mostly dicotyledonous, though there were some 'monocots' and occasional 'tricots'. The plants from tricot seedlings produced mainly dicots, but also up to 3% of tricots, a few tetracots and an occasional monocot. It is clear that the whole gamut of pleiocotyly segregates as a single biometrical character and is controlled by the same polygenic system.

Some of the pleiocots grew abnormally. For example, one monocot seedling derived from a tetracot was very weak and straggly, and its growing point ended in a tubular structure. A monocot derived from a monocot produced a monstrous first leaf and later a shoot which had golden-edged leaves. Several of the monocot seedlings had an enormous cotyledon but nothing else. One tricot derived from a pseudo-tetracot parent was a dwarf, and its fruits had from 2 to 9 loculi. The dicot sibs were normal.

It is clear that within stable inbred lines, selection away from the norm—i.e., away from the typical dicotyledonous condition of standard tomato varieties—produces abnormalities in the stabilized hormonal balance of the plants. There is therefore strong evidence for correlated responses to selection even in highly inbred strains of tomato. The selection pressure will be maintained to determine what further abnormalities of morphology, growth and fruiting can be released by this technique. (G. Haskell, E. B. Paterson.)

## CYTOLOGICAL INVESTIGATIONS

### *Phase-Contrast Microscopy for Small Chromosomes*

Not long ago the chromosomes of such fruit genera as *Rubus*, *Ribes*, *Fragaria*, *Malus* and *Pyrus* presented technical difficulties to the cytologist. This was partly because of the small size and the uniformity of the chromosomes, which made it difficult to differentiate within the genome, and partly because the chromosomes sometimes failed to take up stains. The lengthy processes associated with microtome sectioning and staining often culminated in failure, and much time could be wasted on such unsuccessful endeavours. The tempo was considerably speeded up by the introduction of squashing techniques with aceto-carmine or aceto-orcein, but there were still failures to find suitably dividing cells. Further improvement followed the introduction of pre-fixatives such as para-dichlorobenzene, oxyquinoline and α-bromonaphthalene, which destroyed the spindles in meiosis and allowed greater opportunity for finding plates with the chromosomes widely spread. Examination of cells with high numbers of small chromosomes of similar size was thus made easier.

The counting of chromosomes, particularly in root tips, has been further facilitated by the use of the phase-contrast microscope. Even when modern staining and squash techniques are followed, chromosomes do not always take up stains sufficiently well to be viewed with clarity under the normal microscope. Yet they can be seen clearly under phase-contrast: even the satellites, difficult to observe in the best of preparations, may now be seen with greater clarity.

This means that nowadays root-tips can be collected in the morning and, if the cells are dividing, chromosome counts may be obtained by late afternoon. The combination of phase-contrast and modern squashing techniques undoubtedly represents a step forward in the routine counting of chromosomes in horticultural plants, as well as in more precise cytological studies on subjects such as chromosome morphology and genome analysis.

### Rubus *Cytology*

Stocks of the raspberries La France and Perpetuelle de Billard imported from France were found to be tetraploid ($2n=28$); but the Institute's stock of supposed Hailshamberry proved to be triploid ($2n=21$), not tetraploid as postulated. The Hailsham was once widely used as a tetraploid parent, but all the stocks recently examined cytologically in Britain have been found to be triploid. The cause of this change in chromosome number—if that is indeed what has occurred—is unknown. A small seedling raised from a small seed of selfed Malling Jewel proved to be diploid ($2n=14$), although it had been

selected as a possible haploid. One of the apparently polyploid seedlings which occurred in a family raised recently in the Pomology Department from open-pollinated flowers of a crumbly-fruited type of Malling Promise was found to be triploid; but an abnormal type of Malling Jewel having enlarged laterals and floral parts, and suspected of being a tetraploid mutant, was a diploid (Jennings, D.L., *Nature, Lond.*, **191,** 302-3). Several seedlings of selfed Loganberry were hexaploid ($2n=42$) as expected.

Eldorado, an American tetraploid cultivated blackberry, on selfing produced both diploid and tetraploid seedlings, which were morphologically distinct. The diploids ($2n=14$) had narrower leaves than the tetraploids ($2n=28$). *Rubus ulmifolius* var. *alba*, a variety which lacks anthocyanin and produces yellow-green berries, was confirmed to be a diploid.

The phase-contrast microscope allows examination to be made of the satellited chromosomes with greater accuracy than hitherto. All the diploid *Rubus* species examined have two satellites. Particularly interesting is the occurrence of five satellites, the highest number yet recorded in the genus, in a tetraploid wild blackberry from Angus. As this plant is also the most northerly *Rubus* which has been recorded for chromosome number in Great Britain, it would be interesting to know whether satellites have an adaptive function in relation to climate.

Ribes *Cytology*

Two large and two small seedlings of Seabrook's Black x *Ribes moupinense* bred by the Pomology Department had the expected chromosome complement of $2n=16$.

The occurrence of only one satellited chromosome in a hybrid between two *Ribes* species, both of which possess a pair of such chromosomes, was previously noted by Miss N. N. Tun (1960-61 Report). A cytological investigation of red currants was started in order to determine whether similar variations in satellite number occur in hybrids between more closely-related *Ribes* species. This investigation is still incomplete, but differentiation of satellite size has been seen in at least one variety. The differences are best seen in disjoined metaphase chromosomes, after pre-treatment with para-dichlorobenzene. (G. Haskell, A. B. Wills, E. B. Paterson.)

## PUBLICATIONS

### Research Papers

Haskell, G. (1961). Seedling morphology in applied genetics and plant breeding. *Bot. Rev.*, **27,** 382-421.
(This review discusses the use of seedling techniques as short cuts in genetical and cytoplasmic studies, and the relationships between seedling morphology and changes in ploidy. The economic applications of such techniques, particularly in plant breeding, are assessed. Correlations between seedling and adult characters may be useful, especially for fruit and forest-tree breeding, where there are long intervals before adult characters can be assessed.)

Haskell, G. (1961). The genetics of *Rubus* breeding. *Phyton*, **17,** 173-87.
(This paper examines the roles of diploidy and polyploidy in the genus *Rubus*, the use of 'wild' germplasm for cultivated raspberry improvement, the difficulty of retrieving recessive genes in polyploids, and problems of breeding from apomicts and species-hybrids in this genus.)

HASKELL, G. (1962). Some aspects of fruit genetics in Britain. *Der Züchter*, **32**, 33-40.
(Some recent advances made by the author and his associates in the genetics of British fruit crops are described. These include work on stamen patterns in top fruits, effects of polyploidy on distribution, genetics of the wild raspberry, and subsexual reproduction and correlated responses in apomictic blackberries.)

HASKELL, G., and HILL, J.[1] (1961). Segregation in tetraploid blackberries. *Heredity*, **16**, 354-8.
(A detailed analysis is here provided of the subject outlined on pp. 43-44 of the 1959-60 Report. The values of the statistic α are compared with those of tetraploid maize and tomatoes.)

TUN, N. N.,[2] and HASKELL, G. (1961). A squash technique for the small chromosomes of *Rubus* and *Ribes*. *Hort. Res.*, **1**, 62-63.
(This note describes a simple and rapid technique, involving pre-treatment, fixation, hydrolysis, and staining in Feulgen.)

WILLS, A. B. (1961). The rapid preparation of leaf epidermis strips. *Hort. Res.*, **1**, 120-1.
(A method is described for rapidly preparing leaf epidermis strips by the use of adhesive 'Scotch' tape. The strips, which appear to be undistorted, are useful for stomatal or epidermal cell measurements of a kind unsuited to impression techniques.)

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# VIROLOGY

C. H. CADMAN

None of the staff paid visits overseas this year but several visitors from Europe came to work in the department. Dr. G. Barabino, of the Institute of Plant Pathology, University of Milan, came in April to spend a year studying viruses affecting Italian grape vines, and has recently been awarded a scholarship for this work by the University of Milan. In July Mr. F. van der Meer, Institute for Phytopathological Research, Wageningen, spent two weeks comparing British soil-borne viruses with viruses isolated in the Netherlands from cherry, strawberry and red currant. Mr. C. J. Asjes, of the Agricultural University, Wageningen, came in August and spent six weeks as a student worker; and in November Mrs. Eeva Tapio, of the Agricultural Research Centre, Tikkurila, Finland, spent three weeks learning the techniques used here.

In April Miss Pat Duncan, who joined the staff in 1957, was appointed Assistant Experimental Officer. This left vacant a Scientific Assistant's post to which Miss Sheila Mearns was appointed. Miss Duncan herself left in February to be married.

Soil-borne viruses are still the major interest of this department, but the year has been one of consolidation rather than of new developments in their study. More information on the transmission of the viruses by nematodes and through the seeds of infected plants has helped to resolve some of the puzzling features of the spread and persistence of these viruses in the field. Detailed studies of the properties of these and of several other new viruses have posed time-consuming and somewhat unrewarding problems of handling and purification. In much of this work the electron microscope has been an invaluable, if crude, aid in following the fate of virus preparations.

## NEMATODE-BORNE VIRUSES

### *Identification and Properties*

Vineyards throughout Europe seem to be affected by virus diseases that cause loss of vigour and yield, and in Italy such diseases have become widespread and important in recent years because of the common use of grafting as a means of propagating vines. Two of these diseases, malformation and *giallume* (yellows), are most probably spread by nematodes, but this is not established. In Milan, all attempts to transmit virus mechanically from infected vines had failed, probably because the herbaceous test plants used resisted infection. At Mylnefield, however, viruses were readily transmitted mechanically from each of eight different infected clones of Italian vines to *Chenopodium* spp. and other herbaceous plants, suggesting that the environment in which the test plants are grown is of prime importance in the mechanical transmission of viruses from 'difficult' host plants. The Italian isolates are all distantly related serologically to arabis mosaic virus but closely re-

lated to North American and European isolates of grape vine fanleaf virus. However, the Italian isolates seem different in some respects; these differences are being studied and attempts are being made to infect healthy grape vines by grafting them to plants of *Chenopodium amaranticolor* containing the different virus isolates. (G. Barabino.)

Further work has shown that viruses isolated from blueberry (*Vaccinium corymbosum* L.) affected by necrotic ringspot disease in Illinois, Michigan and New Jersey are serologically indistinguishable from a virus isolated from *Gladiolus* in Ayrshire (see below), and are related to North American tobacco ringspot virus. The Ayrshire isolate came from plants imported from Canada, where tobacco ringspot virus is known to occur in *Gladiolus*. Although the occurrence of this virus in Britain and Europe has often been claimed, this would seem the first authentic record. Tobacco ringspot virus is thought to have a nematode as a vector; but there was no evidence of the virus in the soil at the Ayrshire site, nor is there yet proof that blueberry necrotic ringspot disease is contracted from the soil. However, it is interesting that blueberry seedlings readily became infected with arabis mosaic and raspberry ringspot viruses when grown in infective soil in the glasshouse. (R. M. Lister.)

Further experiments have confirmed that strawberry varieties differ in the rate at which they contract ringspot viruses when grown in soils containing infective nematodes. Of fifteen varieties tested, Redgauntlet was outstandingly the most susceptible to tomato black ring virus and Madame Lefebvre the most susceptible to arabis mosaic virus. The results with other varieties were equivocal. When grown in soil containing both tomato black ring and raspberry ringspot viruses, plants of most varieties became infected by only raspberry ringspot virus, or rarely by both. Strawberry varieties differ in their ability to support populations of *Longidorus elongatus*, the vector of both these viruses (see below), but there was no clear connection between this and proneness to infection. Differential 'pick-up' of the two viruses is at present inexplicable.

Tests on leaf samples have indicated that strawberry plants often become only partially infected by ringspot viruses. The propagation of crown cuttings from Talisman plants infected with raspberry ringspot virus seems to have confirmed this, because a high proportion of $\frac{1}{4}$-inch cuttings taken from the crown-systems of such plants produced young plants which were virus free. (R. M. Lister.)

In crops where nematode-borne viruses cause devastating diseases the degree of loss of yield is obvious. In others, such as sugar beet, where plants apparently recover from infection and grow normally, this is not so. A field experiment designed to assess the effects of different ringspot viruses on the yield of sugar beet showed that plots inoculated with arabis mosaic virus (89% of plants infected) yielded 18·9% less, and those inoculated with tomato black ring virus (52% of plants infected) yielded 10·8% less, than comparable plots of healthy plants. Both decreases in yield were statistically significant. There is no information yet to show to what extent sugar beet crops become infected with these viruses in the field. (A. F. Murant.)

Work on the properties of tobacco rattle virus was continued, and a study of the particle structure was begun in co-operation with workers in the M.R.C. Unit of Molecular Biology, Cambridge. (C. H. Cadman, J. Cathro.)

*Transmission and Dissemination*

In earlier experiments which established that *Longidorus elongatus* is a vector of tomato black ring virus, fewer transmissions were obtained than were expected from the level of infectivity of the soil from which the nematodes were extracted. It now seems that, to transmit efficiently, the nematodes need repeated access to a source of virus. A high proportion of turnip 'bait-plants' became infected with the virus when grown in pots of sterilized soil each of which received 50 *L. elongatus* hand-picked from soil in which artificially-infected cucumber plants had been grown for at least 8 weeks. High frequencies of transmission were also obtained when lots of 50 *L. elongatus* from soil of low infectivity were added to pots sown with virus-infected seeds of chickweed (*Stellaria media*) and cropped with turnip bait-seedlings. Although the infectivity of a soil may decline rapidly in the absence of infected plants, populations of *L. elongatus* can remain infective in the absence of any host plant for as long as 49 days.

Discovery of a vector for raspberry ringspot virus has been impeded by the lack of a suitable bait-plant: raspberry plants are inconvenient for use in short-term pot experiments. The spinach variety Toftegaard appears to be a differential host for the virus and was used in experiments which showed that *Longidorus elongatus* is a vector of raspberry ringspot virus. Experiments still in progress indicate that the virus may persist in the nematode for at least 42 days. Both adult and larval nematodes transmit the virus but larvae may be the more efficient vectors.

Transmission of both tomato black ring and raspberry ringspot viruses by *L. elongatus* has long been suspected, because of the frequent occurrence of the viruses together in soils and the correlation between the pattern of disease outbreaks caused by them and the distribution of this nematode. Although a useful clue, the correlation is probably fortuitous and merely reflects the events that have followed the introduction of sources of virus, either in the form of infected plants or infected weed seeds, into an extant population of nematodes. *L. elongatus* is widely though patchily distributed in association with many different types of soil and vegetation. The largest populations have always been found associated with strawberry crops; raspberry seems a less favoured host. Even so, pot experiments have shown that strawberry varieties differ in their ability to support populations of *L. elongatus*, perhaps indicating some kind of plant resistance to the nematode. (C. E. Taylor.)

Soil from sites of large outbreaks of tomato black ring and raspberry ringspot viruses is usually rich in *L. elongatus* and highly infective. The results of the transmission experiments suggest that the level of infectivity is mainly dependent upon the abundance of sources of virus. Support for this idea comes from other experiments which have shown that the infectivity of soil can be manipulated without greatly affecting the numbers of nematodes, simply by introducing or removing sources of infection. For example, poorly infective soil from a field that had previously borne a crop of infected

strawberry plants, and which contained infected weed seeds and many *L. elongatus*, was rendered uninfective by being kept rigorously weeded for 6 weeks, whereas comparable soil on which infected weeds had been allowed to grow became highly infective. Tomato black ring and raspberry ringspot viruses were re-introduced into the uninfective soil by sowing with infected seeds of chickweed (*Stellaria media*).

The role of infected weed seeds in the spread and persistence of other nematode-borne viruses is less clear. A pot experiment with arabis mosaic virus and uninfective soil containing large numbers of *Xiphinema diversicaudatum* showed that the soil became highly infective when cropped for 15 weeks with infected chickweed seedlings. However, insufficient tests have been made with soils containing arabis mosaic virus to know if these as frequently contain infected weed seeds as do soils containing the other two ringspot viruses. With tobacco rattle virus there is evidence that, in seed transmission as in other properties, this virus differs somewhat from the ringspot viruses. Tests with several weed species have shown that the virus is transmitted to a smaller percentage of the progeny than are the ringspot viruses. In two instances, progeny of *Myosotis arvensis* plants infected with a multiplying form were found to contain a non-multiplying form of the virus.

There seems little doubt, at least with tomato black ring and raspberry ringspot viruses, that infected seeds are important sources of infection in soils. The numbers of infected seeds found in soils from different disease outbreaks differ widely; this may be fortuitous, or perhaps reflects differences in age of outbreak or in the extent to which local strains of the viruses are transmitted through the seeds of common weeds. It is reasonable to suppose, but difficult to prove, that dissemination of infected weed seeds is a means of spread of these two viruses over a distance. A small proportion of the seedlings of *Stellaria media* that grew on air-dried soil from 50 yd. outside the site of a severe outbreak of raspberry ringspot virus in strawberry were found to contain both raspberry ringspot and tomato black ring viruses.

Transmission of these two viruses through the pollen and ovule of both raspberry and strawberry has been demonstrated, but there was some evidence in raspberry that infected pollen competed poorly with healthy pollen. It seems unlikely that pollen transmission is of any importance in the dissemination of these viruses in the field.

Attempts to detect virus in seeds by grinding them or their dissected embryos with 'Celite' abrasive powder and inoculating the sap to test plants largely failed, but virus was detected in very young seedlings germinated on filter paper in daylight. (R. M. Lister, A. F. Murant.)

*Trichodorus primitivus* (det. J. W. Seinhorst) extracted from soil from Elgin, Morayshire, was shown to transmit tobacco rattle virus. (W. P. Mowat, C. E. Taylor.)

*Control*

Weed control and the use of appropriate crop rotations may possibly be simple means of decreasing the infectivity and nematode content of soils, but chemical treatments, aimed at eliminating the nematodes, have given promis-

ing results. Of five different treatments applied in 1960 to infective soil at Coupar Angus, Perthshire, those containing DD were the most efficient and decreased the average population of *L. elongatus* per 500 gm. of soil from 126 to 9. Virus-free Talisman strawberry runners were planted on the experimental area in April 1961, and nematode populations have been estimated and the plants and soil assayed for infectivity at intervals since then. So far, this experiment has shown that treatment with DD effectively controls *L. elongatus*, but that, even where no chemicals are used, a period of winter fallow can result in an appreciable decrease in nematode populations and almost complete loss of soil infectivity. Field-scale experiments with DD at five other sites in the district, made with the aid of the Auchincruive soil-injector kindly lent by Dr. J. Grainger, have given similar results.

Following a report from the U.S.A. that adding sucrose and glucose to soil controls nematodes, some simple tests were made with soils containing *L. elongatus*. After exposure for 72 hr. to estimated concentrations of 10 and 20% sucrose in the soil water, 80-95% of the nematodes were dead. As some 18 tons of sugar per acre would be needed to raise the concentration to 10% in the top 9 in. of most soils, this scarcely seems a feasible means of control. (A. F. Murant, C. E. Taylor.)

### OTHER SOIL-BORNE VIRUSES

Work on the mode of transmission of viruses of the tobacco necrosis group has been hampered by lack of consistently infective soils. Samples from fields where naturally-infected plants occurred were usually uninfective when cropped with susceptible bait plants in the glasshouse. Although virus can sometimes be detected in the roots of plants grown in soil watered with infective virus, it is difficult to know if this is indicative of true root infection or merely of surface contamination of roots by free virus.

When French bean plants were grown in soil from a site in Ayrshire, the roots in six pots out of eight contained a tobacco necrosis virus. Virus could not be eluted from this soil, nor were any transmissions obtained when nematodes extracted from the soil were added to pots of sterilized compost containing healthy French bean plants. Further experiments were made to test the claim that the fungus *Olpidium brassicae* is concerned in the transmission of viruses of this type, and studies were made of the host range of different isolates of the fungus.

Work was also begun on the properties of a virus of the tobacco necrosis type isolated from naturally infected pea roots. (W. P. Mowat.)

### APHID-BORNE VIRUSES

*Raspberry*

Aphid-borne viruses, transmitted by raspberry aphids (*Amphorophora rubi*), have spread into the propagation plots of virus-free material so consistently during the last three seasons as to question the feasibility of continuing field propagation at Mylnefield. All the stocks were again down-graded this year and the time spent in raising them was therefore largely wasted.

To see if heat-treated material is unusually susceptible to re-infection by aphid-borne latent viruses, plants of six varieties were exposed to infection in a randomized-block trial begun in 1960. Tests made in 1961 confirmed the results of earlier experiments in showing that Lloyd George was highly susceptible and Norfolk Giant resistant to infection. Malling Jewel, a variety not tested earlier because no virus-free plants were available, proved more susceptible than Lloyd George. These results bear out the experience gained from testing samples from the propagation plots: most infections found there were in Malling Jewel and Lloyd George.

Virus-infected plants of Seedling M were again heat-treated, and preliminary tests indicate that one plant may have been cured. (J. Chambers.)

There was little opportunity to pursue work on the viruses transmitted by *A. rubi* which are transmissible mechanically from infected *Rubus occidentalis* to herbaceous test plants. These viruses seem stable when kept frozen, have thermal end-points in the range 50-52°C, and retain infectivity for several days when kept in sap at room temperature. (C. H. Cadman.)

*Strawberry*

Field experiments on the spread of aphid-borne strawberry viruses gave results like those reported earlier. Collation of the data so far obtained confirms that, by contrast with southern England, spread of virus in eastern Scotland occurs to an important extent only between August and November, when populations of the strawberry aphid (*Pentatrichopus fragaefolii*) reach their peak. Much of the spread is consistent with the idea that apterous aphids, rather than alatae, are the important vectors and that physical isolation affords excellent protection against spread of virus. (R. M. Lister.)

Throughout 1961, only small populations of strawberry aphids occurred on all the five varieties sampled. As in previous seasons, these reached their peak in the autumn. (C. E. Taylor.)

OTHER VIRUSES

*Carrot*

Premature yellowing of the haulms and poor yields of roots were typical of many carrot crops in Angus this year, and occurred on a scale not noticed before. Plants from five different farms contained apparently similar viruses which were transmissible both by the carrot/willow aphid (*Cavariella aegopodii*) and mechanically to *Datura stramonium*, causing symptoms like those of carrot motley dwarf virus. As further epidemics could threaten the continuance of carrot growing in this area, an investigation of the problem is planned. (A. F. Murant.)

*Gladiolus*

The majority of commercial stocks of *Gladiolus* seem to be infected by viruses that cause leaf mottling and flower-break symptoms. Samples of twenty different varieties all contained strains of yellow bean mosaic virus, which was transmissbile mechanically to *Chenopodium* spp. and *Vicia faba* and identified serologically. One sample from Ayrshire, referred to above, contained tobacco ringspot virus. (J. Chambers, C. H. Cadman.)

*Prunus*

Bushy dwarf, a virus primarily of raspberry but which occurs also in *Prunus* spp., shares some properties with another, unnamed virus that occurs widely in plum and ornamental *Prunus* spp. Both these viruses in some respects resemble tomato spotted wilt virus, and studies on all three are being made. They are unstable and difficult to purify, and attempts to produce antisera to any have failed. (C. H. Cadman.)

## PUBLICATIONS

### Research Papers

CADMAN, C. H. (1961). Raspberry viruses and virus diseases in Britain. *Hort. Res.*, **1**, 47-61.
(This is a review of current knowledge on the viruses affecting cultivated raspberry in Britain.)

CADMAN, C. H. (1962). Evidence for association of tobacco rattle virus nucleic acid with a cell component. *Nature, Lond.*, **193**, 49-52.
(Single lesion cultures of tobacco rattle virus behave in one of two ways. Either they multiply well in inoculated tobacco leaves, producing quantities of stable, infective, antigenic rod-shaped particles, or they multiply poorly. Isolates of the second kind (NM isolates) are often difficult to transmit mechanically, and although they usually produce severe systemic symptoms in plants, sap from such plants contains few or no characteristic virus particles and no detectable virus antigen, and its infectivity is unstable. This paper reports experiments which showed that virus of the NM type probably exists as nucleic acid which fails to initiate synthesis of virus protein, and remains bound to or localized in a cell component which is sedimented by low-speed centrifugation.)

### General Papers

CADMAN, C. H. (1961). Soil-borne plant viruses. *Rep. agric. Res. Coun., 1960*, 45-52.

CADMAN, C. H. (1961). Soil-borne viruses. *N.A.A.S. Quart. Rev.*, **54**, 52-58.

LISTER, R. M. (1962). Virus diseases of horticultural plants. *J. R. Caledonian hort. Soc., 1962*, 44-49.

# MYCOLOGY

A. R. WILSON

The biology and control of *Botrytis cinerea* as a pathogen of soft fruit and tomatoes continued to be the major interest of the department. Of particular significance in the design of control measures have been investigations on the pattern of initial infection of immature raspberry and strawberry fruit and tomato stems, on the subsequent latent phase of the fungus, and on its transition from a quiescent to an aggressive state in relation to physiological changes associated with ageing of the host.

A welcome development during the year was the establishment of close contact with plant pathologists of the Botany Department at Queen's College, Dundee, particularly in connection with work there on raspberry stamen blight.

Miss K. S. Forbes, who joined the staff in 1957, left to be married in August and was replaced by Mr. H. M. Wilson in September.

Among the many who have assisted the department during the year the following deserve special mention: Robert Niven & Son, Essendy; J. & A. Henderson Ltd., Airdrie; and W. D. Soutar, Esq., Kirriemuir.

## GREY MOULD OF SOFT FRUIT

*Auteocology of* Botrytis cinerea

The dispersal of spores in a strawberry plantation at Mylnefield was studied for the first time with the aid of a Hirst spore trap. This was sited in the centre of a plot of the variety Talisman, measuring 25 yd. × 25 yd., on the northern edge of about two acres of strawberries. The trap was operated at an airflow rate of 10 lit./min. and with the intake orifice 0·25 m. above ground level.

During the flowering and fruiting period the concentration of airborne spores was usually less than 100 spores/m.$^3$. The maximum figure, about 8,000/m.$^3$, was recorded near the end of fruit picking. These figures are very much lower than comparable ones obtained previously in a raspberry plantation. The midday and evening peaks in concentration and those related to rainfall, so frequently recorded in the raspberry plantation, were absent, but small peaks occurred which coincided with periods when the fruit was being picked. On these days the correlation between total spore count and percentage diseased fruit was highly significant. Because of the very low frequency of infections attributable directly to spore germ-tube penetration, it seems unlikely that the frequency of diseased fruit depends on the airborne spore concentration; on the contrary, the concentration of airborne spores would appear to be directly related to the number of major sporulation sites exposed and disturbed during picking. It is suggested that the main factors, air currents and rain splash, responsible for dispersing spores in a raspberry plantation, are inoperative or less effective in a strawberry plantation because the fruit is close to the ground and screened by foliage and straw.

Infection of the fruits of raspberry (var. Malling Exploit) and strawberry (var. Talisman) was often found to have occurred at a very early stage in development. Isolations were made from newly-opened flower buds at intervals during the flowering period, beginning 26 days before the first picking day in strawberries and 17 days before in raspberries. Symptomless attached petals, sepals, stamens and carpels all yielded *B. cinerea* after surface sterilization. The frequency of successful isolation was higher in raspberry than in strawberry flower parts, and in both it was higher when the flowers, although showing no symptoms of grey mould, had been slightly damaged by late frosts. The frequency increased as the flowering period progressed, although isolations were all made from flowers of the same physiological age. On one occasion *B. cinerea* was obtained in 71·4% of attempted isolations from frost-damaged raspberry stamens, and the average percentages of successful isolations for all flower parts over the whole period were: strawberry undamaged, 6·6; frost-damaged, 9·6; raspberry undamaged, 28·6; frost-damaged, 47·3. It appears that following this early infection the mycelium remains latent and usually only develops when the fruit is ripe or nearly so, and the appearance of symptoms may even be delayed until after harvest. Preliminary histological work confirmed the presence of latent infection in strawberries, recently reported from Oregon, and suggests that it occurs even more frequently in raspberries. The implications of this condition in the design of control measures are, firstly, that fungicide programmes will probably have to be re-timed to cover the period of flower-bud opening, and secondly, that methods of plantation management must, *inter alia*, be designed to reduce the chances of infection at this stage.

*Control*

Work continued on the effects of various management practices and fungicide programmes on the control of grey mould of strawberries and raspberries. In general the results of 1960 were confirmed. Two applications of a mercury fixtan formulation were made in February and March respectively to plots of Talisman strawberry in an attempt to eradicate *B. cinerea* from the debris in the crowns, and these treatments were followed by a standard captan post-blossom programme. No significantly better control of fruit grey mould was obtained than with the post-blossom treatment alone. Preliminary trials were made with an anti-sporulant material, hexachlor-2-propanol,[1] in combination with a standard captan programme. This treatment reduced the incidence of grey mould in strawberries, but the level was not significantly lower than that given by captan alone.

The use of captan at 5 lb./250 gal./acre at the normal times in both strawberries and raspberries gave significantly better control than the lower rates and volumes of standard programmes. Applied at a very early stage in fruit development, as suggested above, this programme appears promising.

Trials showed that when intervals between picks were lengthened, or diseased berries were not removed, grey mould losses were higher than when all ripe and diseased berries were picked frequently.

[1]Supplied by Dr. J. G. Horsfall, Connecticut Agricultural Experiment Station, and by Dr. Merrill M. Darley, Allied Chemical Corporation, New Jersey.

*Varietal Susceptibility*

Work continued on physical and chemical factors underlying varietal susceptibility. In eight strawberry varieties there was no correlation between the mean percentage of fruit infected (w/w) and any of the following factors: dry weight of berries, percentage of berries touching others, percentage of berries lying on the soil, relative humidity of air beneath the leaf canopy (as estimated by cobalt thiocyanate papers), percentage spores of *B. cinerea* germinating in expressed juice of ripe berries, and the rate of germ-tube growth in such juice. (W. R. Jarvis.)

GREY MOULD OF TOMATO

*Varietal Susceptibility*

Counts of natural stem infection by *Botrytis cinerea* on nine tomato varieties in a yield trial at Mylnefield in early September showed no significant intervarietal differences, but the overall level of infection was only moderate and variation between replicates considerable.

*Effect of Physiological Age on Susceptibility*

Clear differences in susceptibility to stem infection by *B. cinerea* between plants of different physiological age have been demonstrated. In a typical experiment with plants in 5-in. pots, fresh leaf-scars on plants of five different ages were inoculated each with a drop of spore suspension; half of the inoculated scars became infected in plants twenty weeks old but none in plants four weeks old. The basal node, and frequently also the first and second nodes above this, remained resistant after the higher nodes became susceptible. These nodes apart, however, observations on plants in the glasshouse border suggested that the change from the resistant to the susceptible phase progressed up the plant.

When small areas on the scars were cauterized before inoculation, or if some other form of saprophytic base was provided for the fungus, resistance was broken down. This indicates the importance of leaving clean scars without snags when de-leafing, and of removing moribund leaves at all times.

*Latent Infection*

Fresh leaf-scars on susceptible and resistant nodes were examined 72 hours after inoculation with a drop of spore suspension. At the susceptible nodes there was a well established mycelium penetrating 1 cm. or more from the wound surface. At the resistant nodes the spores had germinated normally on the surface of the wound but penetration rarely extended deeper than one or two cells, and there was evidence of host reaction in the form of localized browning. Both at susceptible and at resistant nodes, spores had been sucked into the exposed ends of xylem vessels and were found germinating therein at depths of over 2 mm. Examination of resistant material at intervals up to four weeks after inoculation indicated that the mycelium in the vessels and at the wound surface did not develop further during this time. It remained viable, however, since on each occasion *B. cinerea* was isolated from 90-100% of the symptomless leaf-scars after surface sterilization. Isolations from comparable uninoculated scars were unsuccessful. The relative importance of the limited mycelium in the xylem vessels and the superficial

mycelium below the wound surface in initiating the aggressive phase of stem lesions is now being investigated.

The demonstration that the fungus can survive as a latent mycelium in symptomless plants may provide an explanation for the appearance of lesions at the nodes of plants many weeks after de-leafing, presumably at the time when the tissues are entering the susceptible phase. The fact that spores can be sucked into the xylem vessels during de-leafing may have some bearing on the erratic results often obtained elsewhere when control was attempted with protectant fungicides applied after de-leafing.

*B. cinerea* was also found to infect unwounded stem tissue. The mycelium was very limited in extent and appeared to be either sub-cuticular or within the epidermal cell wall. Except in moribund plants no macroscopic reaction to such invasion was seen, but the cell wall adjacent to the infection peg was often swollen and had altered in its staining reaction. Isolation at weekly intervals from surface-sterilized resistant stem internodes which had been inoculated by spraying with a spore suspension showed that the mycelium frequently remained viable for at least four weeks, but certain evidence suggested that this type of latent mycelium may not develop further except possibly in senescent plants, when the disease is no longer economically important.

*Resistance Mechanism*

Some preliminary work was done on the nature of the resistance mechanism. The dry weight of mycelium of *B. cinerea* in liquid enzyme-inactivated extracts of tomato stems varied directly with increasing physiological age, growth in extracts of old (19 week) stems being 50% more than in extracts of young (7 week) stems. The length of lesions on excised portions of stem, ten days after inoculation at their basal end, varied from less than 1 mm. in young (7 week) stems to 30 mm. in old (19 week) stems. Stem discs, 2 mm. thick, cut from susceptible (12 week) and resistant (4 week) plants had no effect on spore germination or germ-tube growth during 16 hr. when placed on water agar plates previously seeded with spores of *B. cinerea*.

These and the other observations previously discussed indicate that there is no inhibition or retardation of the spore germination and initial penetration phases of parasitism; the resistance mechanism appears to be a temporary inhibition of subsequent mycelial growth.

Work was begun on the interaction of pectinase and phenolase systems, as pectic degradation products have been shown elsewhere to activate latent phenolase, while polyphenol oxidation products can inhibit pectinase activity. A preliminary comparison was made of non-latent and latent phenolase [tyrosinase, *o*-diphenol oxidase (catecholase), *p*-diphenol oxidase and *p*-cresolase] activities in stem tissue from tomato plants in the resistant and susceptible phases. There was a markedly higher non-latent phenolase activity per unit dry weight in the young (resistant) than in the old (susceptible) stems, but the differences between the tissues in total phenolase activity were less marked after activation of the latent phenolase with sodium dioctyl sulphosuccinate. Activation increased total phenolase activity in the old tissue but scarcely at all in the young tissue. (A. R. Wilson.)

DIE-BACK OF RASPBERRY

Only the mycological aspects of work on this disease complex are reported here. Work on the role of various other factors in die-back etiology is being continued by Mr. T. G. Rubens.[1]

The fungus isolated from sunken lesions on green raspberry canes and previously reported as *Coryneopsis* sp. has been redisposed as *Truncatella laurocerasi* (Westd.) Steyaert by Dr. B. C. Sutton, of the Commonwealth Mycological Institute. Inoculations of maturing canes in August were unsuccessful, but work on pathogenicity is continuing. (W. R. Jarvis.)

To determine the incidence of *Phytophthora* spp. in a plantation of Malling Promise severely affected by die-back, soil at a depth of 3-8 in., adjacent to the stools, was sampled in transects crossing affected and unaffected areas. Apples were inoculated with the soil but no *Phytophthora* sp. was isolated. A number of *Pythium* spp. were isolated but their distribution was not related to the distribution of die-back. Apples inoculated with homogenized roots from affected stools failed to yield either *Phytophthora* or *Pythium* spp. but, as previously, *Cylindrocarpon radicicola* was frequently isolated. (A. R. Wilson, W. R. Jarvis, T. G. Rubens[1].)

STAMEN BLIGHT OF RASPBERRY

A limited but severe outbreak of stamen blight of raspberry (*Hapalosphaeria deformans* Sydow) was noted in a plantation of Malling Jewel at Kirriemuir in June. Other cases were seen in east Perthshire and Angus, and it would appear that this disease is more widespread than has hitherto been supposed. The effect on the fruit is not unlike that of late frost and, unless the white spore-mass on the stamens is observed, the condition may well be confused with frost injury.

Work on the epidemiology and control of this disease is now being continued by Mr. J. S. W. Dickens at Queen's College, Dundee, under the joint supervision of Dr. T. H. Nicolson (Queen's College) and Dr. Wilson. (A. R. Wilson, W. R. Jarvis.)

STORAGE OF POTATOES FOR PROCESSING

The deterioration which occurred in a stack of potatoes in February 1961, which was briefly noted in the last Annual Report, is now considered likely to have been initiated by condensation in the lower levels of the stack during the early stages of periods of air recirculation. The relative humidity of the store air was normally in the region of 90% and its temperature 5°F or more above that of the lower level of the stack, so that the dew point would have been reached when the ingoing air was cooled by only about 3°F. It is therefore essential to obtain more precise information on the effects of air recirculation and reversed-flow air circulation on temperature distribution in large stacks of potatoes, particularly in stacks held at 50°F or above for later crisping.

In February 1961, rubbery but otherwise apparently sound tubers from areas of deterioration in the stack imparted a serious off-flavour to large batches of crisps. Dr. A. C. Stirling, of the Bacteriology Department, Edinburgh School of Agriculture, found the flesh of these tubers to be abnormally

[1]The Edinburgh and East of Scotland College of Agriculture.

acid (pH 4·0-5·7), and in a sample of pH 5·7, lactic acid accounted for 2·03% of the dry weight. *Lactobacillus plantarum* was isolated, which suggested almost anaerobic conditions. Until more is known of the contributory factors in this type of spoilage, the inclusion in consignments for crisping of apparently sound tubers from areas of deterioration may be unwise.

Further work on management problems and weight loss, undertaken in the same commercial store in the 1961-62 season, had to be abandoned in November because of deterioration in the experimental section following the inadvertent inclusion of one wet load. (A. R. Wilson.[1])

## MISCELLANEOUS

Co-operative work on bacterial canker of plums continued with Dr. A. M. Paton, University of Aberdeen, and Dr. A. E. W. Boyd, Edinburgh School of Agriculture. (A. R. Wilson, W. R. Jarvis.)

## PUBLICATIONS

### Research Papers

Jarvis, W. R. (1962). Problems in the control of raspberry and strawberry grey mould. *Proc. Brit. Insecticide and Fungicide Conf., 1961*, **2**. 315-19.

(The number of fungicides which may be used on soft fruit, and the methods of applying them, are limited by considerations of disfiguration, of toxicity and, particularly in the case of fruit for processing, of taint. Those which are acceptable even on only the first two criteria have been shown to be only moderately effective in the field in spite of their known effectiveness against *B. cinerea* in other crops and *in vitro*. Two main reasons are advanced for these results: one is the infection of floral parts as the flowers open, with the result that a latent mycelium is established prior to the normal time of first applying fungicides; the other is the very high proportion of fruit infections occurring from previously infected fruit, plugs, straw and other debris, which type of infection is not amenable to control by fungicides. In addition there are technical difficulties in maintaining adequate fungicide cover on fruit in widely different stages of development and with rapidly expanding surfaces.

Methods are discussed of supplementing modified fungicide programmes with management practices designed to reduce the incidence of saprophytically-based inocula and to modify the microclimate.)

Jarvis, W. R. (1962). Splash dispersal of spores of *Botrytis cinerea* Pers. *Nature, Lond.*, **193**, 599.

(Water-drops falling upon loose masses of spores of *B. cinerea* disperse spores in three ways. Dry spores are dispersed on air shock waves and turbulent air currents, a few spores are sufficiently wetted to be dispersed within splash droplets, and many dry spores coat the surface of splash droplets and are dispersed as composite projectiles. These are extremely stable and may travel for horizontal distances of 1 m. or more. If the water within the projectile evaporates slowly, as is usual, many spores become wet enough to begin germinating. These projectiles may thus be an important and efficient means of spore dispersal.)

Jarvis, W. R. (1962). The infection of strawberry and raspberry fruits by *Botrytis cinerea* Pers. *Ann. appl. Biol.*, **50**. (In press.)

(*Botrytis cinerea* is abundant throughout the year as a saprophyte and facultative parasite on a wide variety of plant materials in raspberry and strawberry plantations. Despite high concentrations of airborne spores at the time of fruit development, relatively few infections have been attributed to penetration of fruit surfaces following the germination of spores in drops or films of water. The majority of fruit infections

[1]In collaboration with the Agricultural Research Council's Ditton Laboratory.

are initiated from hyphae growing from saprophytic colonies in adhering or attached plant material, or from spores germinating in solutions trapped between the fruit surface and moribund tissues.

Dry spores of *B. cinerea* do not readily germinate when placed on the surface of strawberry fruits and incubated in a saturated atmosphere, but they germinate rapidly in a water film under similar conditions. In contrast to the wide difference in susceptibility to infection between ripe and unripe fruit, there are only small differences in the rates of spore germination on such fruit. Field observations suggest that although spore germination may be very rapid, water films generally do not persist on the surface of the fruit long enough for the post-germination infection process to be completed. Such films, however, may persist for much longer periods when trapped between floral parts, and spores germinating there are able to infect these tissues, sometimes almost as soon as the buds open. Infection may be accelerated by the presence of necrotic tissue, particularly in flowers damaged, for example, by frost. As has been demonstrated elsewhere in strawberries, infections of floral parts may lead to the establishment of a mycelium in the proximal end of both strawberry and raspberry receptacles. This mycelium may remain quiescent and give rise to no symptoms until the fruit ripens, so that infected fruit may escape notice during picking and marketing.

Some methods are suggested of supplementing fungicidal control measures by reducing the incidence of sources of infection.)

JARVIS, W. R. (1962). The dispersal of spores of *Botrytis cinerea* Pers. in a raspberry plantation. *Trans. Brit. mycol. Soc.*, **45**. (In press.)

(The dispersal of spores of *Botrytis cinerea* has been studied in a raspberry plantation at Mylnefield over a period of five years. Spores are released from the conidiophores by a hygroscopic mechanism and are then dispersed by air currents or rain splash. Maximum airborne spore concentrations occur when the relative humidity is rising or falling rapidly between the approximate limits of 65% and 85%, but rainfall often results in dispersal at other times. Concentrations depend on the amount of sporulating material available, which in turn depends on temperature, humidity, the magnitude of previous dispersals and the stage of development of the crop, since generally only ripe fruit and freshly exposed receptacles support heavy sporulation. Levels of the order of $10^4$ spores/m.$^3$ of air have been recorded frequently during the fruiting period.

The implications of the dispersal mechanism in relation to disease control are discussed.)

WILSON, A. R., TWISS, P. T. G.,[1] and LESSELLS, W. J.[2] (1962). Weight loss and sprouting of bulk-stored maincrop potatoes in England. *Eur. potato J.*, **5**, 147-65.

(This paper reports work done by the Agricultural Research Council's Potato Storage Investigation Team at Sutton Bonington and by Rothamsted Experimental Station. The loss in weight of maincrop potatoes stored in bulk under normal commercial conditions in England was found to increase from 2·5% by the end of January to almost 7% by the end of May in indoor stores and from 2·5% by the end of February to 5% by the end of May in clamps. These figures refer only to tubers remaining sound throughout storage and do not include any losses from rotting; allowance must be made for the latter when estimating the possible financial advantage of storing potatoes over selling them from the field. Weight-loss figures obtained in an indoor store, ventilated in different ways, suggest that once the 'holding' temperature has been reached, shrinkage is least when ventilation is restricted. Judicious use of forced-draught ventilation in the early winter may reduce such losses by shortening the time necessary to achieve the 'holding' temperature. The relation of weight loss to the position of sample sacks in stores and clamps is discussed. The specification of an open-mesh nylon sack for embedding samples in heaps of potatoes or other roots is given in an Appendix.)

### GENERAL PAPERS

WILSON, A. R., and TWISS, P. T. G.[1] (1960). Management of ware potato stores. *Ministry of Agriculture, Fisheries and Food Advisory Leaflet* No. **488**. H.M.S.O.

WILSON, A. R., and TWISS, P. T. G.[1] (1961). Buildings for bulk storage of potatoes. *Ministry of Agriculture, Fisheries and Food, Fixed Equipment for the Farm Leaflet* No. **24**. H.M.S.O.

[1] A.R.C. Ditton Laboratory, Larkfield, Maidstone, Kent.
[2] Statistics Department, Rothamsted Experimental Station.

# WEST OF SCOTLAND UNIT (AUCHINCRUIVE)

R. D. Reid

This unit continued its work of strawberry breeding, in which the objective is the production of new varieties combining high productivity and other good commercial qualities with resistance to red core root rot. Associated mycological work with *Phytophthora fragariae*, the causal organism of the disease, continued to concentrate on the identification and inheritance of plant resistance to specialized physiologic races of the fungus.

## STRAWBERRY BREEDING

### *Fruiting Trials*

The 1961 season was made difficult by much rain during the fruiting period. Nevertheless, an excellent crop was secured and fruit of very fine quality was obtained from a number of the newer seedling selections.

In the fruiting trials the interest was largely centred on 125 selections, some of them derived from the 1956 crosses but most from the crosses of 1957. These had been selected in 1959 as single-plant units and fruited again in 1960 under cloches (see 1960-61 Report). In 1961 they were fruited mainly in units of 15, 30 or 45 plants, but a further assessment was made on the performance of each in a small matted bed. Selection for pomological merit was exceedingly difficult because of the large number which showed good promise. Eventually it was decided to retain all of these seedlings for fruiting again in 1962, meanwhile selecting twenty-three of them for more intensive testing. These included several of the nine which had been specially selected for their performance in 1960.

Among the twenty-three advanced selections are four to which special priority is being given. One of these, which has been outstanding for the three seasons from 1959, has been virus tested and a clonal stock of it raised. Approximately 350 plants of this clone have been sent for further propagation at Mylnefield, so that if the fruiting performance over the next two years continues to be satisfactory a stock will be available for distribution with minimum delay. Two others of the leading four will be handled similarly in 1962. The fourth falls into a special category, in that whilst it is not considered of special merit for open field work, it has given very good results for two successive seasons at Auchincruive when grown under cloches. In order to see how far it is really adapted to this special but limited use, arrangements have been made to have this selection tried out elsewhere in Scotland, and also at two N.A.A.S. stations in England, in areas where cloche growing is commercially important.

Nearly three inches of rainfall during the picking period in July provided humid conditions which were very conducive to the rotting of fruit by the grey mould fungus (*Botrytis cinerea*). It was of interest to note that selections

growing under identical conditions showed very large differences in susceptibility to this form of loss, and it was possible to take this into account when making the season's assessments. No protective fungicide was applied.

From each of seventy selections made from single-plant units which fruited first in 1960 (all derived from 1957 and 1958 crosses) four plants were fruited in 1961 under cloches. Twelve of the selections were chosen for more intensive work and the entire seventy will be grown in the open field in 1962 to fruit as 15-plant units.

More than 4,000 seedlings derived from crosses made in 1958 and 1959 were fruited as single-plant units in 1961, many of them derivatives of species-crosses and representing a stage in the longer-term breeding programme. Pomologically the results were in general disappointing, and further back-crossing and outcrossing will be necessary. Just over fifty individual seedlings were retained for further work. More than 5,000 seedlings from the remainder of the 1959 and part of the 1960 crosses were planted out as single-plant units in 1961 after surviving the first screening for red core disease resistance. These will be re-examined for red core, and also fruited, in 1962.

*Red Core Disease and Rainfall*

The rainfall recorded at Auchincruive in 1961 was 39·66 inches, nearly 4 inches more than the ten-year average. What is still more significant for red core disease infection is that 24·5 inches fell during the five months from August to December, compared with 18·28 inches during the corresponding period of 1960. These are the most critical months for root infection, and a high incidence of the disease in 1962 would therefore not be surprising.

*Field Resistance to Red Core*

Although fundamental work on the mycological side (see below) encourages the hope that complete genetical immunity to all races of *Phytophthora fragariae* will ultimately be obtained, the incorporation of new factors for immunity or high resistance cannot have any influence on selections likely to be introduced in the near future. Considerable importance is therefore being attached to the occurrence of 'field resistance', a subject discussed at length in the last two Reports. In 1961 some of the strongly field-resistant selections—one of them nine years from seed—showed larger proportions of diseased roots than in previous years; but there was still an abundance of healthy roots to enable normal growth to be maintained, and during a summer in which red core symptoms were acute in susceptible varieties these resistant selections continued in vigorous and healthy growth, with no wilting or other above-ground signs of disease. It is considered, therefore, that breeding for the combination of this general character of field resistance with complete immunity from as many races of the fungus as possible still offers a promising basis for the introduction of new varieties.

*Bench Testing*

Routine initial testing for red core resistance by the glasshouse bench technique was concentrated largely on seedlings raised from the pollinations of 1960. These amounted to nearly 18,000 seedlings from 92 successful

crosses and selfs, the largest number of seedlings yet raised here in any one year. More than 14,000 were bench-tested, and a summary of the results shows that 36% remained uninfected, 46% were infected with red core and 18% were lost from other causes. The remaining 3,900 seedlings are being exposed to intensive infection under field conditions and have not yet been examined. (R. D. Reid, A. M. Sutherland, K. C. McConnell.)

## MYCOLOGICAL INVESTIGATIONS

### *Physiologic races of* Phytophthora fragariae

The existence of at least four races in a collection of more than thirty isolates of *P. fragariae* was recorded in the 1960-61 Report, the differentiating varieties used being Huxley, Perle de Prague and Auchincruive Climax. When the same isolates were used in 1961 to inoculate American Aberdeen, Redgauntlet, Talisman and the Auchincruive selection 52AC18, five more races could be identified, making nine in all. Still further differences in pathogenicity among these isolates are suggested by preliminary tests in which

TABLE I

*Reactions of strawberry varieties to physiologic races of* Phytophthora fragariae

| Variety | Number of races (out of 9) | | |
|---|---|---|---|
| | Susceptible | Resistant | Immune |
| Huxley .... .... .... | 9 | — | — |
| Perle de Prague .... .... | 5 | — | 4 |
| 52AC18 .... .... .... | 1 | 3 | 5 |
| Climax .... .... .... | 4 | — | 5 |
| Aberdeen .... .... .... | 4 | — | 5 |
| Redgauntlet .... .... .... | 4 | — | 5 |
| Talisman .... .... .... | 2 | — | 7 |

Cambridge Vigour, Siletz and the Auchincruive selections No. 11 and 53Q13 have been used as differentials. For example, if results obtained with Auchincruive No. 11 and a number of the isolates are considered, thirteen races can be demonstrated, as was reported last year. Table I indicates the number of races to which each of the main differentiating varieties so far used has been found to be susceptible, resistant or immune.

One of the nine races is pathogenic to all the named varieties and breeders' advanced selections so far inoculated with it in these tests. It is represented at present by nine isolates, nearly all of which were obtained from plants of Auchincruive Climax growing in various localities in Scotland.

Isolates obtained from varieties found naturally infected in different parts of Scotland account for eight of the nine races now clearly differentiated. The ninth race is represented by two isolates from Huxley growing in the south of England and two obtained by Prof. C. J. Hickman from a variety growing in New Zealand. This race is the most limited in its pathogenicity to the differentials so far used, infecting only the variety Huxley. A third isolate from New Zealand material shows a pattern of pathogenicity which differs from that of the two just mentioned, but is similar to that shown by

certain isolates from strawberries in Scotland and by one obtained by Dr. W. E. McKeen in British Columbia from the loganberry. This pattern consists of pathogenicity to Huxley, Perle de Prague and 52AC18 and non-pathogenicity to the other differentials.

The assessment of a wide range of named strawberry varieties and numbered selections for resistance to or immunity from red core was continued. Separate inoculations were made with a representative isolate of each of two races of the fungus, one of them pathogenic to Huxley, Perle de Prague and 52AC18 but not to Climax, American Aberdeen, Redgauntlet or Talisman, and the other pathogenic to all these varieties. The results of this work appear in Table II: of the twenty-four varieties and four selections tested, sixteen showed no immunity or resistance towards either isolate, and not one showed immunity from both isolates.

TABLE II

*Results of inoculating strawberry varieties and selections with zoospore suspensions of isolates representing two physiologic races of* Phytophthora fragariae (I=*Immune*, R=*Resistant*, S=*Susceptible*)

| Variety or Selection | Isolates representing 2 races: No. 81 | No. 74 | Variety or Selection | Isolates representing 2 races: No. 81 | No. 74 |
|---|---|---|---|---|---|
| American Aberdeen | I | S | Oberschlesien | S | S |
| Auchincruive No. 6 | R | S | Perle de Prague | S | S |
| ,, No. 11 | I | R | Redgauntlet | I | S |
| ,, Climax | I | S | Royal Sovereign | S | S |
| Avant tout | S | S | Ruskin | S | S |
| Cambridge Favourite | S | S | Senga 54 | S | S |
| ,, Profusion | S | S | Senga Sengana | S | S |
| ,, Rearguard | S | S | Siletz | I | S |
| ,, Sentry | S | S | Sonjana | S | S |
| ,, Vigour | I | R | Sparkle | I | S |
| ,, 54 | S | S | Talisman | I | S |
| Huxley | S | S | Ydun | S | S |
| Little Scarlet | R | S | 52AC18 | R | S |
| Merton Princess | S | S | 53Q13 | I | S |

*New Sources of Red Core Immunity*

No further seed collections were acquired. Inoculations were continued with seedlings from a *Fragaria vesca* collection from Jugoslavia and one of *F. virginiana* from Ontario, and a few of the *F. vesca* seedlings showed apparent immunity from an isolate of one race of the fungus. This is the first time that resistance or immunity has been observed in this species. The *F. virginiana* collection gave 20% of seedlings immune from this same isolate, a figure similar to those obtained in earlier tests on various collections of this species.

Since sources of immunity from eight recognized races of *P. fragariae* are already available, a search for additional sources must be concerned principally with finding immunity from the race which infects all the strawberry varieties and selections on which it has been tested. A large number of seedlings from seed of wild species collected in Canada, U.S.A. and Chile have therefore been tested by inoculation first with an isolate of limited patho-

genicity and then, in the case of the surviving seedlings after these have produced runners, with a highly pathogenic isolate, one of the nine constituting the most pathogenic race available. (The isolates actually used were again Nos. 81 and 74—see Table II.) Only three plants—one of *F. ovalis* and two of *F. virginiana*—have by this means been found immune from the more pathogenic isolate. A further search for sources of immunity from this isolate has been made in families raised by selfing varieties, selections and species seedlings which show immunity or resistance when inoculated with other recognized races. In this way additional sources of immunity from the highly pathogenic isolate have been found in the first and second generations raised from Cambridge Vigour and in the second generations from Auchincruive No. 11 and from single seedlings of *F. ovalis* and *F. virginiana*. Altogether twenty-three plants so far have remained immune from this isolate: these are the thirty plants briefly mentioned in the 1960-61 Report, less two which died and five which failed to maintain complete immunity after further testing. In addition to offering further sources of immunity for breeding, such immune plants should provide an invaluable extension to the range of differentials available for the identification of races of the fungus.

On initial inoculation with the less pathogenic isolate used in this test programme, families from open-pollinated wild species of *Fragaria* have contained smaller proportions of immune seedlings (11-21%) than families from selfed varieties or selections (26-72%). The difference is even more marked with families raised from wild species collected in isolated habitats: these have yielded only 2-7% of immune seedlings. (I. G. Montgomerie.)

# METEOROLOGICAL RECORDS, 1961

J. SUNDERLAND

The warm and fairly dry spring was very favourable for sowing and planting. Vegetable crops and strawberries, including cold-stored strawberry runners planted during the latter part of May, established well and made quick growth.

The flowering season for raspberries and plums was the earliest since the records began in 1953.

Several ground frosts which occurred during May and June [including −2·8°C (27°F) on 27 May and −2·2°C (28°F) on 13 June] were mainly responsible for reducing the strawberry crop to less than half that of 1960. The raspberry, plum and apple crops were also reduced and many apples showed cracking. Varieties particularly affected by frost were Redgauntlet strawberry, Lloyd George raspberry and the early-flowering apples. No damage was seen in potatoes or vegetable crops.

Rainfall was slight during the early part of the picking season and some of the older strawberry plantations suffered from wilting, which contributed to the reduction in yield. However, heavy rain at the beginning of July increased the size of the later fruit. The rainfall in July, August and September was rather high and temperatures were cool. Root crops (carrots, beet and potatoes) were harvested under sticky ground conditions and dirt tares were high. Onions ripened slowly, and this adversely affected their keeping quality.

Ground frosts were recorded again rather soon in late summer and early autumn [−0·6°C (31°F) on 24 August and 0°C (32°F) on 29 September]. The combination of wetness and early frosts during autumn produced poorly-matured raspberry canes (notably in Lloyd George), many of which died during the winter.

A gale on 16 September was one of the most severe on record and caused considerable damage in the apple and plum plantations. Many trees were uprooted and twenty-nine in the apple variety collection (dwarf bushes on M.IX rootstock) were totally destroyed.

There was slight air frost on 27 October and winter could be said to have set in by the end of November, by which time turnip harvesting was completed. Severe frost and a first snowfall on 2 December brought farm work to an unusually early halt and led to some pigeon damage to winter vegetable crops.

Meteorological records from Mylnefield and Auchincruive for the year are summarized in the tables. The values for Auchincruive are taken from the Monthly Weather Reports issued by the Meteorological Office.

AUCHINCRUIVE, 1961

| Month | Temperature (°C) | | | | Rainfall (inches) | Sunshine (hours) | Ground Frost (days) |
|---|---|---|---|---|---|---|---|
| | Mean of daily maxima | | Mean of daily minima | | | | |
| Jan. | 6·2 | (43·1°F) | 0·3 | (32·7°F) | 2·14 | 68 | 25 |
| Feb. | 8·9 | (48·0°F) | 3·9 | (39·0°F) | 2·74 | 74 | 10 |
| Mar. | 10·8 | (51·4°F) | 5·2 | (41·2°F) | 1·91 | 97 | 10 |
| Apr. | 11·9 | (53·4°F) | 5·3 | (41·6°F) | 2·91 | 108 | 8 |
| May | 14·2 | (57·6°F) | 5·8 | (42·3°F) | 0·82 | 201 | 4 |
| June | 16·2 | (61·1°F) | 9·0 | (48·2°F) | 1·65 | 153 | 2 |
| July | 16·2 | (61·2°F) | 9·7 | (49·1°F) | 2·99 | 139 | 1 |
| Aug. | 17·0 | (62·6°F) | 10·2 | (50·4°F) | 5·11 | 150 | 0 |
| Sept. | 16·8 | (62·2°F) | 10·1 | (50·2°F) | 6·47 | 109 | 0 |
| Oct. | 12·8 | (55·0°F) | 7·3 | (45·1°F) | 5·73 | 107 | 3 |
| Nov. | 8·7 | (47·5°F) | 2·9 | (37·2°F) | 4·41 | 62 | 15 |
| Dec. | 5·2 | (41·4°F) | −0·8 | (30·4°F) | 2·78 | 56 | 25 |
| Year | 12·1 | (53·8°F) | 5·7 | (42·1°F) | 39·66 | 1,324 | 103 |

## SUMMARY OF WEATHER AT MYLNEFIELD

### JANUARY

Cold and generally unsettled. One inch of snow on the 8th, showers of snow and sleet from the 25th to 29th and a gale on the 27th.

### FEBRUARY

Mild and wet throughout. Two inches of snow on the 4th, thawing within two days.

### MARCH

Unusually mild, dry and sunny. A windy month, with gales on the 20th and 26th. Slight showers of hail and snow in the fourth week.

### APRIL

Mild, wet and dull, with slight hail and snow showers in the first week.

### MAY

Dry and sunny, but with damaging ground frosts, accompanied on the 27th by air frost.

### JUNE

Fairly dry, but with heavy showers of rain from the 7th to 10th. Further damaging ground frosts, but a rise in temperatures towards the end of the month.

### JULY

Cool, wet and generally unsettled. A gale on the 4th.

### AUGUST

Cool, except for the last few days, and wet and unsettled. Slight ground frost on the 24th.

SEPTEMBER

Fairly warm but very wet. A violent thunderstorm on the 2nd accompanied by heavy rain, and a further rainfall of 1·82 inches on the 8th A strong gale on the 16th. Slight ground frost on the 29th.

OCTOBER

Fairly warm and sunny, but with frequent rain showers. Gales on the 18th and 23rd. Slight air frost on the 30th.

NOVEMBER

Cold, dry and foggy, with frequent frost. Winds light.

DECEMBER

Cold and rather wet. Snow showers frequent, with falls of 2 inches on the 7th, 3 inches on the 28th and 4 inches on the 29th.

| Month | Temperature (°C) | | | | | | | | | | | | | Rainfall | | Sunshine | | Run of Wind |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean of daily maxima | | Deviation from average[1] (C°) | Mean of daily minima | | Deviation from average[1] (C°) | Accumulated Temperature (C°) | | Highest Max. | | Lowest Min. | | Soil Temperature at 1 ft. depth | | Ground Frost (days) | Inches | Deviation from average[2] | Hours | Deviation from average[1] | Miles |
| | | | | | | | Above 5·6°C | Below 5·6°C | Temp. | Date | Temp. | Date | Mean | Deviation from average[3] | | | | | | |
| Jan. | 5·1 | (41·2°F) | −0·7 | −0·5 | (31·1°F) | −0·8 | 4 | 104 | 10 | 27 | −7 | 16 | 1·8 | −0·2 | 25 | 1·75 | −0·18 | 39 | −11 | 5,301 |
| Feb. | 8·6 | (47·4°F) | +2·2 | 2·8 | (37·1°F) | +1·9 | 39 | 36 | 12 | 5 | −5 | 5 | 3·9 | +1·8 | 16 | 1·89 | +0·04 | 80 | +4 | 6,049 |
| Mar. | 11·8 | (53·3°F) | +3·2 | 4·3 | (39·7°F) | +2·5 | 94 | 17 | 15 | 29 | −1 | 19 | 6·4 | +2·1 | 13 | 0·64 | −1·21 | 123 | +18 | 8,621 |
| Apr. | 11·3 | (52·4°F) | +0·3 | 4·7 | (40·4°F) | +1·5 | 94 | 19 | 16 | 11 | −3 | 4 | 7·8 | +0·5 | 5 | 2·58 | +0·97 | 103 | −37 | 4,947 |
| May | 14·2 | (57·5°F) | +0·2 | 5·5 | (41·9°F) | +0·2 | 130 | 7 | 21 | 11 | −1 | 27 | 10·8 | −0·6 | 5 | 1·15 | −0·85 | 210 | +44 | 5,241 |
| June | 17·1 | (62·7°F) | −0·6 | 8·2 | (46·7°F) | 0 | 215 | 2 | 23 | 30 | 2 | 12 | 12·8 | −0·8 | 2 | 1·38 | −0·31 | 177 | −5 | 6,555 |
| July | 17·8 | (64·0°F) | −1·6 | 9·6 | (49·3°F) | −1·1 | 249 | 1 | 24 | 1 | 4 | 14 | 14·5 | −0·8 | 0 | 2·90 | +0·34 | 142 | −12 | 5,258 |
| Aug. | 18·2 | (64·8°F) | −0·5 | 9·1 | (48·4°F) | −1·1 | 252 | 1 | 27 | 29 | 3 | 24 | 14·0 | −0·8 | 1 | 3·84 | +0·57 | 166 | +25 | 5,455 |
| Sept. | 16·7 | (62·0°F) | +0·3 | 9·2 | (48·6°F) | +1·1 | 222 | 0 | 22 | 1 | 5 | 25 | 13·2 | +0·3 | 1 | 3·74 | +1·74 | 113 | −9 | 4,408* |
| Oct. | 12·7 | (54·9°F) | +0·1 | 6·4 | (43·5°F) | +1·1 | 130 | 6 | 16 | 2 | 0 | 30 | 9·9 | +0·2 | 5 | 2·49 | −0·11 | 109 | +14 | 6,315 |
| Nov. | 7·5 | (45·6°F) | −1·0 | 1·8 | (35·2°F) | −0·7 | 29 | 54 | 13 | 1 | −5 | 28 | 5·6 | −0·3 | 20 | 1·13 | −1·19 | 68 | +5 | 4,140 |
| Dec. | 3·6 | (38·4°F) | −3·1 | −1·9 | (28·5°F) | −3·1 | 6 | 154 | 9 | 12 | −8 | 8 | 2·3 | −1·4 | 29 | 3·24 | +0·72 | 46 | +5 | 3,340 |
| Year | 12·0 | (53·8°F) | −0·1 | 4·9 | (40·8°F) | +0·1 | 1,464 | 401 | — | — | — | — | 8·6 | +0·1 | 122 | 26·73 | +0·53 | 1,376 | +41 | 65,630 |

[1, 2] Recorded at official Dundee meteorological station, 1921-1950 and 1881-1915 respectively.

[3] Recorded at Mylnefield, 1954-1961.

* Four days' records missed through instrument failure.