AGRICULTURAL RESEARCH COUNCIL

WEED RESEARCH ORGANIZATION

Third Report 1967-1968

BEGBROKE HILL, SANDY LANE, YARNTON, OXFORD. OX5 1PF
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P. Quilt, B.Sc. (S.R.C. Fellow)

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R. F. Clements, N.D.H. (Horticulture)

Agricultural Chemicals Approval Scheme Liaison:
R. J. Makepeace, B.Sc.

MINISTRY OF OVERSEAS DEVELOPMENT

Editor PANS C: B. Steele, B.Sc., Ph.D.

*Part-time Staff

Report of the Director

J. D. FRYER

INTRODUCTION

The Weed Research Organization (WRO) was set up by the Agricultural Research Council (ARC) in 1960 to undertake applied research on methods of weed control for the benefit of agriculture and horticulture in Britain. The Organization stemmed from the ARC Unit of Experimental Agronomy in Oxford, which since 1950 had specialised in research and information on herbicides.

Whilst WRO is controlled and financed by ARC through the Department of Education and Science, its work is also supported by grants from the Ministry of Overseas Development and the Commonwealth Agricultural Bureaux (CAB). The former enables research and advisory work to be undertaken to assist those concerned with weed problems in developing countries in the tropics. The CAB grant supports the work of the Information Section in producing the journal *Weed Abstracts* and providing an international information service.

The work of WRO is linked as closely as possible with the farming and horticultural community through the attachment of two liaison officers of the National Agricultural Advisory Service. A further link with the Ministry of Agriculture is achieved through the attachment to WRO of the herbicides specialist of the Agricultural Chemicals Approval Organization. WRO is not, however, itself directly concerned with the official approval of herbicides.

Close liaison is maintained with Industry and with other research institutes. The Organization plays an important part in the work of the British Crop Protection Council.

WRO is situated five miles north-west of Oxford. It has no formal links with the University but has access to libraries and other facilities. There is an experimental farm of 286 acres, including 110 acres of grassland. An extensive programme of field experiments is undertaken each year at Begbroke Hill as well as at other experimental establishments and on private farms throughout England and Wales. Laboratory-based research is also undertaken.

The second biennial report of WRO was published in March 1967. This present report covers the period January 1st, 1967, to December 31st, 1968.

VISITING GROUP

An ARC Visiting Group inspected WRO in March 1967. The Group consisted of Professor P. W. Brian (chairman), Mr. J. D. Alston, Professor S. H. Crowdy, Mr. W. Emrys Jones and Professor R. L. Wain, together with members of Headquarters staff. The research programme of WRO was approved with only minor changes and the Group made a number of helpful suggestions.

HERBICIDES AND CROP PRODUCTION

In Britain, as in most countries with developed agriculture, herbicides are seen to have a far more fundamental role than increasing crop yields through removal of weed competition. Because of their ability to control all unwanted vegetation without soil disturbance and with the maximum economy of manpower and machinery, they are providing a key to increasing productivity at a time when costs are soaring and farm workers continue to leave the land at a rate approaching 30,000 a year.

Much has been said and written since the publication of the last report about the possibilities of herbicides replacing the plough and many farmers have found economic and practical advantages in adopting systems of crop production based on 'minimum tillage'. These revolutionary practices, made possible by the use of herbicides, break clean away from the traditional approaches to crop husbandry. Given effective weed control by chemicals, soil cultivation now need only be viewed in the light of what is required for healthy crops to be grown and harvested.

WRO has helped to pioneer many of the new techniques of reduced cultivations in cereals, potatoes, fodder crops and grassland. That the functions of the Organization must extend beyond its title was recognised by ARC when WRO was set up in 1960. Its wider role in studying the practical consequences of herbicide use on crop growth and crop production methods has been stimulated during the period under review by the formation during 1967 of an ARC committee to promote and co-ordinate collaborative research between the Grassland Research Institute (GRI), the Radiobiological Laboratory (ARCRL) and the Weed Research Organization. With the approval of this committee a joint project between WRO and ARCRL was initiated in 1968 to study the influence of tillage on the growth and root system of barley. An encouraging start has been made in both laboratory and field experiments. To assist in this work, and in the programme of WRO on grassland reseeding and forage crop production by minimum cultivation, an additional experimental officer (N.R.W. Squires) was appointed to the Agronomy Section in September 1968.

GRASS WEEDS IN ARABLE LAND

Throughout Britain but particularly in areas where cereals are grown extensively, grass weeds are an ever-growing menace and give rise to much concern. A major part of the research programme of WRO has now been directed towards this problem. The comprehensive investigations by the Botany, Evaluation and Agronomy Sections include botanical studies to find out why the weeds are so successful, detailed testing of new and old herbicides and agronomic work in collaboration with farmers on programmes of stubble treatment for couch grass control. This programme has been much helped by the valuable contribution of Dr. D. J. Turner working on the influence of defoliation on the growth of *Agropyron repens* (couch grass) during a two-year fellowship generously sponsored by the Grasshoppers Club. In 1968, as a result of a recommendation by the Visiting Group, the programme of the Botany Section was expanded to include ecological studies on the competition between weeds and crops. *Avena fatua* and *A. ludoviciana* (wild oats), amongst the most intractable problems facing the cereal grower to-day, were selected for study and it is expected that the programme will give active support to the other Sections of WRO actively concerned with developing chemical and other control methods. The work will be assisted by the appointment to the Botany Section in January 1969 of an experimental officer (N. C. B. Peters).

CEREAL SPRAYING

In due course it is hoped to extend work on weed ecology to include other weeds of cereals. With decreasing profitability of cereal production and reduced weed populations due to regular spraying, farmers are tending to view expenditure on herbicides for broad-leaved weed control more critically. During the past few years, largely due to the efforts of the National Agricultural Advisory Service (NAAS), it has become generally accepted that it is the exception rather than the rule for major yield increases to follow routine spraying of cereals—at least in the south-east of England and the Midlands. There are, however, many other benefits from producing weed-free crops and individual farmers must themselves decide whether the cost of spraying is likely to be justified on any given field in any particular year, bearing in mind the long-term consequences of inefficient weed control. The wet summer of 1968 convinced many doubters that spraying continues to be very worthwhile provided the cost is not excessive.

NEW HERBICIDES

During the past two years, the output of herbicides has continued to soar. In 1967 herbicides to the value of some £17 m. were sold by British manufacturers. A bewildering assortment of chemicals is now available to the farmer and grower. At WRO we no longer attempt to test all new herbicides in field trials, having decided that it is more profitable to concentrate on a few major problems. The Evaluation Section does, however, endeavour to include all the more promising chemicals in a series of glasshouse experiments to assess systematically their activity and selectivity. Persistence in the soil is also examined as far as resources permit. This information provides a valuable guide to promising uses and possible snags. Arising out of the programme during the past two years, the following are of particular interest and importance: the selective phytotoxicity of sulphonyl carbamate herbicides such as asulam to *Rumex* spp. (docks) and to established grasses, the use of chlorthal dimethyl or Glenbar for the selective control of *Agrostis* seedlings in newly planted grass and grass/clover swards, and the surprising activity of tri-allate granules for post-emergence control of wild oats in cereals.

During the period under review S. D. Hocombe left the Evaluation Section to join Geigy (UK) Ltd., and was replaced by Dr. J. Caseley to undertake a study of the influence of environmental factors on the activity of herbicides. Mrs. A. Wilson and I. E. Henson were replaced respectively by W. G. Richardson and R. H. Webster.

APPLICATION OF HERBICIDES

It is perhaps not said often enough that herbicides can only be as good as their application allows. Whilst there has been a steady improvement in the design and construction of spraying equipment, the basic principles in general remain unaltered. Many farmers do not give much attention to maintenance or to the calibration of nozzles, and recent surveys have shown that a deplorable lack of precision of application is by no means uncommon. This may be of little significance with such tolerant herbicides as MCPA but can lead to indifferent weed control or crop damage with others. The truth of the matter is that so little research has been done to relate biological results of herbicides with the method of application that there is litttle guidance to farmers or manufacturers or indeed to research workers concerned with the development of new herbicides. The need for more information is now widely recognised and was stressed in a recent report of the Joint Application Committee of the British Weed Control and Insecticide and Fungicide Councils. A collaborative research programme has now been developed by WRO with the National Institute of Agricultural Engineering (NIAE) to investigate the problem. An experimental officer (W. A. Taylor) who joined the Evaluation Section in November 1967, is responsible for much of the biological work of this project.

WEED SURVEYS

With rapid changes in patterns and methods of crop production and in weed control techniques it is difficult to keep track of changes in weed populations and the practical problems experienced by farmers and growers. Apart from the results of occasional small-scale surveys, little accurate information is available. A proposal put to the Visiting Group in 1967 that WRO urgently needed guidance on this subject led to the appointment of a surveys officer (T. W. Cox) to the Agronomy Section in July 1968, and a pilot survey in collaboration with a firm of agricultural merchants has been successfully completed. With the increasing and already very large scale annual inspection of farms by weed control specialists of herbicide suppliers, there is a wealth of information on arable weeds becoming available each year. Given the continuing collaboration of the industry, it should be possible to build up quickly a procedure by which major shifts in weed populations and changes in control procedures will be readily detected.

WEED CONTROL ON ORGANIC SOILS

Weed control continues to be one of the major problems facing farmers and growers on the high organic soils of the fens in East Anglia and the Lancashire moss. Whilst a number of herbicides are widely used, often with considerable success, the results are variable and there are many difficulties. With the formation of the Arthur Rickwood Experimental Husbandry Farm near Chatteris in 1964, the Ministry of Agriculture invited WRO to undertake weed control investigations there specially directed towards solving some of the problems. Some preliminary work was undertaken by the Agronomy and Evaluation Sections in 1966 and 1967. In 1968 an experimental officer (E. Ramand) was appointed to the Evaluation Section of WRO to lead a small team able to devote all its time to the work. A promising start has been made, and in November 1968 a meeting sponsored by WRO of 30 to 40 local farmers, advisers, suppliers and spraying contractors concerned with weed control in the fens showed enthusiasm for the project and produced constructive ideas for collaboration.

EFFECT OF HERBICIDES ON SOIL FERTILITY AND WILD LIFE

The regular and already very extensive use of herbicides on the cultivated land of this country continues understandably to give rise to some concern as to the possible long-term effects on soil fertility and wild life. At Begbroke the long-term field experiments in which certain herbicides are applied regularly to the same plots of ground have now completed their sixth year. The test crops continue to remain unaffected by the treatments and the studies on soil respiration undertaken by the Microbiology Section have detected no significant changes that can be attributed directly to the chemicals. It is the responsibility of the Nature Conservancy rather than of WRO to investigate the effects of herbicides on wild life. Manufacturers are now required to submit evidence of safety in this respect when notifying new chemicals to the Pesticides Safety Precautions Scheme. The great majority of herbicides in use to-day have very low toxicity to wild life in general and the major influence they are likely to have is in providing more efficient weed control throughout our arable crops than has been possible hitherto, thus reducing cover and food for some species. This is a trend which must be accepted but which makes uncropped land of ever-increasing importance. The extensive use of herbicides in non-agricultural areas forming the reservoirs of wild life needs, of course, to be viewed with caution.

The long-term experiments will be continued at Begbroke for a further period. Collaborative work between WRO and the Food Research Institute at Norwich, also with the Lord Rank Research Centre at High Wycombe, has been started to investigate certain aspects of quality of the produce grown on treated and untreated plots. K. Kirkland, who has been concerned with these experiments since 1963, resigned in 1968 in order to take up a research fellowship in Oregon State University. He obtained the award of M.I.Biol. for his thesis on these investigations. The effects of herbicides on soil micro-organisms continue to be studied by the Microbiology Section and the programme has beeen much assisted by the appointments of J. A. P. Marsh and T. H. Byast, also by "sandwich" students, R. Brans, P. Adams and Miss H. C. McAllan.

CHEMICAL ANALYSIS OF HERBICIDES RESIDUES

The long-term herbicide investigations and many other projects have greatly benefited from the work of the Chemistry Section in developing and undertaking chemical analyses of herbicide residues in plants and soils. The programme of the Section was stimulated by two visiting research workers, R. S. Tamés of the Plant Physiology Department, Facultad de Farmacia, Universidad Santiago de Compostela, Spain, October 1966 to November 1967, and Dr. R. Grover of the Canada Department of Agriculture Research Station, Regina, Saskatchewan, September 1967 to August 1968. The Head of Section, Dr. R. J. Hance, left WRO on the 3rd September 1968 for a six-month visit to North America to widen his experience by working at the University of Saskatchewan, Canada, and the University of Wisconsin, U.S.A.

HORTICULTURAL WEED CONTROL

The horticultural work of WRO is mainly directed to the weed problems of fruit and ornamental crops. Research on herbicides for vegetables continues to be the responsibility of the National Vegetable Research Station. Close liaison is maintained between the two institutes and the glasshouse evaluation work on new herbicides at Begbroke includes vegetable crops in its range of horticultural crops and weeds. The Head of Section, Dr. G. W. Ivens, left WRO on the 23rd October 1966 to take up a four-year secondment to FAO as bush control specialist to the UNDP/FAO Range Management Project in Kenya. Dr. Ivens will be returning to Begbroke in 1970 to occupy one of the two 'home based' posts sponsored by the Ministry of Overseas Development. Dr. J. G. Davison, formerly the herbicides Liaison

Officer to the Agricultural Chemicals Approval Organization, succeeded Dr. Ivens. With the agreement of ARC, the opportunity was taken to review the requirements of growers of fruit and ornamental crops for improved weed control methods and to make recommendations for future research. Dr. Davison visited growers, advisory officers, research workers and chemical firms concerned with weed control in horticulture throughout the United Kingdom. His report is under consideration. In the meantime it is clear that a major problem in fruit crops is presented by weeds which are tolerant to existing herbicides. Much more information is also required on the persistence of residual herbicides in soil in different parts of the country. The work of the Horticulture Section is currently directed towards these problems.

AQUATIC WEEDS

The survey on the problem of aquatic weeds in England and Wales undertaken by T. O. Robson in 1964-5 led to a decision by ARC to form a small research team, under Mr. Robson, at WRO to investigate the role of herbicides and other control measures in maintaining the drainage channels of agricultural land. An experimental officer (P. R. F. Barrett) was appointed in July 1968. The programme of the Section, which is being guided by an ARC Technical Committee on Aquatic Weeds, will include glasshouse and field experiments. Mr Robson made a three-week visit to the USA in 1968 to study the relevance of work on aquatic weeds in the States to the problems in Britain. Acknowledgment of the multi-purpose role of water in Britain and of the importance of maintaining habitats for wild life and valued plants is a pre-requisite of this programme.

OVERSEAS ASPECTS

At the Ninth British Weed Control Conference held at Brighton in November 1968 two sessions were devoted to weed control in tropical agriculture. These proved outstandingly successful and confirmed the tremendously important role that herbicides will play in the future in increasing supplies of food and fibre. WRO has long been actively concerned with tropical weed control, in providing information and undertaking liaison and advisory visits and research. Discussions have been held with the Ministry of Overseas Development (ODM) on how the WRO contribution can be made more effective in view of the urgent need for weed research to be developed in many tropical countries.

Proposals for a reorganization and expansion of this part of the programme have been agreed. Dr. E. C. S. Little, Overseas Liaison Officer at Begbroke since 1963, after a period of secondment to FAO in Rome as a consultant on weed control, left WRO in order to take up another appointment with FAO. It is a pleasure to acknowledge here the important contribution of Dr. Little in building up liaison between WRO and workers in the many tropical countries he visited. In his absence, C. Parker has made three very successful visits to Africa and S.E. Asia on behalf of ODM, the Commonwealth Development Corporation and the South East Asia Treaty Organization. In November 1968, L. Kasasian, a former colleague and well known for his pioneer work on weed control in the West Indies, joined WRO for a three-year appointment sponsored by ODM to write a tropical weed control handbook. There is an urgent need for information on modern weed control methods for use in tropical crops to be made available to agronomists, advisers, research workers and teachers in developing countries.

Overseas interests of WRO are not confined to the tropics. Close ties now exist between WRO and weed control specialists throughout the world. Particularly close collaboration has been built up with Dr. W. van der Zweep and his colleagues at the Institute for Biological and Chemical Research on Field Crops and Herbage (IBS) at Wageningen, the Netherlands, both in research and in the affairs of the European Weed Research Council. The latter is making valuable progress in promoting the interchange of information and contacts between weed workers throughout the countries of West and East Europe.

INFORMATION AND PUBLICATIONS

The international role of WRO is reflected in the number of visitors and enquiries from overseas. That assistance can be given is in no small measure due to the continuing activities of the Information Section, which reviews and indexes the world literature on weeds and weed control. The Section's efforts are widely disseminated in the form of *Weed Abstracts* published by the Commonwealth Agricultural Bureaux. Two other publications deserve special mention in this review.

PANS C, the journal of tropical weed control, sponsored by the Ministry of Overseas Development, has blossomed under the active editorship at Begbroke of Dr. B. Steele. During 1968 ODM decided to amalgamate the three separate parts of *PANS,* devoted respectively to insect, plant disease and weed control, into a combined publication. Dr. Steele left WRO in late summer 1968 to take up the appointment of overall editor. Whilst it is to be regretted that the Section C with which WRO has for so long been concerned will now lose its identity, there is much to be said for the new arrangement, provided close links with WRO are maintained.

The second publication is the *Weed Control Handbook,* 5th Edition. Sponsored by the British Crop Protection Council, it was the outcome of the joint effort of more than 70 specialists from research institutes, advisory organizations, universities and industry. This edition was compiled and edited by members of WRO with the assistance of S. A. Evans, the NAAS agricultural Liaison Officer at Begbroke. WRO staff contributed several major sections to the two-volume book, which contains over 900 pages of information and recommendations.

NINTH BRITISH WEED CONTROL CONFERENCE

Another time-consuming but important exercise in which WRO has played a major part was the Ninth British Weed Control Conference held at Brighton, 18th to 21st November 1968. Apart from a major responsibility for organizing the programme, WRO staff contributed no less than 30 of the 214 papers. One thousand and fifty-eight delegates attended the Conference, a third of whom were from overseas. A major problem has now developed in that the scale of the Conference has reached such proportions that the existing voluntary organization for dealing with the programme can no longer cope satisfactorily in the time available with the number of papers submitted.

NATIONAL AGRICULTURAL ADVISORY SERVICE

After 15 years' service as NAAS weed specialist attached to ARC, S. A. Evans, Liaison Officer to WRO, left in the autumn of 1968 on promotion. During his stay at Begbroke and before that in Oxford, he made a major contribution to weed science, to NAAS and to WRO through his liaison activities and through his active membership of the British Weed Control Council, serving as joint editor of the *Weed Control Handbook* and Chairman of the Council's Application Committee. He was replaced by P. J. Attwood. The NAAS/WRO Liaison Group continues to meet regularly for exchange of information and joint planning of programmes of field experiments.

STATISTICS

Following a recommendation of the Visiting Group that the work of WRO would benefit from having the local services of a statistician, Dr. R. Scott Russell, Director of the ARC Radiobiological Laboratory, kindly agreed to make available Mr. B. O. Bartlett together with the institute's facilities to assist WRO. Since January 1968 Mr. Bartlett has spent not less than one day a week at Begbroke and has given help and advice which has been of much value and greatly appreciated. In 1968 his team was increased by an experimental officer (C. J. Marshall) to allow this work to be expanded. As in the past, WRO continues to enjoy the computer facilities at Rothamsted Experimental Station and to benefit from the advice of members of the Statistics Department.

FIELD EXPERIMENTS

Much of the programme of WRO is based on field investigations. Some 120 new experiments are started each year and half as many again are carried over from one year to another. The work is divided between Begbroke Hill Farm and outside sites.

Co-ordination of land, equipment, chemical supplies and facilities is essential if the work is to proceed smoothly and efficiently. This is undertaken by the Field Experiments Committee with the assistance of a full-time clerk. The Committee also has a major responsibility for the receipt, storage and indexing of experimental results.

COMMITTEES

Members of WRO have served on the following committees, etc.:

Agricultural Chemical Approval Scheme Advisory Committee
ARC Committee for Collaborative Research: ARCRL, GRI, WRO
ARC Technical Committee on Aquatic Weeds
ARC Technical Committee on Potato Problems
ARC Working Party on the Development of Herbicides in Potatoes
British Crop Protection Council (BCPC)
BCPC: Application Committee
Conference Organizing Committee
Programme Committee
Steering Committee
4th and 5th Annual Reviews of Herbicide Usage

British Grassland Society Journal Committee
British Standards Institution Technical Committee PCC/1
British Weed Control Council (BWCC)
BWCC: Handbook Committee
    Recommendations Committee
BWCC/BIFC Joint Working Party to consider possible amalgamation
European Weed Research Council (EWRC)
EWRC: Evaluation Committee
    Finance Committee
    Research Group on Annual Grass Weeds
    Research Group on Aquatic Weeds
    Symposium Programme Committee
Ministry of Agriculture, Fisheries & Food:
    Pesticides Analysis Advisory Committee, GLC Panel
    Research Group on Pesticides in the Aquatic Environment
    Working Party on Weed Seeds
Ministry of Overseas Development PANS Policy Committee
Ministry of Overseas Development/WRO Liaison Committee
NAAS Experimental Husbandry Committee, Cereal Experiments:
    Minimum Cultivations Working Party
NAAS Experimental Husbandry Committee, Cereal Experiments:
    Couch and Wild Oats Working Party

VISITORS

Some 2,000 visitors came to Begbroke Hill during the two-year period. They were not only technical people from the U.K. and from overseas, but also from the farming and horticultural communities, from universities and schools, and from local voluntary organizations. Those who came from overseas represented 14 Commonwealth and 27 foreign countries.

NEW BUILDINGS

A new office and service block for the field teams and an extension to the existing laboratories will be completed early in 1969. These, together with the existing buildings, should meet all the requirements for accommodation and facilities for the foreseeable future. The new field block will allow for the first time the accommodation of field experimental staff on a sectional and team basis and will provide excellent facilities for soil processing, nozzle testing, equipment and produce storage. The laboratory extension will include laboratories for the Evaluation, Chemistry, Microbiology and Aquatic Weed Sections, together with two additional glasshouses. Again the architects, Messrs. Brian and Norman Westwood, Weybridge, Surrey, have done an excellent job in designing buildings which harmonize with those which already exist.

ADMINISTRATION

The WRO Administration has continued to give reliable support to the research staff. Following visits made by the ARC Staff Inspector, Mr. Mason, a major reorganization of the Workshop was made early in 1968, and a redistribution of work within the Secretary's office staff will coincide with the move to fresh accommodation in 1969. Both these are re-appraisals of functions and responsibilities after the first eight years of WRO, during which the Administration has grown in proportion to the expansion in research.

In the Workshop, with R. Kibble-White in overall charge, there is a team of two working wholly on Experimental Requirements, a Building Maintenance team and a Common Services team (Carpenter, Electrical and Plant Fitter) working on both experimental and maintenance needs.

The Secretary's office staff has an Establishments and Services team (Mrs. L. M. Hall) and a Supplies and Accounts team (Mrs. E. M. Rushworth and L. G. Young).

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the abundant help and goodwill received from members of the ARC Headquarters staff and the interest and encouragement from members of the Ministry of Overseas Development. My colleagues and I are also grateful to all the many people in industry, in universities, in other ARC institutes and in many other organizations in Britain and overseas who show an interest in our work and who are so willing to collaborate.

I should also like to thank all the staff of WRO for their loyalty, support and hard work. I am specially grateful to my colleagues, J. G. Elliott, Head of the Weed Control Department, Dr. K. Holly, Head of the Weed Science Department, and B. A. Wright, Secretary, for their unstinting help, co-operation and efficiency.

Finally, I wish to record my gratitude to D. O'D. Bourke for editing this report and making arrangements for its publication.

Changes in Scientific and Experimental Staff

NEW APPOINTMENTS

Miss C. N. Hasnip	EO	Information	3. 7.67
W. A. Taylor	AEO	Evaluation	29. 8.67
J. C. Caseley	SSO	Evaluation	23.10.67
W. G. Richardson	EO	Evaluation	13. 2.68
E. Ramand	EO	Evaluation	15. 2.68
J. A. P. Marsh	AEO	Microbiology	1. 3.68
D. J. Turner	SSO	Evaluation	15. 3.68
T. W. Cox	AEO	Agronomy	1. 7.68
P. R. F. Barrett	AEO	Aquatic Weed	8. 7.68
N. R. W. Squires	AEO	Agronomy	16. 9.68
L. Kasasian	PSO	Overseas	1.11.68
R. H. Webster	EO	Evaluation	1. 1.69
N. C. B. Peters	AEO	Botany	1. 1.69

RESIGNATIONS

S. D. Hocombe	SSO	Evaluation	21. 7.67
D. L. Jones	AEO	Microbiology	15. 9.67
Mrs. A. K. Wilson	AEO	Evaluation	29. 2.68
E. C. S. Little	PSO	Overseas	8. 3.68
D. J. Turner	Temp. Res. Gt.	Agronomy	14. 3.68
K. Kirkland	AEO	Long-Term Herbicide Project	31. 8.68
I. E. Henson	AEO	Evaluation	2.10.68

Perennial Grass Weeds of Arable Land

G. W. Cussans and J. G. Elliott

One of the features of the agricultural scene during recent years has been a steady increase in the importance of perennial grass weeds in arable land. Several species are involved but the two most widespread are *Agropyron repens,* the true twitch or couch grass, and *Agrostis gigantea,* black bent. Both species can be controlled in cereal stubble by herbicides but the treatments are expensive and the results can be variable. Even where a high degree of control is obtained the surviving population may soon build up to its original level if the circumstances are conducive to recovery. A system which allows these grasses to flourish in the first place will also favour their recovery from treatment.

The work on these grasses at the Weed Research Organization has been established along two main lines. All herbicides entering glasshouse evaluation are tested for their activity against these species; any showing promise are investigated further by means of field experiments. The other and contrasting approach involves critical examination of the weed itself: its biology and growth in relation to different crops. By obtaining an understanding of the reaction of these weeds to different environmental and management factors, systems of control to suit individual forms can be logically worked out and put to the test.

Essentially the grass weeds pose a long term problem with no easy short term solutions. A detailed knowledge of weed biology and herbicide technology must be combined with an understanding of farm management in the development of new control techniques. This review, which is mainly but not entirely concerned with the work of WRO considers some recent developments in current knowledge of perennial grass weeds and methods of controlling them.

Biological investigations

Seed of these weeds may be spread in contaminated lots of crop seed, straw or on machinery and may survive in the soil in a dormant state. It is, therefore, a potential source of new infestation, of the introduction of new clones and of recontamination of areas of land previously cleared.

A programme of work has been initiated at Rothamsted to study the production of seed by *A. repens* and *A. gigantea* and the subsequent behaviour of this seed. The results so far have indicated that most of the seeds of both species are viable and that the seedlings are vigorous and quick to initiate new rhizome (Williams, 1968). The seed appears to have little natural dormancy at first but dormancy may occur later in seed which is buried.

Growth from rhizome fragments and particularly the production of new rhizome has been studied by the Agronomy Section. It appears that the growth of *A. repens* is comparatively slow in spring. Shoot emergence is slower and more protracted than that of barley planted at the normal time for the region (Cussans, 1968a). New rhizome growth does not appear to be initiated until the aerial shoots have started tillering. The maximum rate of new rhizome growth has been recorded during early and mid-summer but production continues at a slower, though substantial, rate during the autumn.

Competition from a crop suppresses growth and can delay the formation of new rhizome by a month or more. Spring barley, which establishes a complete cover of foliage very rapidly in the spring, appears to be particularly suppressive, spring wheat is a mediocre competitor and spring beans are relatively poor in this respect (Cussans, 1968b). Although spring cereals outgrow the weed during the early summer, *A. repens* retains its potential for vegetative growth after the crop has commenced ripening and no longer offers appreciable competition. The weed is therefore able to make growth during the ripening period of the crop and during the post-harvest period. During damp weather in the Midlands, it must be expected that the rhizome weight per acre in a cereal stubble will at least double between early September and early November.

The success of *A. repens* is in no small measure due to its ability to regenerate from cut rhizome fragments, after cultivation, and this subject has been studied by Agronomy and Botany Sections. When a rhizome is detached from its apex, a proportion of the rhizome buds ceases to be restricted by apical dominance and produces aerial shoots. Chancellor (1968) has shown under laboratory conditions that 70-80% of the buds make some growth but most of them are re-inhibited within 10-20 days. This re-inhibition is presumably due to the re-assertion of apical dominance by the most well-developed shoots. This shoot activity uses up carbohydrate reserves in the rhizome. The loss of carbohydrate from the rhizome continues until after the dominant shoots have emerged above ground and photosynthesis can restore the situation. The minimum level of rhizome reserve appears to be reached when the aerial shoots have about 2 leaves or are 2-4 in. high. After this stage, the products of photosynthesis are channelled first into restoration of the original rhizome reserves and subsequently into the formation of new rhizomes. The degree of exhaustion of reserves is greatest in the case of short pieces of rhizome planted deeply in the soil, and least with long pieces planted shallowly (Vengris, 1962 and Turner, 1966).

Stimulation of bud activity and depletion of the rhizome food reserves are important consequences of cultivation. Desiccation may also be important. The rhizomes are vulnerable to the effects of freezing and drying but can gain protection from even shallow burial.

Control measures

Traditional control methods based on cultivation have commonly attempted to draw rhizomes to the surface of the soil for desiccation, subsequent burning or re-burial by mouldboard plough. Some systems of rhizome fragmentation by rotary cultivation have been described by Fail (1956), Proctor (1960) and others. Essential to the success of such systems is the requirement that disturbance should occur at regular intervals as part of a summer or autumn fallow. Other implements may also be used as agents of repeated disturbance: tined cultivators and heavy discs have been successfully used on a farm scale.

Now that defoliants are available to prevent growth in weather that is too wet for cultivation, such programmes of repeated cultivation can be started with greater confidence.

A notable contribution to the control of grass weeds has been made by Dr. Turner working at WRO on a grant from the Grasshoppers Club. He has demonstrated that the rhizome carbohydrate reserves can be drastically reduced by a technique involving initial cultivation to chop up the rhizome followed by defoliation at regular intervals by low doses of 1 to 4 oz./ac paraquat ion or by cultivation. The practical implications of this technique are being evaluated. It appears that attrition of the carbohydrate reserves is more efficient if paraquat is applied at a low dose on a number of occasions than if it is applied as a single high dose (Turner, 1969). Preliminary stimulation of bud activity by cultivation is essential to this technique and indeed the activity of a number of other herbicides is generally enhanced by cultivation.

The possibility of increasing the effect of dalapon by first cultivating and then applying the herbicide to the young regrowth was suggested by Sagar (1961) and this technique has since been adopted with some success for this chemical and for activated aminotriazole. The activity of certain soil-acting herbicides is increased by cultivation for different reasons. Such chemicals require incorporation to bring them into the zone of bud activity or to reduce loss by volatilization. In addition, however, the increased bud activity resulting from rhizome fragmentation must always play a part in the response to cultivation.

Interest in the placement of herbicides in the soil has led to a joint research project between WRO and the National Institute of Agricultural Engineering (NIAE) aimed at the development of machinery for the application of herbicides below the soil surface. A prototype machine has been built, using a nozzle operating in a hollow horizontal share and some interesting preliminary results have been obtained by the Evaluation Section using EPTC as a test herbicide. Obviously such a technique is not without its problems, but the prototype machine has been found to have the advantage of a low draught requirement when pulled through the soil and it is therefore potentially capable of covering a large area in a day's work. Another implement has been devised at the Edinburgh School of Agriculture whereby TCA is sprayed at high volume on to the curtain of soil thrown up by a rotary cultivator (Ramand *et al.,* 1968). The technique has given good control of *A.*

repens in Scotland. TCA can also provide a successful control when applied to bare soil and followed by rotary cultivation (Elliott *et al.*, 1966).

The organizational problem

The reader will by now have formed the impression that a great deal is known about the major grass weed *A. repens* (and much of this knowledge is applicable to *A. gigantea*) and that there are numerous possible cultural or chemical control measures. There is little difficulty in prescribing forms of control that are technically effective, but many such measures are unacceptable to farmers for economic or organizational reasons.

It has frequently been suggested that a return to crop rotations would help the situation and, in some break crops, useful control measures can be applied, but most of the farm break crops available offer little scope for the control of perennial grass weeds. Valuable contributions may be made by developments in these crops but the hard core of the problem is in the cereal crops. Control has to be obtained within a cereal rotation and against a background of little money for chemical purchases and little spare labour for cultural activities. This means in practice that control measures are restricted to the period between harvesting one crop and sowing the next. The biological studies have shown that the period during which the crop is ripening or ripe but unharvested should be kept as short as possible and that a control programme should commence as soon as possible after harvest. In this respect the delayed and protracted harvest which is commonly experienced in the North and which was a feature of most of Britain in 1968 is a major obstacle. The problem is more acute in successive winter wheat crops than in spring barley. It may even be that the development of early maturing varieties that would spread the harvest and allow at least a proportion of the land to be cleared early would be justified even where such varieties do not excel in the normal conditions of variety testing.

Three activities are necessary for the start of a grass weed control programme and the importance of early action has emphasized the need to plan and organize them as a concerted effort. These are grain removal, straw disposal and the first treatment of the stubble.

WRO Farm has taken a keen interest in this aspect of the research and the 1968 cereal harvest was a planned and recorded operation involving the three basic activities. It is evident that straw can be a major stumbling block. While in swathes it can be burnt or chopped with an acceptably low labour input but once baled the labour requirement (and often, therefore, the delay in dealing with it) can increase considerably. It seems important not to bale more straw than is specifically required. In dry weather burning and baling are easy to achieve but in wet conditions they can delay the control programme. The approach at WRO has been to chop all unwanted straw, normally within two days of combining. This operation can be carried out despite the weather and allows timely cultivation but the litter of straw is such that the choice of implements is restricted to a heavy disc or rotary cultivator. Tined implements cannot be used immediately after chopping but they can be introduced into a control programme later in the autumn. A defoliant is used to kill top growth if weather, soil conditions or labour shortage makes cultivation difficult.

This approach needs careful and determined organization but it can be extremely successful in suppressing grass weeds. The system interferes with the autumn ploughing programme by competing for man and tractor power. In addition the efficiency of ploughing may be reduced by loss of traction on the cultivated surface. A solution to this difficulty may be to abandon the practice of ploughing on at least a proportion of the acreage and to continue cultivation whenever conditions are favourable. In many situations this modified approach to cultivation may be the best way to combine the requirements of perennial grass control and soil management.

In all, the prospect of perennial grass control is encouraging. A great deal of new information has come to hand in recent years and it does seem possible to integrate routine control measures into cereal farming systems at an acceptable cost in both financial and organizational terms.

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Wild Oats

R. J. Chancellor and J. Holroyd

It is significant that the saying "to sow wild oats" has long been used to illustrate indulgence in heedless folly, for the aptness of popular metaphor underlines not only the fallibility of mankind, but serves also to emphasize the importance of the weed. Furthermore, it is a reflection of the unchanging nature of man and of the difficulties presented by the weed that both are still equally applicable to-day.

Species of wild oat

There are three wild oats in Britain. *Avena fatua,* the spring wild oat, is the most important and it occurs in all the cereal growing areas of England. Whilst some germination occurs in the autumn, the main period lies between March and May. This species occurs therefore mainly in spring crops. In contrast, *Avena ludoviciana,* the winter wild oat, germinates over winter from October to March and so occurs mainly in winter crops. *A. ludoviciana* is found only in central and eastern England, because its introduction supposedly near Oxford dates only from the First World War or soon afterwards, and it is still spreading. *Avena strigosa,* the black or bristle oat, is the least common. It is unusual in that it can be a relic weed of cultivation in the south and yet is still, because of its hardiness, grown as a crop in the north. It has no seed dormancy, which possibly accounts for its lack of success as a weed. All wild oats are related to and closely resemble the cultivated oat, with which they occasionally hybridize.

Spread of wild oats

Wild oats are very similar to the cereal crops in which they grow and this makes the finding of selective control measures more difficult. In addition a number of inherent characteristics contribute greatly to their success. Their seeds mature rapidly and many are shed before the crop is harvested, an advantage accentuated by the tendency to harvest late due to the needs of combining. Seed dormancy and persistence are also important. The dormancy of *A. fatua* is due to the impermeability of the seed coat. In the field germination must wait upon rotting of the seed coat. As a result seedlings from one crop of seeds emerge over a number of years, with the largest number in the second spring after shedding. So, even if a field is grassed down for five years as a preventive measure, it will still contain sufficient viable seed to re-infest the field afresh when ploughed up again. Some seeds may even survive for a decade, particularly in undisturbed soil.

Another advantageous feature of the seed is the long spiral awn, which responds to changes in humidity by twisting. This helps to propel seeds down cracks or beneath clods and contributes towards long-distance dispersal by catching in machinery, sacks, or packing straw.

Two other factors have favoured the increase of wild oats over the last three decades. These are intensive cereal growing, which started during the last war and entails the loss of the traditional cleaning root-crop and, secondly, the decline of broad-leaved weeds through extensive use of growth regulator herbicides. This decline has left a niche which wild oats have been quick to occupy.

Damage caused by wild oats

There is little doubt that severe infestations reduce yields substantially besides reducing the value of grain contaminated by wild oat seeds, which are difficult and expensive to clean out completely (they are listed as injurious in the Seeds Regulations). It is commonly said that when there are ten flowering heads per square yard, the loss of crop yield is equal to the cost of spraying. A new project has recently been started at WRO to investigate competition and crop losses due to weeds. Because wild oats are considered one of the most important annual weeds in British agriculture, they have been chosen for the first investigation (see the Botany and Agronomy Section reports).

The competition of wild oats has previously been studied extensively at Rothamsted by Miss J. M. Thurston, who observed that seedlings of wild oats, although smaller than those of cereals to start with, grow faster and soon overtake the crop. Increased fertilizer has little effect upon competition, for both crop and weed take equal advantage of the extra nutrients. The competitive balance can be upset by soil acidity, disease and by the crop variety grown, for cultivars apparently differ greatly in their suppressive ability.

The control of wild oats

One of the first essentials is to prevent the infestation of clean land by sowing uncontaminated seed. When wild oats first appear every effort should be made to prevent them from seeding, by hand-pulling if necessary. Once established, a change in cropping programme will greatly reduce both species. Populations of *A. ludoviciana*, which is winter-germinating, can be controlled by growing a series of spring crops.

The spring-germinating *A. fatua* can similarly be controlled by the late planting of spring barley, although this has been shown by M. Selman at Boxworth Experimental Husbandry Farm to reduce crop yield severely in most years. He also found that the soil-acting herbicide, tri-allate, when used in early-sown crops, gave an equivalent reduction of wild oats, without any loss of yield, and this was economically better than late sowing.

Two effective herbicides have been available for the control of wild oats in cereals since 1961 and in view of this, it is rather surprising that the weeds have continued to spread and increase. The reason is partly economic and partly technical, for both treatments are expensive and both present problems of application to the farmer.

Tri-allate is a volatile herbicide which has to be mixed with the soil immediately it has been applied, either before or after drilling the crop. Its incorporation is often difficult for seed beds of winter crops are rarely anything but lumpy, and in spring crops too, soil conditions are often poor. Furthermore, farm implements are designed for cultivations and not for mixing herbicides with the soil. The distribution of the herbicide is therefore often very uneven and can result in crop thinning or poor weed control.

The other herbicide barban, unlike tri-allate, is applied when both the crop and the weed have emerged. The farmer can therefore wait until he can see the weed before applying the herbicide. However, timing of the application is critical because wild oats are most susceptible when they have 1 to $2\frac{1}{2}$ leaves. In some seasons the emergence of wild oats is extended over a relatively long period; this results in poor control because the plants that emerge after treatment are unaffected and those that have more than $2\frac{1}{2}$ leaves are only temporarily checked, particularly in crops of poor competitive ability. In addition some varieties of barley, e.g. Proctor, are themselves severely damaged by barban. Winter wheat can also be checked in growth, although recovery is generally complete. Application can be a major difficulty, for it often has to be made in the depth of winter. Both herbicides, therefore, have difficulties associated with their use and moreover neither is cheap.

Recent developments

New compounds are continually being screened by industry for their toxicity to wild oats and the more promising of these are studied at WRO. However, few with worthwhile activity have come to light in recent years.

In 1968 a promising lead has come from work at WRO, which suggests that some of the problems connected with tri-allate may be overcome by using granular formulations post-emergence. These eliminate the need for mixing the herbicide with the soil and should therefore make distribution more even. In addition tri-allate in this form controls wild oats which have already emerged and so extends the period during which application can be made. Selectivity may also be increased.

Future prospects

The factors influencing the movement, and the expansion and contraction of wild oats are being investigated by a surveys officer recently appointed to the Agronomy Section while other work is concerned with the influence of autumn and spring cultivations on subsequent wild oat populations.

New herbicides will undoubtedly be discovered and one which is under development is mentioned elsewhere (see Evaluation Section report). Other lines of attack may also be fruitful. For example, research at WRO has been directed towards finding a treatment, which could be applied overall, to prevent the onset of dormancy in wild oat seed. Unfortunately none of the compounds tested so far have had sufficient activity. Other lines of attack could be to prevent seed set or to delay seed ripening.

Whilst the problem remains an intractable one there is good reason to hope that the intensive search for better methods of control will soon be fruitful.

Department of Weed Science

Evaluation Section

Head: K. Holly

During the two years covered by this Report the work of the Evaluation Section has continued to diversify. Essentially the Section is concerned with studies on the potentialities and performance of herbicides in British and tropical agriculture and on the factors which may influence their efficiency of use. This has extended to such topics as the special problem of herbicides for use on high organic matter soils and the influence of application technique on biological effectiveness. The research by the Section is divided about equally between laboratory glasshouse work and experimentation in the field.

PRELIMINARY EVALUATION OF HERBICIDES

Selectivity

During 1967 and 1968 the flow of new herbicides from the agricultural chemical industry has continued. Twenty-three such herbicides have been subjected to the initial activity test described in the WRO Second Report, 1965-66, and designed to answer simple questions such as the relative importance of root and shoot entry in securing effects on emerged plants or whether incorporating into the soil or leaving on the soil surface gave the greater pre-emergence effectiveness. The detailed selectivity over a wide range of species both pre- and post-emergence was investigated as previously and some 26 new herbicides were examined in this way. The demand for the results of these experiments expanded, and towards the end of the present period the system of personal circulation as unpublished reports to appropriate individuals around the world was replaced by publication in the WRO Technical Report series.

Toxicity to perennial weeds

A few perennial species have always been included in the routine selectivity experiments but only in a very early stage of development. Occasional experiments have been conducted on well-established plants of *Cyperus rotundus* (nutgrass), *Agropyron repens* (couch grass) or *Oxalis latifolia* (oxalis).

A more comprehensive system for evaluating post-emergence treatments was introduced in 1967, in which up to thirty perennial species have been established each year in pots and treated with a range of the more interesting new herbicides, or with mixtures which it is believed might show useful additive effect or interactions.

The plants are established several months beforehand (over twelve months in the case of *Pteridium aquilinum,* bracken), so that underground rhizomes or tubers or other perennating systems are well established and reasonably comparable with naturally occurring populations in the field. Most species are grown outside, but nine are tropical or sub-tropical, and are raised in the glasshouse (see Overseas Work).

The results have shown up interesting susceptibilities and tolerances. Asulam for instance is highly active on *Equisetum arvense* (common horsetail), and *Tussilago farfara* (coltsfoot) and several of the tropical perennial grasses as well as on *Rumex obtusifolius* and *R. crispus* (docks). Chlorflurecol is particularly active on *Tussilago farfara*. Terbacil and bromacil show high activity on most species, but *Ranunculus repens* (creeping buttercup) and *Mentha arvensis* (corn mint) are conspicuously tolerant. It is intended to publish the results in the form of WRO Technical Reports.

SPECIFIC WEED AND CROP PROBLEMS

Avena spp. (wild oats)

The magnitude of the wild oat problem provides the justification for a major research effort by the Section.

A potentially significant finding from the 1968 experiments was that tri-allate, when formulated as a granule, had a marked post-emergence activity on wild oats both in the glasshouse and under field conditions. Mixing of the granules with the soil proved to be unnecessary, and their activity was of the same order as similar doses of an emulsion formulation mixed into the soil before emergence, and several times greater than the emulsion applied and left on the soil surface after emergence. Wild oats were severely affected up to early tillering by doses of ¼ lb/ac but wheat and barley were apparently little affected by similar doses.

However, before this technique can be generally recommended, its reliability needs to be more fully investigated. Other aspects such as the importance of temperature, soil moisture, the age of the weed seedlings and the depths from which seedlings arise in the soil, and crop safety also need to be more fully evaluated. Some of these will be included in the research programme for the coming season. One of the more interesting aspects of this particular work is that it is one of the first instances in which the vapour activity of a herbicide is being utilised for the selective control of an emerged weed.

Other work on wild oats this season has been concerned with the evaluation of a new post-emergence herbicide Bidisin (2-chloro-3-(4-chlorophenyl) propionic acid methyl ester), which shows some promise, with activity of a similar order to that of barban. In addition, an investigation was made of the influence of application technique on the activity of barban on wild oats in a crop of barley (see *Application*).

Alopecurus myosuroides (blackgrass)

Together with wild oats, *Alopecurus myosuroides* is the major annual grass weed problem in cereals in Britain at the present time. It is mainly confined to the winter wheat growing areas and therefore the heavier land, although its incidence in spring crops also seems to be increasing.

Very recently the number of herbicides commercially available and under development for the control of blackgrass has increased sharply. Many of the commercial firms have relatively large development programmes under way and so this project will receive less attention by WRO in the future.

However, during the last two years the programme, started in 1965 to compare the effectiveness of the various herbicides available under the same conditions, has been continued. A further twenty-two herbicides and various herbicide mixtures have been examined in a total of five experiments. All the treatments were applied as logarithmically reducing doses, over the range $x \rightarrow x/_{16}$ lb. a.i./ac. Applications were made pre-emergence and/or at various times after the crop and the weed had emerged.

One of the most effective herbicides was terbutryne used pre-emergence at 3 lb a.i./ac which gave consistently good selective control though at the recommended dose of 2 lb a.i./ac control it was not so consistent. The details of the whole of the results from this project are summarized in papers presented at the 1966 and 1968 British Weed Control Conferences.

Agropyron repens (couch grass)

An ideal time for using herbicides to control couch is in the autumn when there is a period of several months free from cropping. Alternatively, herbicides can be applied pre-drilling in the spring to suppress couch long enough for crop competition to assist in control. Autumn applications of herbicide mixtures have received priority, sometimes the two herbicides being applied simultaneously and sometimes with an interval in between. One possibility was that sprouting of couch might be induced by one compound and the resulting growth killed by another. In fact, none of the mixtures provided good control. Four organo-arsenical compounds which have provided good control of perennial grass weeds elsewhere in the world have not given control comparable with that provided by paraquat. Herbicides used as spring pre-drilling applications were generally not very effective as they either did not control the couch or were too persistent in the soil for a succeeding cereal crop. The control of couch in brassica crops is discussed in a later paragraph.

Rumex spp. (docks)

Work began on specially planted stands of *Rumex obtusifolius* (broad-leaved dock) in 1963 (WRO Second Report, 1965-66). This continued during 1967 with applications of a range of herbicides both alone and in mixture at different times during the year. The results have confirmed the superiority of asulam and the related sulphonyl carbamate M & B 8882 to most other compounds. Further work using asulam and M & B 8882 on a dock-infested, intensively managed S23 ryegrass pasture has shown that applications in July were still giving good control after one year. Both these sulphonyl carbamates gave better results than maleic hydrazide at 2 lb a.i./ac. In November the latter severely damaged the ryegrass. Dicamba at 1 lb a.i./ac did not give the necessary lasting control. M & B 8882 and asulam gave good results when applied in spring, summer or very early autumn but after October they become much less effective. This work provided part of the foundation for the subsequent commercial exploitation of the dock control potentialities of asulam.

Tussilago farfara (coltsfoot)

There has been evidence in recent years that *Tussilago farfara* is becoming an increasing problem in cereal crops. It is particularly troublesome on heavy soils but can occur in abundance on all soil types. It spreads rapidly by means of rhizomes which often penetrate the soil to a considerable depth, making eradication difficult by normal cultivations. There are several herbicides recommended for controlling this weed but there is scope for improved treatments.

Of the six treatments applied in a 1967 experiment to an infestation of *T. farfara* in autumn stubble, none controlled the weed completely, although asulam, picloram and 2,4-D-amine were giving excellent suppression of growth throughout the early months of growth of the following spring cereal. The major part of the competition with the crop was thus eliminated.

Grass weeds in grassland

The part played by weed grasses in restricting the productivity of intensively managed grassland is often overlooked. In anticipation of a future demand for the selective control of such weeds, the Section has undertaken research on this problem since 1961. The investigation has been divided between three main possibilities of grass control: 1) pre-emergence at germination, 2) post-emergence during seedling establishment, 3) post-emergence when established. The potential for these treatments lies in preventing the invasion of newly sown leys and as a remedial measure to extend the productive life of older established grass.

A more immediate application lies in weed grass control in herbage seed crops. This has not been specificially investigated by the Section but close collaboration has been maintained with the National Institute of Agricultural Botany (NIAB), Cambridge, and advice given on the choice of new herbicides for their programme on this topic.

During the last two years work with certain terephthalate herbicides has shown that these compounds offer particular promise for the control of *Agrostis tenuis* (common bent), *A. gigantea* (black bent) and *A. stolonifera* (creeping bent) as they germinate, without damage to emerging perennial ryegrass. In the future, investigations are planned of the factors which may affect this selectivity and the persistence of control.

Over the same period some substituted urea herbicides have been found to give good control of seedling weed grasses, but timing of application may be critical.

Several years, work by the Section has clearly demonstrated the ability of asulam and closely related benzene sulphonyl carbamates to control established plants of *Holcus lanatus* (Yorkshire fog) and *Agrostis* species selectively in swards where ryegrass and meadow fescue are the desired grasses. This promising lead is being followed up by other workers. In a collaborative experiment, the tolerance of a large range of crop grasses to dalapon, asulam and M & B 8882 is being tested, using an area of sown grasses at the NIAB and already there do appear to be quite marked differences in the response of different varieties of the same species.

Brassica crops

The weed problem in brassica crops has always been a serious one. No comprehensive remedy, other than mechanical or hand-hoeing, has been available until recent years, when five herbicides have been produced commercially for the control of annual weeds in these crops. However their limitations include the narrow spectrum of weeds that they control, and the specificity of their use to only one or two of the brassica crops. There is a still a need for a herbicide with a wider spectrum of activity on annual weeds in a range of crops. Several candidate herbicides were tested in 1967 with this in mind, and a few looked promising. CP 50144 (2-chloro-2,6-diethylphenyl-*N*-methoxymethyl acetamide) was more active than its close relative propachlor which is presently recommended for use in Brussels sprouts and cauliflowers. R 7465 (2-(α-naphthoxy)-*N, N*-diethylpropionamide) and R 2063 (*N*-cyclohexyl-*N*-ethyl-*S*-ethyl(thiocarbamate)) also gave selective control of many annual weeds, including grasses.

In 1968 the control of perennial grass weeds in brassica crops was examined. These weeds, especially *Agropyron repens,* are an increasing problem, not only in brassicas, but in all arable crops. TCA at 15 lb/ac applied six weeks before drilling of the crops was the most effective treatment tested. Excellent control of *A. repens* was achieved with no damage to any of the crops (rape, kale and swedes).

Field beans

Field beans are often used as a break crop for intensive cereal production. For this break to be effective it is essential to eliminate, as far as possible, perennial weed grasses, which can act as alternative hosts for cereal diseases. Fortunately there is a possibility of controlling these weeds by herbicides which are unsuitable for use in the cereal crop.

Investigations made in 1968 on the tolerance of field beans to herbicides which had already shown promise for the control of *Agropyron repens* indicated that beans are resistant to EPTC at rates which give useful control of the weed, i.e. between 4 and 6 lb/ac.

STAFF OF WRO. SEPTEMBER 1968.

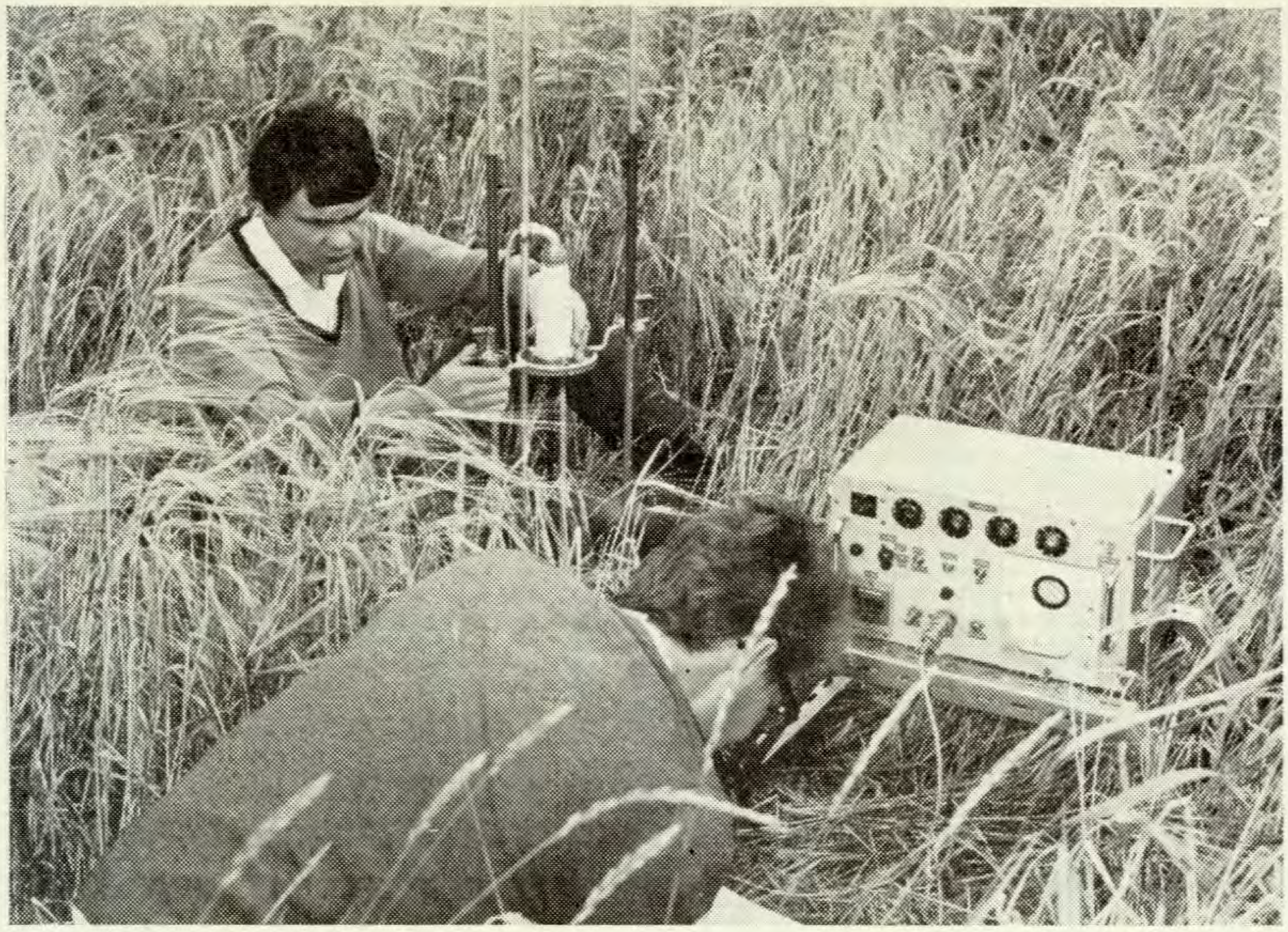
Back Row—1, T. J. Woodward; 2, P. Ayres; 3, A. K. Oswald; 4, P. Bate; 5, J. Mayall; 6, J. A. Bailey; 7, J. Capel; 8, W. Macklin; 9, P. D. Smith; 10, B. J. Wilson; 11, C. J. Briscoe; 12, F. A. Penfold; 13, B. J. Viles; 14, R. J. Webb; 15, J. Vigor; 16, D. J. Wright; 17, A. F. W. Savage; 18, P. A. Savin; 19, W. R. Charlton; 20, R. A. Jeffery.

Second Row—1, T. H. Byast; 2, R. E. Dhanaraj; 3, M. Damanakis; 4, M. P. Thompson; 5, T. W. Cox; 6, R. Collery; 7, L. Austin; 8, W. G. Richardson; 9, D. J. Turner; 10, G. G. Hawkins; 11, M. J. May; 12, D. V. Clay; 13, G. P. Allen; 14, J. Heal; 15, J. I. Green; 16, A. J. Dunford; 17, R. Colegrove; 18, R. W. Foddy; 19, A. W. H. Gardner.

Third Row—1, J. A. Slater; 2, Miss E. A. White; 3, Mrs N. M. Willis; 4, Mrs B. Clements; 5; Mrs J. Thompson; 6, Mrs L. M. Hall; 7, Mrs J. Martin; 8, Mrs D. Tutte; 9, Mrs E. N. Luke; 10, Mrs E. George; 11, Mrs V. A. Bird; 12, Mrs V. Millard; 13, Mrs E. Dowdeswell; 14, Mrs M. Weedon; 15, Mrs M. Marsland; 16, Mrs B. Schweder; 17, Mrs B. Burton; 18, P. Reece; 19, J. A. P. Marsh.

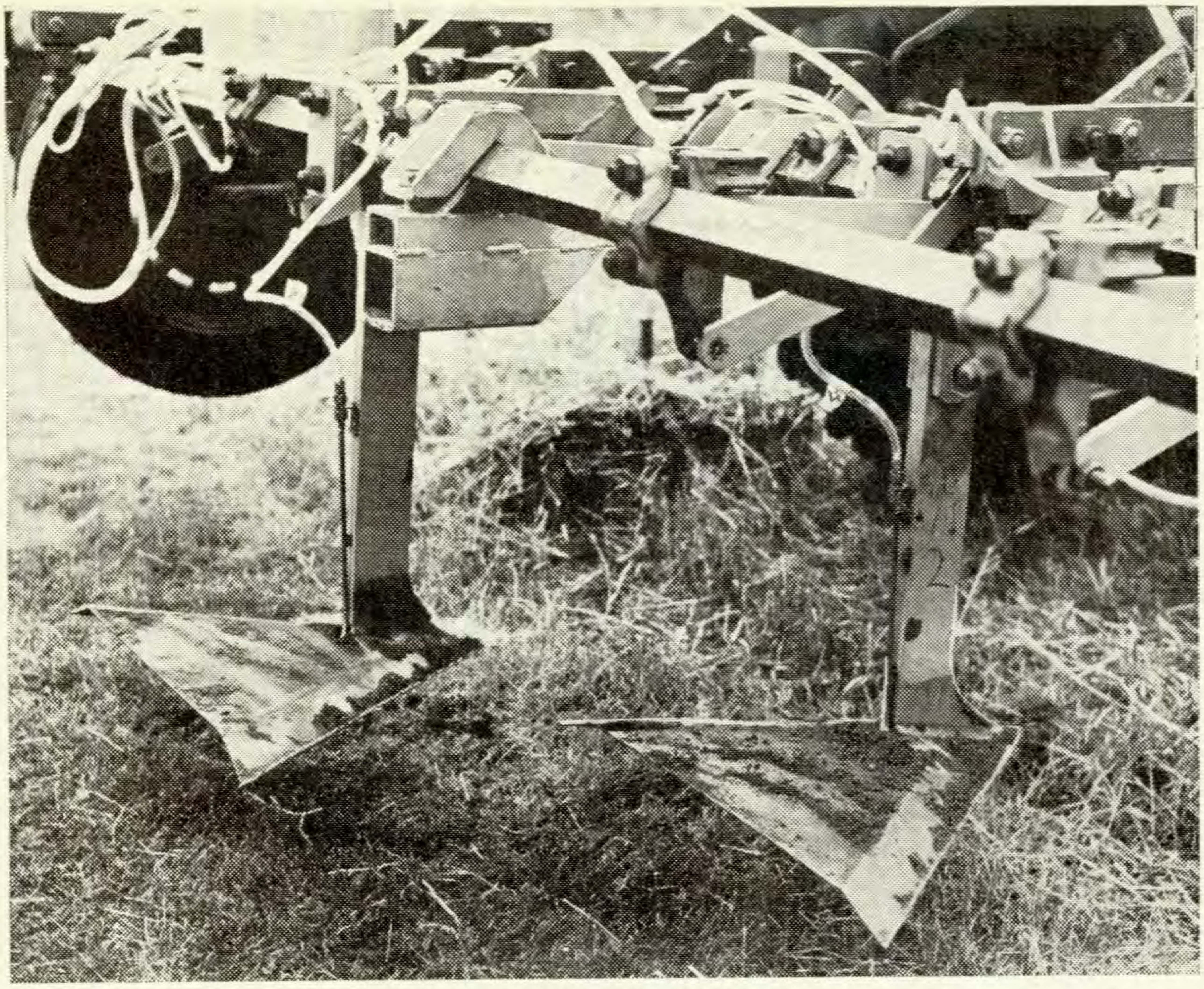
Fourth Row—1, H. Bywater; 2, C. E. McKone; 3, Mrs B. Hayward; 4, A. M. Blair; 5, R. Kibble-White; 6, J. Caseley; 7, D. O'D. Bourke; 8, J. Holroyd; 9, B. A. Wright; 10, K. Holly; 11, J. D. Fryer (Director); 12, J. G. Elliott; 13, J. G. Davison; 14, Miss E. Grossbard; 15, F. Barnes; 16, R. F. Clements; 17, P. J. Attwood; 18, W. A. Taylor; 19. H. A. Wilkinson.

Front Row—1, Miss L. Coles; 2, Miss S. Pratt; 3, Miss S. Hill; 4, Miss J. Belcher; 5, Miss J. M. Laughton; 6, Miss G. Crum; 7, Mrs I. R. Litt; 8, Mrs M. E. Hunt; 9, Miss H. C. McAllan; 10, Miss M. Aldridge; 11, Miss D. McMiken; 12, Miss C. Hayward; 13, Miss J. J. Barratt.



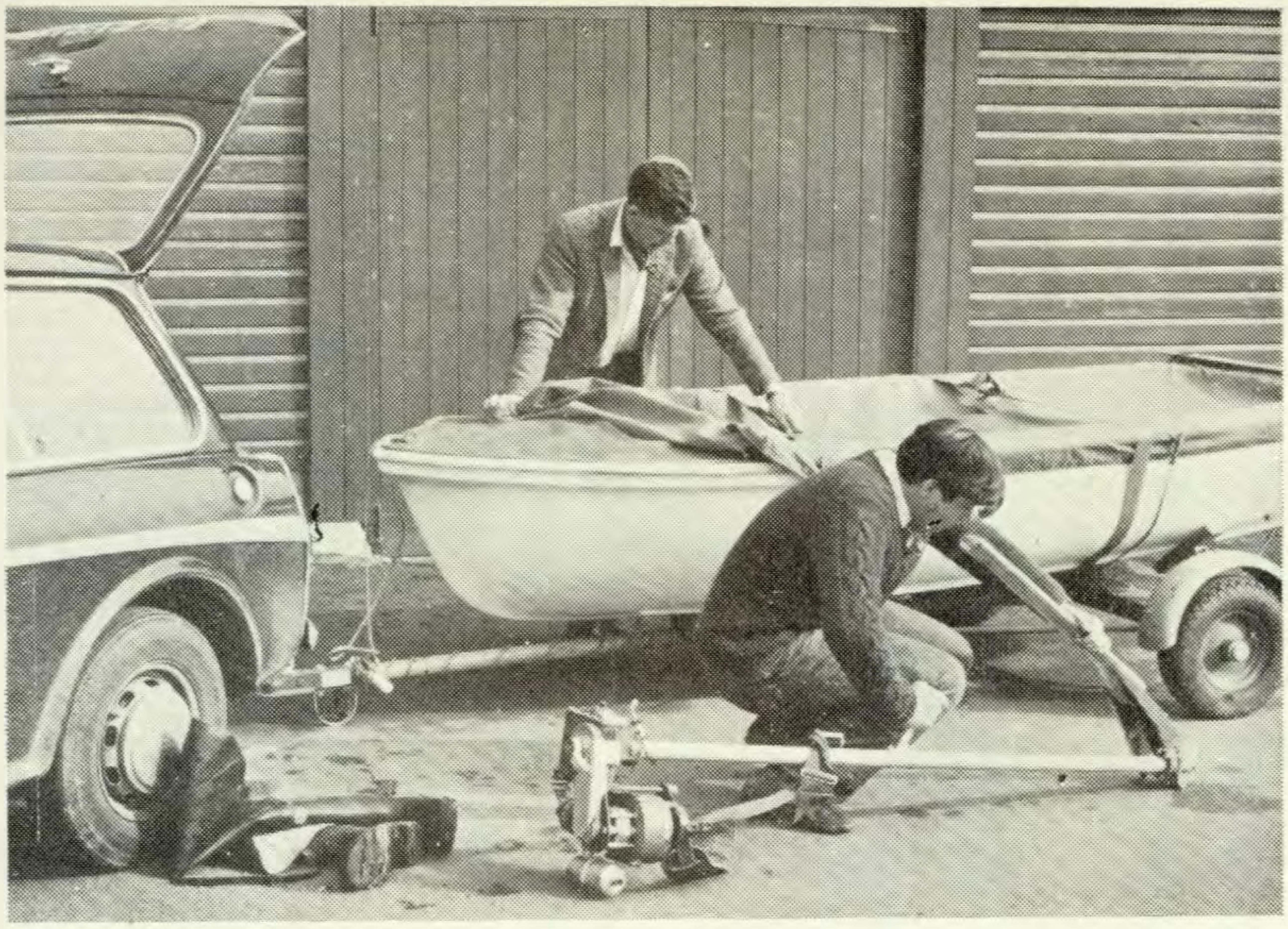
Preliminary work by members of the ARC Radiobiological laboratory on the joint project on barley at WRO

Special plots and equipment for the joint project.



Equipment for the sub-surface application of herbicides developed by the National Institute of Agricultural Engineering for the joint WRO/NIAE application project.

Cereal grass weeds such as couch (*Agropyron repens*) are currently receiving much attention.



Some equipment obtained for the new aquatic weed control team

An experiment to assess the persistence of herbicides in soil

Other work in 1968 was concerned with the influence of triazine herbicides on the protein content of field beans. Work abroad had already given an indication that the protein content of a wide range of crops could be increased by simazine when applied in low doses, either pre- or post-emergence. Work on the protein analysis of the field beans has not yet been completed.

Woody plants

From March 1968 funds have been provided to extend herbicide studies to woody species. The project is not expected to be fully operational until early 1969, when laboratories and glasshouse space will be available. Some preliminary work has however been undertaken, particularly with regard to the selection of suitable test species and the development of herbicide application techniques.

The programme has two principal objectives: the evaluation of new herbicides on a range of British and tropical woody plants to serve as a guide to those concerned with their control and the development of methods to increase the activity and selectivity of established herbicides. In addition the project may include some more fundamental studies on the factors affecting herbicide uptake, movement, and persistence in woody plants.

SPECIAL PROJECTS

Weed control in the Fens

Most soil-acting herbicides are adsorbed to a greater or lesser extent by soil organic matter. When adsorbed they are not available or become available only slowly to plants. On fenland areas where the soil contains a high proportion of organic matter the herbicidal activity of many soil-acting compounds is very much reduced. During the past few years the Section has had a limited number of experiments on highly organic soils mostly at the Arthur Rickwood Experimental Husbandry Farm. However with the appointment of an experimental officer specifically for this project in 1968, which has allowed a two-man team to be stationed at the EHF from March to August, the work has been expanded considerably.

The primary objectives of the programme so far are:

1. To investigate the potentialities of various soil-acting herbicides for the selective control of specific weeds in different crops.

2. To study some of the factors which can influence weed control performance such as soil moisture, herbicide formulation and distribution in the soil.

3. To establish the pattern of weed emergence on fenland soils and consider how this influences the use of herbicides.

The experiments to date have confirmed the relatively high activity of a number of herbicides such as some of the substituted ureas—linuron, monolinuron and fenuron, the carbamate—chlorpropham, and the uracils—lenacil, terbacil and bromacil. However they have also emphasized the influence of soil moisture on herbicide activity generally, and its particular importance to certain specific herbicides such as propachlor, which was very much more effective on moist soil.

The importance of distribution of the herbicide in the soil was emphasized by lenacil. This is a relatively insoluble herbicide which is normally considered to have little activity on fen soils. However, mixing the herbicide into the top two inches of soil was found to increase its activity several fold. The activity of linuron in the same experiment was reduced by incorporation.

The studies on the pattern of weed-emergence were begun rather too late in the season to give a clear picture but emphasized the importance of early establishment for the success of a weed.

A number of very useful leads have already been discovered and these will be actively pursued in the subsequent programme.

Persistence of herbicides in soil

Over a period of years a relatively simple form of experimentation under glasshouse conditions has been used at WRO to assess the comparative persistence in the soil of a large number of new herbicides. The results were described in the WRO Second Report, 1965-66. The next stage is to compare the persistence under a sample set of natural field conditions of those herbicides shown to have a considerable resistance to degradation.

In 1967 a very large experiment was set out on sandy loam soil at Begbroke in which 24 such herbicides were applied to the soil surface. In addition, six relatively volatile herbicides were applied to the soil surface and incorporated immediately by rotary cultivation to a depth of four inches. Soil samples were taken immediately after application and at a variety of times thereafter, and to increasing depths in the soil. These samples have been assayed for the amount of phytotoxic residue present by pot plant bioassays in the glasshouse. Highly susceptible test species were selected for each herbicide and comparison made with artificial standards. The experiment is continuing with samples still being assayed from plots receiving the most persistent herbicides.

Herbicide activity in soil

The activity of a soil-applied herbicide is governed not only by the intrinsic toxicity to the plant but also by many other factors influencing availability to the plant. In the past much attention has been given to soil characteristics governing inactivation by adsorption as one such factor. A series of experiments on several different soil types during 1966 and 1967 by WRO determined the activity of the herbicides prometryne, simazine, linuron and lenacil, using ryegrass and turnip as test species. Under glasshouse conditions there was a reasonable correlation between herbicide activity in samples of the soils and the adsorptive capacity of the soil as determined by chemical means or as based on organic matter content. On the other hand in the related field experiments there was little or no correlation between effectiveness and adsorptive capacity except at the extremes of organic matter content.

These results prompted an attempt to find out the range of effectiveness which could be obtained from application in a similar manner to the same soil, but under a variety of weather conditions. The same herbicides as before were applied on ten separate occasions over a period of three months at the same site. Equi-effective doses varied by up to 8x between application times. Selectivity between the two test species also changed. Incorporation into the soil reduced this variation partially but not completely. Soil moisture and other natural environment factors are clearly implicated but much work is needed to analyse fully the situation.

Effect of environment on herbicide activity

Established herbicide treatments which are usually effective in the field occasionally fail to give good results. Sometimes the crop is damaged and at other times the weeds are not controlled. New compounds may show good herbicidal activity in evaluation trials under glass but may be ineffective in the field. Assuming that the correct dose has been applied, these failures are usually attributed to unfavourable weather and or soil conditions. At present relatively little is known of the combinations of environmental factors which lead to maximum and minimum selective weed control. The objective of this project is to investigate the influence of environmental factors on herbicide performance. These studies will contribute to our understanding of herbicide action and aid in decision making on the timing of herbicide applications. The first phase of this programme concerns the influence of light, temperature and humidity on certain foliage-applied herbicides at the time of and immediately following application. Plants for these experiments are grown in controlled environment cabinets in which the light, temperature and humidity levels can be regulated. Work on this project has been delayed due to the presence in the cabinets of a phytotoxic vapour, the source of which has been difficult to locate. An activated charcoal filter has been found to eliminate toxicity at the National Vegetable Research Station (NVRS), Wellesbourne, and this technique is about to be used at WRO.

Application

The development of new and more effective herbicides is a continuing process but application techniques have changed little over the past 20 years. The influence in activity and selectivity of changing spray volume, concentration, angle of spraying, droplet size, droplet spacing, formulation and carrier has not been critically established for the majority of herbicides. In 1967 an experimental officer was appointed to institute research on the biological aspects of this problem in collaboration with the NIAE.

During 1968 some preliminary experiments were carried out on a field scale. These were the first of a series involving wild oats in spring barley. At two stages of crop growth, three doses of barban were applied at two volume rates and at two spray angles. At the first stage more herbicide was retained using the 45° angled jets than the conventional 90°, resulting in a higher kill of the wild oats at all doses. With all types of application the wild oat was most vulnerable at the earlier time of application. The denser crop canopy at the second stage intercepted more of the spray generally and retention by the wild oats was not aided by angling the jets. As the programme develops droplet size, spacing and retention will be examined in the more controlled conditions of the laboratory.

In a collaborative project the NIAE have constructed a machine capable of placing a layer of herbicides at a selected depth beneath the soil surface. This is being used in a programme to explore the possible advantages of applying herbicides in close proximity to the roots or rhizomes of perennial weeds. In the first completed series of experiments EPTC placed at two inches below the soil surface gave a promising degree of control of *Agropyron repens*.

Propagation of weeds

In order to grow weeds successfully in pots for experimentation at all times of the year a considerable amount of investigation into the necessary techniques has been required. Work on germination requirements of seeds of annual weeds has shown, amongst other things, an interaction between light and nitrate in the germination of *Chenopodium album* (fat hen). Studies on a variety of perennial weeds, both temperate and tropical, have enabled conditions for successful propagation to be defined in a large number of instances.

EXPERIMENTAL APPLICATION EQUIPMENT

The development of equipment for the application of herbicides to experimental plots has been the special responsibility of the Evaluation Section. This specialized equipment cannot be compared with machines used on a commercial scale for field work and many refinements have to be developed to cater for specific problems in experimental application. Up to the present most attention has been given to spraying equipment for applying finite or logarithmic doses to small or large plots. The initial construction and modification of this equipment is carried out in the WRO workshops using as far as possible components that can be purchased. The Oxford Precision Sprayer has been particularly successful. Designed 16 years ago it has been developed commercially, and has become accepted as standard equipment in many parts of the world for small plot work. Continuous improvement and modification to this equipment has been made as the result of experience and the specification for the latest variation in use at WRO includes propane gas operation and nylon pressure containers.

To ensure maximum precision in spray application a sophisticated apparatus for the assessment of the performance of spray nozzles has been constructed and brought into use in conjunction with WRO Workshop during the present period. This experimental application equipment attracts a great deal of interest by visiting research workers to whom advice is readily given.

NON-RESEARCH ACTIVITIES

In addition to its research function the Section provides many services to WRO as a whole which make considerable demands on its resources. The Section manages the Field Laboratory, organizing the provision of all herbicides for field experimentation and the facilities for handling them. The glasshouses and associated facilities are the responsibility of the Section which provides help in the provision and maintenance of plant material for experiments. The meteorological observations are made by the Section and the recording station has been expanded and mechanized in the past year.

Section staff have been heavily involved in work for the British Weed Control Council: notably in connexion with the Weed Control Handbook, the Weed Control Conference, and the Herbicide Usage Symposium. There is also much effort expended in many forms of collaboration with NAAS, the Ministry of Overseas Development and other outside bodies. Discussions have started with I.B.S., Wageningen, the Netherlands, with the intention of co-operating in the dissemination of information and results relating to new herbicides.

Chemistry Section

Head: R. J. Hance

The activities of the Section continue to be divided about equally between analytical service work and studies of the behaviour of herbicides in the soil.

Analytical work

Routine determinations of residues of the substituted ureas, *s*-triazines, tri-allate, picloram, EPTC, dichlobenil and chlorthiamid in a variety of substrates have formed the major part of the work in this category.

A method has been developed in which the substituted ureas are determined by the gas chromatography of the parent molecule rather than as a derivative produced by hydrolysis or pyrolysis. Using this method a procedure for the extraction and measurement of diuron in natural surface waters has been developed capable of detecting 0·001 ppm. A series of analyses was carried out on a field experiment in collaboration with the Aquatic Weed Section. An electronic integrator has been constructed to facilitate the measurement of responses obtained from the gas chromatograph. This device has already proved useful for measuring peak areas of herbicides in formulation analysis using flame ionisation gas chromatography. The Section is collaborating with other laboratories in the analysis of herbicide formulations as part of a programme organized by the Collaborative International Pesticides Analytical Committee (CIPAC).

Recently investigations have begun to assess how far polarographic methods can improve the flexibility and perhaps the speed of the analytical service. In association with Dr. R. Grover, a visitor from Canada, the persistence of picloram at two concentrations in incubated soil is being studied to determine the rate of breakdown and whether a lag phase exists as suggested by previous bioassay experiments. Samples of soil are being withdrawn at regular intervals and the picloram determined by gas chromatography.

The behaviour of herbicides in the soil

The ultimate object of this work is to improve the prediction of the performance of soil-applied herbicides. Since the adsorption of a herbicide by soil particles is an important factor controlling its behaviour, studies of this process have been given much attention.

Attempts to relate absorption with the chemical properties of the adsorbate have continued and it has been found that for non-ionic chemicals an empirical factor derived from the parachor of a molecule and the number of groups it contains that can form hydrogen bonds with water gives a reasonable estimate of its adsorption characteristics on many soils.

Organic matter frequently appears to be the soil fraction most involved in the adsorption of non-ionic herbicides. The mechanisms by which the process occurs are still somewhat obscure and little is known of the components concerned. Experiments have been performed using model adsorbents the results of which suggest that aliphatic groups may play a significant part.

In a collaborative experiment with the Evaluation Section an attempt was made to predict the activity of soil-applied herbicides on a variety of soils from measurements of the adsorption capacity of the soils. A routine adsorption test was devised that could be applied in the laboratory, or in a simplified form in the field. The results of pot trials in the glasshouse showed good correlations between the adsorption measurement and herbicide activity. The results of field trials showed poor correlation with both the adsorption measurement and the glasshouse results. In addition, field results obtained in the spring bore little relation to those obtained in the autumn. It appears, therefore, that under British conditions climatic effects can override the influence of the soil. (See also Evaluation Section report).

Further studies have been made of the non-biological chemical breakdown of herbicides in the soil. The results suggest that the conclusion reported previously, that such processes were unlikely to be important, is incorrect. It appears that the rate of breakdown is unrelated to the extent of adsorption and that only certain sites in the soil can take part in these reactions.

Experiments are in progress to determine how far the movement of herbicides in soil columns can be described by chromatographic theory. Results obtained so far indicate that the agreement is poor. The discrepancy may be associated with the relatively slow attainment of sorption equilibrium in soil systems.

Two visitors, R. S. Tamés from Spain and Dr. R. Grover have spent periods with the Section. Mr. Tamés made observations of the adsorptive capacity for herbicides of the roots of a number of plant species. He found that these capacities were lower than that of soil organic matter but were of a similar order of magnitude when considered on a dry weight basis. With the plants and herbicides studied the extent of adsorption was not related to toxicity in any obvious way but it seems possible that in some cases adsorption could be a step in the process of plant uptake of herbicides. Dr. Grover has extended this work to include mixtures of soil and roots. He has shown that their adsorbing surfaces may interfere less than that of the sum of the capacities of the components. He has also investigated the adsorption of herbicides by soil-water systems in which the water content is near field capacity. Adsorption under these conditions is less than that measured in conventional slurries in which water is in excess. The differences seem to be a function of particle size as under slurry conditions soil aggregates tend to disperse more completely during agitation than they do at low water contents.

Botany Section

Head: R. J. Chancellor

The Section is concerned at present with two main topics of research: the regeneration of perennial weeds from vegetative fragments and the competition between weeds and crops.

The regeneration of perennials has been studied for several years. The first of two main aspects currently under investigation is the growth pattern of individual buds and shoots on rhizome fragments of *Agropyron repens* (couch grass). This weed has remarkable properties of regeneration and previous studies have established that there is no lower limit of practical importance to the size of fragment capable of regenerating and, furthermore, relatively small fragments are capable of growing into new plants even from considerable depths. For example, 2-node rhizome fragments can emerge from a depth of up to 40 cm.

In America innate dormancy of buds can render the plant difficult to control at certain times of the year, but work by the Section has established that in this country and southern Germany there is no period of innate dormancy in rhizomes of *Agropyron repens* or

Polygonum amphibium (amphibious bistort). The growth behaviour of individual buds on multi-node rhizome fragments has therefore been studied intensively over the last two years to find out more about the dominance system, for this alone appears to account for bud dormancy in Britain. To study this, a system of growing rhizomes under humid conditions in Perspex boxes was developed and proved very successful. It showed that 70-80% of hitherto dormant buds on 7- and 15-node fragments start to grow following fragmentation but after making variable amounts of growth they are re-inhibited by the new dominant shoot. If this dominant shoot is damaged or destroyed then they resume growth until a new dominant asserts itself when they cease growth once again. These re-inhibited, partly-grown shoots account for the plant's ability to grow again rapidly after cultivation. The fact that most shoots soon stop growing before emerging from the soil helps to conserve the food reserves of the rhizome and also keeps a reserve of shoots from which new dominants can arise if necessary.

This study of dominance has proved of considerable interest for it not only indicates its underlying mechanism but it also shows that if a chemical were discovered that inhibited this mechanism rhizomatous plants could be made very vulnerable to other control measures. A system for the *ad hoc* testing of chemicals for this purpose is under development in collaboration with the Evaluation Section.

The second project on perennials is concerned with regeneration from tap roots of *Rumex* spp. (docks) and *Taraxacum officinale* (dandelion). It has been established that *Rumex crispus* and *R. obtusifolius* are incapable of regenerating new shoot buds from fragments originating from lower than 3-4 in. down on the parent tap root. However, *Taraxacum officinale* is more versatile and can initiate new shoot buds in any part of a tap root. The present study is to investigate the age at which tap roots acquire the ability to regenerate.

The project on weed competition which was started in 1968 is designed to investigate the competitive balance between crops and weeds under various conditions in the field and to establish the relative importance of individual weed species in various crops. In addition, investigations will be made into factors that appear to be influential in determining the degree of competition.

During 1968 experiments were concerned with *Avena fatua* (wild oat) in spring barley—one of the most important annual weeds in the most widely grown crop. Both planted and natural populations of *A. fatua* were used. Planted stands were employed in collaboration with WRO Agronomy Section and with Rothamsted and Chesterford Park Research Stations to investigate the importance of weed density and the effect of the date of emergence of the weed relative to the crop. Work on competition will be greatly assisted by the recent appointment to the Section of an experimental officer, N. C. B. Peters.

The start of this project on competition has coincided with preparations for an international programme on the same subject sponsored by FAO. Help has been given in the preparation of a manual on experimentation and a list of research workers interested in competition. Data from the WRO project will help in the furtherance of this programme.

The Section also carries out an annual survey of the weeds in arable fields on the farm using quadrats arranged in a grid system. The results aid in the location of experiments and yield data on changes in the weed flora. The Section also maintains a weed garden and a herbarium.

Microbiology Section

Head: Miss E. GROSSBARD

INTRODUCTION

The Section was established in mid-1966 and its objectives were outlined in the last report. The period under review has been spent largely on recruiting and training staff, developing and proving techniques. The experimental work was concentrated on the main project—the evaluation of the effect of herbicides on carbon dioxide production and mineralization of nitrogen in the soil. Studies on the effect of herbicides on root nodule bacteria have also been undertaken with the assistance of students on industrial training. The work has had to be carried out in temporary accommodation pending the completion of the new laboratories early in 1969.

In view of the considerable routine work involved, an auto-analyser was purchased in 1968 for the estimation of changes in the mineralization of nitrogen. Established methods for the estimation of nitrites and nitrates in plant extracts were adapted for soil analysis and exploratory work is in progress for the valid estimation of ammonia nitrogen in soil.

Much time was spent on testing and re-assessing various methods for measuring the output of CO_2 by soil by static systems of incubation and by others in which an aspiration stream of CO_2-free air is passed over the soil. The latter method is essential for experiments of long duration. Soil respiration studies are now being extended to measure the uptake of oxygen using a Gilson respirometer, a simpler and more rapid instrument than the conventional Warburg.

The estimation of CO_2 and/or the uptake of oxygen serves as a guide to the overall influence of herbicides on microbial activity in soil, but cannot indicate the effect on individual groups. Some of these chemicals may affect the growth of certain microbial species while others grow more profusely at the expense of the susceptible groups, thus giving as the final result a similar amount of CO_2 in treated and control soils. A possible shift in microbial equilibrium may thus be masked. In order to obtain a more accurate assessment of changes in microbial populations and species composition herbicidal effects are now being ascertained on total numbers of microbial propagules as well as on certain specific physiological groups of agricultural interest such as cellulose-decomposing organisms. This work is being undertaken with the assistance of a post-graduate student with a Science Research Council grant.

SPECIFIC STUDIES

A. *Soils from long-term field experiments*

In 1967 and 1968 the analysis was continued of soil samples taken from the uncropped and cropped plots of the long-term field experiments (WRO Second Report, 1965-66, pp. 23 and 37). As in previous years there was no significant effect of MCPA or tri-allate treatment on output of CO_2. However, the soils of the non-cropped plots treated annually with 3-4 times the commercial dose of linuron and simazine produced 20-35% less CO_2 than all the other untreated controls at some but not all sampling dates. The limited data on mineralization of nitrogen available at present showed that less mineral nitrogen was present in some soil samples from the simazine treatments in which CO_2 output had been lower.

The effect of a normal dose of all four herbicides on the cropped soils was negligible. However, in 1967-68 the simazine-treated soil produced significantly less CO_2 than the untreated controls. Linuron did not affect either CO_2 evolution or mineralization of nitrogen.

It is probable that the smaller CO_2 output on the simazine-treated and linuron-treated soil is associated with the difference in organic matter content between treated and control soils. These herbicides at the doses used prevent growth of all vegetation. In contrast and in spite of frequent hoeings, some weeds have inevitably grown from time to time on the untreated plots, particularly during long spells of bad weather. While the tops of weeds have been removed from the plots some residue and the root system have remained, which may have served as a substrate for CO_2 production. A significant toxic effect on micro-organisms by simazine seems unlikely since in several laboratory experiments concentrations as high as 500 ppm either have shown no reduction in CO_2 output or at worst a temporary reduction with recovery setting in after 8-10 weeks of incubation.

A reduction in CO_2 output and/or mineralization of nitrogen is not necessarily associated with a decrease in yield, e.g. on the cropped plots treated with simazine a decrease was observed in 1967 in CO_2 evolution but not in the yield of maize, and similar observations are reported in the literature with respect to mineral nitrogen on plots treated with aminotriazole using wheat as a fertility indicator.

Laboratory experiments

The routine evaluation of eight herbicides (endothal, propanil, simazine, prometryne, linuron, dinoseb, paraquat and picloram) with respect to CO_2 production and mineralization of nitrogen was continued in 1967. For the initial testing a very high concentration (500 ppm) and long periods of incubation (16-22 weeks) were used. Recovery from initial depression of CO_2 output was usually observed. In one experiment, residue analysis carried out by the Chemistry Section showed that picloram had not yet decomposed at the time recovery commenced. The microflora seems therefore to have become adapted to the toxin. However, permanent recovery was not observed in a second experiment with picloram. Several experiments were carried out with simazine at 500 ppm and in no case was inhibition of CO_2 observed.

A new series of herbicides was included in the evaluation scheme, namely atrazine, asulam, M & B 8882, monuron, diuron, metobromuron, fluometuron and chloroxuron. As in previous years the chemicals were mixed with large quantities of soil and incubated. At intervals samples were removed and incubated in a static system. After a one month treatment period long-term experiments were carried out with soils treated with monuron, asulam and M & B 8882, to follow up an observed depression of CO_2 output. For these soils a continuous aspiration system was used. The other herbicides had no effect or stimulated CO_2 output. Prolonged incubation with monuron after 11 weeks revealed a reduction in CO_2 output of 25% as compared with controls. Recovery set in after a further period of 8 weeks. Asulam and M & B 8882 at first did not lower CO_2 output but an inhibitory effect was noted after 11 weeks which continued until the end of the experiment, which had lasted for a total of 23 weeks. This work is being followed up by using a soil with a higher content of organic matter and concentrations closer to those used in field practice. It is possible that the inhibitory effect noted after prolonged incubation is confined to excessively high doses only.

Comprehensive analyses to determine mineralization of nitrogen were postponed until the full development of the auto-analyser system. Information available is limited to soils treated with picloram in an experiment of 22 weeks duration. A lag in the onset of nitrification was apparent in the first few weeks. However, the soils recovered rapidly, the rate of nitrification eventually exceeding that of the untreated controls, although picloram in itself had not been broken down. These results illustrate the value of experiments extending over long periods of time.

B. *The effect of herbicides on the root nodule bacteria and white clover*

The requirement is to assess whether herbicides influence the growth of legumes through affecting the growth of root nodule bacteria

(i) when applied directly to the crop, or
(ii) through any residual effects on the bacterium following application to previous crops.

The present investigation is concerned with the second aspect and refers to both the response of the root nodule bacterium *Rhizobium trifolii* and that of the white clover seedlings when inoculated with bacteria grown in the presence of the herbicides. Atrazine, asulam and M & B 8882 at concentrations well above those used in standard practice were examined.

Results from several small scale experiments were variable. With atrazine at 25-50 ppm there was in most instances no significant effect on the growth of the bacterium as determined by respiration and turbidity measurement. Clover seedlings when inoculated with bacteria treated with atrazine were however invariably killed, due to the small traces of atrazine carried over in the unwashed bacterial suspension. When these traces were removed normal plants developed, suggesting that injury to clover as observed in the field is likely to be due to the toxic effect of the atrazine on the plant and not on the *R. trifolii.* M & B 8882 at 100 ppm rarely caused damage to the bacterium or the clover plant. At 500 ppm injury was more consistent. However, in some instances remarkable stimulatory responses were observed at both concentrations. While asulam behaved similarly it was generally more toxic, especially at 500 ppm.

The general conclusion to be drawn from these preliminary results is that the root nodule bacteria on white clover are fairly resistant to the herbicides studied even at concentrations as great as 100 ppm, which in terms of a pure culture in a liquid medium is excessively high. The occasional inhibitory effects cannot be explained at present. At the doses used in practice, both with atrazine and the sulphonyl carbamates, injury to the bacterium seems unlikely.

List of Research Projects

EVALUATION SECTION (*Section Head*: K. HOLLY)

The activities of this Section involve a closely integrated programme of laboratory, glasshouse and field experiments, and although a primary division is made according to the main location of the project there is no firm demarcation on this basis.

I. *Projects predominantly in the laboratory and glasshouse*:
1. Preliminary investigation of the activity and pre- and post-emergence selectivity of new herbicides: W. G. Richardson.
2. Detailed investigation of properties and potentialities of new herbicides.
    (a) Detailed elucidation of factors influencing interesting selectivities shown up in Project I, 1): W. G. Richardson.
    (b) The response of perennial weeds to herbicides: C. Parker, W. G. Richardson.
    (c) Dormancy in weed seeds and perennial weeds and the effect of chemicals thereon: C. Parker.

(d) The response of woody plants to herbicides: D. J. Turner.
(e) Soil-acting herbicides—their mobility and persistence in soil and the effect of soil type on activity: W. G. Richardson, with collaboration of Chemistry Section.
(f) The effect of environmental factors, particularly temperature, light and humidity on herbicide performance: J. Caseley.

3. Development of bioassay methods for estimation of herbicide residues: C. Parker, W. G. Richardson.
4. Propagation of annual and perennial weeds for experimental purposes: I. E. Henson.

II. *Projects predominantly in the field*:

1. The response of perennial weeds, notably *Agropyron repens* (couch), *Rumex obtusifolius* (dock) and *Tussilago farfara* (coltsfoot) to herbicides: J. Holroyd, M. E. Thornton, A. M. Blair.
2. Herbicides for the control of annual grass weeds (particularly *Avena fatua* and *Alopecurus myosuroides* in cereals): J. Holroyd, M. E. Thornton.
3. Herbicides for the control of annual and perennial weeds in break crops (brassicas and beans): M. E. Thornton.
4. The effect of soil type and condition and weather factors on the activity of soil-applied herbicides: J. Holroyd, M. E. Thornton.
5. The method of application of foliar and soil-acting herbicides in relation to biological performance: J. Holroyd, W. A. Taylor.
6. Development of experimental application equipment: M. E. Thornton.
7. The evaluation of herbicides and development of methods for their use for the control of weeds in crops on highly organic soils: J. Holroyd, E. Ramand.
8. The selectivity of herbicides between weed and desirable grasses in the grassland context (a) at germination (b) in the early stages of establishment (c) with older plants: J. Holroyd, A. M. Blair.

CHEMISTRY SECTION (*Section Head*: R. J. HANCE)

1. The adsorption, mobility and breakdown of herbicides in soil: R. J. Hance
2. The analysis of residues of herbicides, predominantly in soil: R. J. Hance, C. E. McKone.

BOTANY SECTION (*Section Head*: R. J. CHANCELLOR)

1. The biology and regenerative capacity of perennial weeds.
2. Weed/crop competition and weed population studies.

MICROBIOLOGY SECTION (*Section Head*: Miss E. GROSSBARD)

1. Evaluation of new herbicides for possible effects on soil micro-organisms: Miss E. Grossbard, J. A. P. Marsh, T. H. Byast.
2. The effects of herbicides on the soil microflora in long-term field experiments: Miss E. Grossbard.
3. The effect of herbicides on *Rhizobium*: Miss E. Grossbard.

RESEARCH STUDENT

1. M. Damanakis (attached to Evaluation Section): the behaviour of paraquat in soil and its availability to plants.

Department of Weed Control

Agronomy Section

Head: J. G. Elliott

In the WRO Second Report, 1965-66, the particular responsibility of the Agronomy Section was described as a concern for the weed problems that farmers encounter and the possibilities in husbandry that herbicides offer. This description is still particularly apt. As more and more herbicides come into use in British agriculture, and as husbandry becomes progressively orientated to chemical weed control, the unsolved weed problems stand out starkly and seem increasingly to demand solution. It is no longer enough to provide technical remedies, their acceptance by farmers hinges also on organizational and economic issues.

It is becoming increasingly apparent that the role of herbicides in crop husbandry is to allow a new flexibility in methods of crop production with the object of economy in labour and tractor power both of which are becoming increasingly costly. It is for this reason that the Section's programme is placing emphasis on weed control and methods of crop establishment in reduced cultivation systems.

In much of the research, herbicides have to be considered as one of several tools that might be used in furthering the project. Often there are requirements which are cultural, biological, mechanical or agronomic, and these may have to be met by co-operation with other research workers within and without WRO.

Arable Crops

Perennial weed grasses of arable land

The work on the growth of *Agropyron repens* (couch grass) and the competition between this weed and crop plants has been developed since the start of the project in 1965 and has occupied a large part of the effort available. This biological investigation is continuing but the study of control methods has been intensified and is expected to increase in importance. Some of the work of the Section is reviewed elsewhere in this report.

The experiments on the growth of *A. repens* in the absence of competition have now been concluded. Surprisingly the plant has appeared to be a relatively poor performer in winter and early spring. Shoot extension growth occurred during two winters but a loss of dry matter was recorded during this period. No new rhizome was initiated until the aerial shoots had reached the tillering stage, during May. The maximum growth and production of new rhizome has been recorded during June, July and August, although growth has occurred at a slower rate earlier and later than this peak period.

This pattern of growth is powerfully influenced by competition from a crop which delays and reduces the production of new rhizome. Spring-sown barley was much more suppressive than field beans and, in 1967, slightly more so than spring wheat. In 1968 there was little difference between spring wheat and barley in this respect but beans were again inferior as suppressors. It has appeared that a crop which establishes a dense canopy in spring is most effective in suppressing this weed and less affected by competition from it.

The experiments that provided this information were all carried out with artificially established populations of *A. repens.* A simple comparison in the spring of 1968 demonstrated that, under a reasonably wide range of field conditions, shoot emergence of artificial and natural populations of *A. repens* was similar and slower and more protracted than that of barley. The barley started tillering much the sooner at all sites.

From March 1966 to March 1968 funds were provided by the Grasshoppers Club for studies of the biology of arable grass weeds. Preliminary experiments with couch grass in 1966 showed that repeated defoliation at 10-14 day intervals almost exhausted within 2-3 months the food reserves in the rhizomes of plants growing in boxes. The rate of loss of reserves was greatest when vegetative growth was stimulated by adding nitrogen to the soil.

During 1967 and 1968 further box experiments investigating the effects of shoot removal were undertaken. The principal results were as follows:

1. There was no large difference in the response of *A. repens* to nitrogen supplied as a nitrate, an ammonium salt, or urea.
2. Destruction of shoot growth by flaming, or the application of 1 oz/ac paraquat reduced carbohydrate reserves as effectively as clipping.
3. The application of 2 or 4 oz/ac paraquat, at 10-18 day intervals, reduced carbohydrate reserves much more than clipping at a similar time interval.
4. There were differences in the response of different *Agropyron* and *Agrostis* strains to repeated defoliation but these were relatively small and of little practical importance.
5. Of a number of chemicals tested, paraquat was the most promising contact herbicide for killing *Agropyron* and *Agrostis* shoot growth.

Treatments involving repeated application of small amounts of paraquat were examined on an experiment at a badly infested site near Oxford and in several fields. Rotary cultivation followed by repeated applications of 3-4 oz/ac paraquat gave satisfactory control of couch in the whole field trials, but in the replicated experiment this treatment did not provide sufficient suppression of shoot growth the following year. A standard application of 4 lb/ac aminotriazole was also ineffective.

Avena fatua (wild oat)

This new project for the Section commenced in December 1967. The intention is to bring to bear on the problem specialist agronomic research that has previously been lacking from WRO's approach. The remarks that follow are intended to indicate the aspects of the problem that are being examined rather than to provide results.

One approach is to examine the economic significance of the wild oat in cereal cropping, and in particular to relate the level of infestation to the yield of the crop. An experiment was undertaken in co-operation with Botany Section to study the effect of planting different densities (5-64/yd^2) of *A. fatua* into a spring barley crop. The weed seeds were pre-germinated and planted at three intervals before and after drilling the crop. Preliminary results indicate that only the wild oats emerging at the same time as the barley had any appreciable suppressive effect on the barley; those sown at three and five weeks after drilling were suppressed by the crop, but were still able to produce some seed for re-infestation.

Additional effort was added to the wild oat project by the activities of successive "sandwich" students. During the summer the student studied the reaction of the weed to changes in crop density, row spacing and orientation. During the winter the student examined the physical characteristics of the wild oat seed in connexion with ways of attacking it as it lies in the cereal stubble.

One reason for the success of the wild oat as a weed of cereals is its ability to shed seed before the crop is harvested. Studies of shedding of wild oat seed in a winter wheat and in a spring barley crop are being undertaken in co-operation with Boxworth Experimental Husbandry Farm. Selected panicles were counted at intervals at the time of harvest in 1968. The majority of wild oat seed had shed before harvest of the winter wheat, but less than half in the spring barley.

The herbicides currently available for the control of wild oats in cereals are not wholly effective, due in large measure to the irregular emergence of the wild oat seedlings. Any system of cultivation leading to a more uniform emergence of wild oat seedlings may be expected to improve the effectiveness of these herbicides. An examination is being made of the effects of cultivating to different depths on the number of seeds germinating, the depth from which they are germinating, and the span of emergence during the following spring.

A complementary study on wild oats sown at varying depths on two contrasting soil types is also being undertaken. Seed previously collected in 1964 and in 1967 has been sown and the emergence and subsequent growth of the seedlings are being recorded to establish whether there have been changes in dormancy and vigour with storage.

Weed Control in Potatoes

The potato project started in 1961 and finished for the time being in 1967. During this period the subject moved from one of research interest to first commercial marketing of herbicides for potatoes in 1964, and now to a usage on about 40% of the potato crop acreage in 1968. Farmers can choose from a dozen or so approved herbicides to control the weeds in their potatoes. During the same period there has been a progressive reduction in the post-planting cultivation of potatoes.

Throughout this period of change in the agronomy of potatoes, the Section's efforts have been orientated towards balancing the research done by others so as to fill gaps in knowledge particularly with regard to the performance of herbicides. In the last two years of the project three aspects received attention, and these are reported shortly.

When weeds in potatoes are controlled by cultivation there is little need to understand the pattern of weed emergence, but the choice and success of a herbicide depends on such knowledge. A three year study was carried out on the contrasting soils of WRO (sandy loam) and Arthur Rickwood Experimental Husbandry Farm (peat). The general pattern of weed emergence was similar on the two soils, though different species occurred and there were differences in density. The emergence occurred as a distinct 'flush', thought to be due to the disturbance of seedbed preparation in association with a rising soil temperature; after the flush very few annual weeds emerged unless the soil was disturbed. The main flush had emerged 5-6 weeks after potato planting and before the emergence of unchitted potato seed. The effect of chitting was to bring forward the time of potato emergence by 1-2 weeks into the period of weed emergence. Crop and weed emergence were slow when planting occurred in March, but delay in planting through to late April telescoped the sequence of events. With herbicides applied just before potato emergence, a foliar chemical would have some chance of success where unchitted seed is used, while foliar and soil acting properties would be required for chitted seed.

Provided with a knowledge of the pattern of weed emergence on the peat soil of Arthur Rickwood EHF, a comparison was made of chemicals and cultivations in terms of weed control and their effect on crop growth and yield during three seasons. Main reliance for chemical weed control was placed on a mixture of paraquat and linuron used at a slightly higher dose of linuron than is used on mineral soils. In the experiments chemical weed control (without soil disturbance after planting) resulted in as good or better weed control and crop yield as with cultivation.

Although relatively unimportant in the intensive arable areas of the East, perennial grass weeds are widespread in the Midlands, West and North where potatoes are usually grown in rotation with cereals and leys. There is thus a need for grass control in order to ensure a healthy potato crop and, further, it would be advantageous if potatoes could be considered a grass control break for cereals. Many of the potato herbicides are ineffective on perennial grasses and there has been a need for additional herbicides. Initial development was undertaken with EPTC and this chemical is now available for commercial use. Tests have been carried out with low doses of TCA applied in the spring at intervals before potato planting. Although the effect on the grass weeds has been satisfactory, the reaction of the potatoes has not always been acceptable and the situation has been made more complex by differences between varieties in their response to TCA.

Reduced Cultivation

The Section's role in exploiting the possibilities of herbicides in changing crop production, has led to an increasing awareness of their impact on traditional cultivation. For example, in potatoes the substitution of chemical for cultural weed control has led quickly to a situation in which many thousands of acres of the crop receive no cultivation between planting and harvest. From a reduction in cultivation during the growth of the crop, it was a short step to consider a reduction in that for the seedbed, with consequent economy in labour and tractor power.

Having been set up with responsibilities in weed control, the Agronomy Section has in the past been unable to devote much research effort to the subject of reduced cultivation. However, in 1967 encouragement was received from the Agricultural Research Council to become involved in research on crop establishment by reduced cultivation and two new appointments have been made to further this work. Part of the research, that concerned with the production of barley, is in co-operation with the ARC Radiobiological Laboratory and the National Institute of Agricultural Engineering. The past year has been devoted to the accumulation of appropriate equipment and to the establishment of the techniques necessary for the research.

In planning the project, account has been taken of experience elsewhere in growing crops without cultivation or with modified cultivation. It is apparent that a distinction must be drawn between crops that form their produce in the soil (the root crops) and the surface-harvested crops (cereals, grasses, etc.). The former seem at the present time to require deep soil disturbance for growth and for harvesting and they have therefore been excluded from the project, which is concerned only with surface-harvested crops. A distinction is also being made between grain crops which require a narrowly-defined plant population and vegetative crops that are not so demanding in this respect.

Surface-harvested crops require of the soil that:

1. the seed is covered at sowing as protection from predators;
2. moisture, air and warmth for germination are adequately available during this phase of the plant's life;
3. the primary shoots may emerge through the soil;
4. a suitable medium is available for subterranean growth;
5. there is sufficient anchorage to prevent the plant being injured by external forces.

Requirements 1, 2 and 3 are attributes of the soil close to the seed, while 4 and 5 are concerned with the general state of topsoil and subsoil. With soils possessing an inherent ability to provide for items 4 and 5 the requirement for cultivation is limited to items, 1, 2 and 3;

where such ability is lacking deeper disturbance would be necesssary. The intention is to assess the growth of specific crop plants in soil as modified by cultivation along the lines of the diagram below:

Crop Production by Reduced Cultivation

TREATMENTS

Depth and character of tillage for the seedbed.

as affecting

ASSESSMENT

THE SOIL ENVIRONMENT AND CROP GROWTH

1. **Organic matter**
2. **Physical environment**
3. **Chemical environment**
4. **Biological environment**

1. **Germination**
2. **Seedling establishment**
3. **Growth (a) aerial (b) subterranean**
4. **Maturation**

PREREQUISITES

1. Weed control
2. Trash disposal
3. Machinery performance
4. Pest and disease control
5. Water and nutrient supply

GRASSLAND

The selective control of weed grasses in pasture

Past experiments by the grassland team have shown that dalapon applied at doses between 2 and 5 lb a.i./ac in early July can be used to suppress selectively *Agrostis stolonifera* (creeping bent), *Holcus lanatus* (Yorkshire fog), *Poa trivialis* (rough-stalked meadow-grass), and *P. annua* (annual meadow-grass) growing in perennial ryegrass pasture, and can lead to the dominance and increased production of the ryegrass.

Three factors influence the success of the treatment: (a) the presence of sufficient ryegrass plants to colonize the ground quickly, (b) the suitability of the environment and management for vigorous growth of the crop plant, and (c) the post-treatment invasion of new weeds often from seed.

Experience indicates that perennial ryegrass plants need to be spaced at not more than 6-9 in. apart in the sward if the species is to form a canopy quickly. Fertilizer, particularly nitrogen, has been shown to speed the colonization of the ryegrass. Nitrogen used in combination with dalapon has caused an increase in the growth of ryegrass greater than when either chemical has been used alone. Presumably dalapon releases the species from competition while nitrogen encourages it to exploit the extra living space made available.

An emergence of seedling weeds, particularly of grasses, has affected the selective improvement in some instances. In the current programme the soil-acting chemicals simazine and chlorthiamid are being used in conjunction with dalapon in an attempt to overcome this problem. Resistant established weeds are another hazard but the majority of broad-leaved weeds can be controlled by growth regulator herbicides and further suppressed by improved management of the grass. A grass which is notably resistant to dalapon is *Festuca rubra* (red fescue) and swards containing more than trace amounts of this species are being avoided.

Because the selectivity of dalapon was first noted on an old pasture, the development of the technique has been on similar swards up to the present. Now the emphasis of the project is being moved to sown swards of various ages from establishment onwards. The 1968 series of experiments is wholly on sown ryegrass and, although the full results will not be known until summer 1969, dalapon appears to be performing much as in previous years.

The selective control of *Agrostis* and *Poa* spp. also appears to be a useful adjunct to the technique of reseeding pasture by chemical sward destruction and direct-drilling. These species are quick to recolonize the uncultivated ground and dalapon was used successfully on a field scale in July 1968 to control their spread in direct-drilled ryegrass pasture in Somerset. In accordance with the suggestion of the Evaluation Section, M & B 8882 was tested for its selective effect on grasses in several experiments on old, weed-infested perennial ryegrass pasture. Doses of 1 to 5 lb a.i./ac have been applied in April, May, July, August and September. Perennial ryegrass was more resistant to the chemical than were *Agrostis stolonifera, A. tenuis, Poa trivialis* and *Holcus lanatus* at all spraying dates and it increased in ground cover and yield. The optimal dose for the selective suppression of weeds and subsequent promotion of ryegrass was between 2 and 4 lb a.i./ac. The speed with which the species and hence the sward recovered from treatment depended on the date of spraying and the growing conditions subsequent to spraying as well as on the degree of suppression caused by the herbicide. Although the selectivity was not affected markedly the herbicide worked more slowly in April and August than in May or July.

Sward destruction and reseeding

This research project is concerned with chemical methods of sward destruction which allow either a minimum of surface cultivation prior to reseeding or the direct drilling of seed into the undisturbed soil.

The success of these techniques depends on the careful integration of a number of separate operations and during the past two years much experience has been gained in their programming. Briefly they involve:

(a) Preparation of the sward for spraying and drilling, i.e.:—adjustments to drainage and nutrient status; the management of sward composition and structure to provide short actively-growing grass on which herbicides appear to act best; the reduction of surface root mat—a process in which all the above treatments assist.

(b) Application of the herbicide treatment.

(c) Surface cultivation if necessary, e.g., where coarse mats exist.

(d) Sowing—usually by one of the specially-developed seed drills.

(e) Subsequent management of the new crop, e.g., pest and weed control in the establishing crop, careful use of fertilizer, grazing and cutting to obtain a vigorous and competitive sward.

It has been found that a number of alternatives are possible in respect of reseeding the low lying grassland at Begbroke and the choice depends on the state of the soil surface. On the old *Agrostis/Festuca* pasture, where the mat responds insufficiently to treatment prior to spraying, the surface generally requires shallow rotary cultivation. Seed can then be sown with a conventional drill followed by light harrowing and rolling. In this case grass can be established successfully alone. Where the mat is present but is less severe a direct seeding drill can be used to sow a pioneer crop such as winter rye, barley or oats and vetches. These larger seeded crops have been shown to establish better than small-seeded grass in such situations. They form a vigorous canopy which competes well with any regeneration of the old sward. The pioneer crop may be grazed or harvested green for silage. Its object is to allow time for the surface mat to decay. After harvest of the pioneer the stubble may be resprayed and direct-drilled to ryegrass. Where there is little or no mat the direct-drilling of ryegrass alone or in mixture with a pioneer can be carried out.

This work is now being extended to cover a wider range of conditions on other sward types on commercial farms. In addition it is emerging that the technique of sod-seeding may be particularly suited to the establishment of annual fodder crops. For example starting from the chemical destruction of permanent pasture in late August a winter rye crop could be direct-drilled. It would be harvested in late April the following year, sprayed on the same day and drilled within a few days with silage maize. This in turn would be harvested in September, the stubble sprayed and drilled with winter wheat or rye. The extremely low inputs of labour and tractor power involved in the surface sowing technique offer the possibility of reinstating sown fodder crops in the livestock farmer's system.

SURVEYS

Following discussions between WRO and the National Association of Corn and Agricultural Merchants (NACAM) in 1966 it was decided to carry out a pilot survey to establish whether the field staffs of member firms of the association could assist WRO in the retrieval of information about farm weeds and the methods used to control them.

A survey was organised during 1967 with Frank Pertwee and Sons Ltd. of Colchester. The organization of the survey and summarizing of results was the responsibility of WRO whilst Pertwee's carried out the farm interviews. The survey sought information from cereal farmers in the Eastern Counties on methods of crop production, the weeds found in cereal crops and the methods used to control them. The interviewers visited 54 farms recording information on which weeds were present and the herbicides used against them. Two fields were recorded on each farm. The presence of weeds was recorded in young crops and prior to harvest, necessitating two visits. A third visit (post-harvest) yielded further data on stubble operations. The results of the survey were published at the British Weed Control Conference in 1968.

With the appointment of a surveys officer WRO is now in a stronger position to organize similar surveys in co-operation with interested bodies. This will lead to an increased flow of the information essential to the proper planning of weed research.

Horticulture Section

Head: J. G. Davison

The primary functions of the Section are to develop new techniques of weed control and to investigate problems that arise from the use of herbicides in fruit and ornamental crops. The type of research required to fulfil these functions changes as new herbicides are introduced and new methods of crop production are developed. The main problem at present is the control of certain weeds that are not susceptible to the herbicides currently available. Projects have begun on *Convolvulus arvensis* (bindweed) and *Heracleum sphondylium* (hogweed). During the period covered by this report, the Section has undertaken research on the persistence of soil-applied herbicides, crop management studies, and the evaluation of herbicides on crops.

PERSISTENCE OF SOIL-APPLIED HERBICIDES

Simazine, the most widely used herbicide in horticulture, and one of the most persistent, has received much attention. In the long-term raspberry experiment 14 lb/ac of simazine have been applied over six years. The amount remaining in any one spring, 12 months after the previous application of 2 lb/ac has not exceeded 0·17 lb/ac and has shown no signs of increasing. In the plots mulched with straw the residues are consistently lower.

The more rapid breakdown at higher levels of soil moisture was mentioned in the previous report. Phosphate and potash were found to have no effect on rate of breakdown but high levels of inorganic nitrogen, 9 cwt/ac of ammonium sulphate two months before simazine application and a further 9 cwt/ac one week before application, reduced the rate of breakdown.

There is still considerable interest among growers about the persistence of simazine. In order to establish the influence of climate and soil-type on persistence 22 experiments have been laid down in the main horticultural areas in England during 1968 to determine the residues remaining from spring and autumn applications. The Scottish Horticultural Research Institute and the Horticultural Centre, Loughgall, Northern Ireland, are also co-operating in this work. An interest in the persistence of herbicides has also led to work on chlorthiamid and lenacil. After applying either chemical at 4 lb/ac in spring, it was possible to detect measurable residues a year later. However, lenacil at 4 lb/ac, or simazine at 2 lb/ac and chlorthiamid at 4 and 8 lb/ac did not affect test crops sown 14 months after spraying. Chlorthiamid at 12 lb/ac checked lettuce and buckwheat sown 14 months after spraying.

MANAGEMENT STUDIES IN RASPBERRIES

In 1967 and 1968 there have been no differences in the yield of raspberries from various methods of weed control in the rows and the alleys, including hand-weeding, rotary cultivation and use of simazine. There have also been no differences in raspberry yield when comparing an annual application of simazine and repeated applications of paraquat. Mulching the rows or the whole area with straw and added nitrogen has increased yields. While all treatments have produced adequate growth for the following crop the straw mulch has resulted in fewer but more vigorous canes. Over a five year period some seasonal variations have merged but the main trends outlined for the last two years have remained constant.

THE EVALUATION OF HERBICIDES ON CROPS

Apples and Pears: The increased use of growth-regulator herbicides in orchards requires more information of the hazards involved. The effect of high doses applied to individual shoots has been investigated. The death of the shoot tip and the dormancy of the treated area are not uncommon. In general, apples are more tolerant than pears or plums. The response of apples is related to the herbicide applied and to the time of application. Cultivars vary in their susceptibility. Damage caused by 2, 4-D, MCPA, and 2, 4, 5-T to Cox, Lord Lambourne and Worcester is confined to the treated area. Bramley is more susceptible, especially to 2, 4-D applied in September, and dormancy and abnormal foliage occur below the treated area in the following year in this variety. Conference and William pears are comparable to Bramley. Despite minor differences between the herbicides and varieties tested, in practice choice should be based on suitability for weed control. The risk of damage from root-uptake is now being investigated.

Blackcurrants: Chlorthiamid and dichlobenil are now used commercially at doses of 10 lb/ac for the control of many perennial weeds. In weed-free crops doses in excess of this (chlorthiamid 48 lb/ac and dichlobenil 24 lb/ac) have not reduced yield of the cv. Baldwin.
Rose rootstocks: Promising results have been obtained elsewhere with chlorthiamid and terbacil on newly planted briars. In the Section's experiments there has been considerable damage with doses in excess of 4 lb/ac and 0·5 lb/ac respectively.
Herbaceous perennial flowers: Overwintering annual weeds can be controlled by diquat and paraquat. Overall applications to 21 herbaceous perennial flowers when the majority had green foliage showed paraquat to be safer than diquat. Applications of paraquat from mid-November to early February did not result in permanent damage. Some crops did not recover completely from March and April applications.
Dahlias: The tolerance of dahlias to several soil-applied herbicides has been investigated. Lenacil applied as an overall spray appears to be the most promising. Prometryne can also be used, as a directed treatment. Linuron and simazine have an inadequate safety margin on many cultivars.

Aquatic Weed Section

Head: T. O. Robson

In mid-1967 the Agricultural Research Council accepted the recommendations of the Visiting Group on the size and scope of the Aquatic Weed Section and made provision for laboratory and glasshouse facilities for the Section to be included in the 1968 building programme. Provision was also made for the recruitment of one experimental officer and one scientific assistant and both vacancies were filled in July 1968.

A site with suitable sub-surface drainage has been prepared on Begbroke Hill Farm for 30 small, plastic-lined pools ($7\frac{1}{2}$ ft × $2\frac{1}{2}$ ft) which will be used for experiments on methods of controlling aquatic weeds. To provide well-established plants for these experiments selected weeds will be grown in baskets in a pool formed by a natural spring on the northern boundary of the farm. These plants will be transferred from the nursery to the plastic pools in their baskets so that their root and rhizome development will be disturbed as little as possible.

The project concerned with the accurate aerial application of dalapon to drainage ditches has continued in collaboration with the Tropical Pesticides Research Unit (TPRU). The experiment that was started in 1965 to compare the effect of dalapon on *Phragmites communis* (reed) when applied at 10 and 20 lb a.i. in 10, 20 and 30 gal/ac was completed in 1967. The results indicated that it may be possible to reduce both the volume and dose of dalapon from the normally recommended 20 lb in over 30 gal/ac without impairing its effectiveness when applied from the air. In 1968 with the co-operation of Shellstar Ltd., the project was extended to include a comparison of coarse aqueous sprays applied through nozzles delivering 10 gal/ac with an invert emulsion system. Physical measurements of spray characteristics and spray-drift were made at TPRU and were then followed in September 1968 by a field experiment on *Phragmites communis* to compare the effectiveness of the two systems. Results of this experiment will be assessed from regrowth in 1969 and 1970.

The project on 2,4-D residues in natural surface waters was terminated in 1967 and the results published. One interesting result was that rapid inactivation of 2,4-D was induced by the addition of soil from a WRO long-term field experiment which had been treated frequently with MCPA and in which MCPA was known to break down within three days.

Co-operation with the Ministry of Agriculture, Fisheries and Food (MAFF) in the Chinese grass carp (*Ctenopharyngodon idella*) project continued. A reliable technique has not been found for the assessment of changes in density of plants in mixed submerged communities without cutting and removal. Estimates of the quantity of weed consumed by the fish have been made from weight gains while in the experimental ponds, and feed conversion factors determined in experiments at the Freshwater Laboratory of the Ministry of Agriculture, Fisheries and Food.

Field experiments to examine the effect of time of application (stage of growth) on the herbicidal activity of dalapon on *Typha latifolia* (great reedmace), *Glyceria maxima* (reedgrass) and *Sparganium erectum* (bur-reed) were started in 1968 and will be assessed on regrowth in 1969.

The Farm

Farm Director: J. G. ELLIOTT

Farm Manager: F. BARNES

Begbroke Hill Farm lies five miles north-west of Oxford, near the road to Woodstock. Its 286 acres fall naturally into two parts, separated by the Oxford-Birmingham railway. The part west of the line on which are the main buildings consists of 176 acres of deep, sandy loam topsoil overlying gravel, most of which is used for arable experimentation and cropping. The area east of the line consists of 110 acres of low-lying, rather wet, alluvial soil, mostly under mediocre permanent pasture. The Farm thus caters for experimentation on arable and horticultural crops and grassland. The holding is now equipped with the basic facilities that go to make both an efficient experimental station and a modern farm. They include all-weather roads, buildings and equipment for the handling and storage of 160 tons of cereals, 200 tons of potatoes and 60 beef cattle. Irrigation is available on the arable land. During the past two years new stockyards have been built which provide winter accommodation for cattle.

Priority is given to the field experiments which now number about 100 annually; thereafter the remainder of the land is farmed intensively. It is considered important that the Farm should run on sound commercial lines, so that new techniques developed by experimentation can be tested on a whole-field scale and that land following experiments can be managed appropriately to make it suitable for further experimentation in due course. A rotational system has therefore been evolved on the arable part of the Farm within which it is possible to meet the requirements of the experimental work and at the same time run the Farm as a normal commercial enterprise.

One 18 acre field (Deal) is progressively being taken up by long-term experiments. The area not in experiments is cropped with lucerne, which provided 2 silage cuts and a hay crop in 1968. The remainder of the arable acreage, comprising 8 blocks of approximately 17 acres each, is farmed on an 8-year rotation: experiments, barley, experiments, barley, barley, winter oats, potatoes and wheat. Dung from the cattle yards is applied to the potato crop.

The grassland is managed in three sections. A block of 27 acres is stocked with beef cattle, no fertilizer is applied and the tall weeds are periodically topped, thus keeping the permanent pasture sward in an unimproved condition. Another section of 50 acres is being used progressively for sward destruction and direct-reseeding experiments. The area out of experiments is cut for hay or silage and is then subsequently grazed. The most southerly two fields (Alberts and Far Field) are split into paddocks on which different fertilizers are applied and the grass then used for intensive rotational grazing of beef steers. The cattle are weighed each month. The object is to equate botanical changes in the sward with the output from the grass.

The stock system involves the purchase of 6-12 month old steers in the autumn which are fed through the winter on lucerne and grass silage and arable and experimental by-products. Most of the beasts fatten on grass for slaughter during the following summer.

The labour force on the Farm consists of a tractor driver, a general farm worker, stockman and an apprentice. The Farm has been accepted as an official training farm under the apprenticeship scheme. Records are kept of all activities on the Farm and a balance sheet is produced annually. The work carried out by the Farm staff on experiments is charged for and the produce from experiments is received back and accordingly credited.

EXPERIMENTAL ACTIVITIES

1. The profitable production of King Edward potatoes; endeavouring to obtain a clod-free environment for planting and with weed control by selective herbicides instead of cultivation.

2. To examine and record techniques for straw disposal and stubble break-up in preparation for post-harvest couch control in cereal crops.
3. Cereal production by minimal cultivation.
4. The performance of beef steers in a paddock grazed system.
5. The factors affecting sprayer performance under field conditions, i.e., pressures, gallonage and marking-out.

List of Research Projects

The Department is responsible for research on practical problems of weed control, for developing the possibilities that herbicides offer in husbandry and for research on the consequences of herbicide use on land and water.

AGRONOMY SECTION (*Section Head*: J. G. ELLIOTT)

The Agronomy Section has two major teams that specialize in arable and grassland agriculture respectively, a minor team on methods of crop establishment, a surveys officer, a special project (for 2 years) and attached students.

I. The Arable Team (G. W. Cussans and B. J. Wilson)—
  (a) The growth and control of *Agropyron repens* (couch) and *Agrostis gigantea* (creeping bent) in cereal land.
  (b) The control of weeds in systems involving minimum cultivation.
  (c) The control of weeds in potatoes.
  (d) Agronomic aspects of the control of *Avena* spp. (wild oats).

II. The Grassland Team (G. P. Allen and A. K. Oswald)
  (a) The selective control of *Agrostis* spp., *Poa* spp. and *Holcus lanatus* (Yorkshire fog) in leys and permanent pasture.
  (b) The use of herbicides for sward destruction prior to surface sowing.
  (c) The long-term effects of grazing and fertilizers on the weeds of permanent pasture.

III. Crop Establishment Team (J. G. Elliott and N. R. Squires).
  (a) Grass and fodder crop establishment after sward destruction.
  (b) The growth of barley in response to reduced cultivation.

IV. Surveys Officer (T. W. Cox).
  (a) The collection of general information about weeds, crops and herbicides necessary for project planning.
  (b) The investigation of the means by which *Avena* spp. (wild oats) are spreading and an enquiry into the economic significance of this weed.

V. Special Project (D. J. Turner).
The biology of perennial grasses of cereal land and their response to defoliation. Grasshoppers Club Grant (ended March 1968).

VI. "Sandwich" Students (K. Boyd and P. Bate in succession). Contributors to the project on *Avena* spp.

HORTICULTURE SECTION (*Section Head*: J. G. DAVISON and D. V. CLAY)

There is an agreed division of effort between WRO and the National Vegetable Research Station by which WRO, apart from early evaluation, does not undertake research on weed control in vegetable crops. The Section's work has been restricted to fruit and ornamental crops.

I. Studies of particular problem weeds, *Convolvulus arvensis* (bindweed) and *Heracleum sphondylium* (hogweed).
II. The persistence of soil-applied herbicides when used repeatedly in horticultural crops.
III. The resistance of fruit and flower crops to herbicides.
IV. The comparison of regimes of weed control in raspberries.
V. The responses of *A. repens* to dichlobenil and chlorthiamid (R. E. Dhanaraj).

AQUATIC WEED SECTION (*Section Head*: T. O. ROBSON assisted by P. BARRETT)

I. The accurate aerial application of herbicides to drainage ditches.
II. The use of grass carp for the control of aquatic vegetation.
III. The breakdown of 2,4-D in natural surface water.
IV. The effect of varying dose and time of application on the efficiency of herbicides applied to aquatic species.

LONG-TERM PROJECT (J. D. FRYER and K. KIRKLAND)

This is concerned with the effects of repeated applications of herbicides to the soil. The herbicides that are being investigated are MCPA, tri-allate, simazine, linuron, paraquat and picloram.

FARM (*Manager*: F. BARNES)

I. The production of King Edward potatoes using herbicides with special attention to a clod-free seedbed.
II. The integration of cereal grain retrieval, straw disposal and stubble break-up in modified cultivation systems.
III. The intensive production of beef from grass by means of paddocks and lanes.

Information Section

Head: D. O'D. BOURKE

The role of the Information Section is to provide library and information facilities for the research staff and to compile *Weed Abstracts** for publication by the Commonwealth Agricultural Bureaux (CAB).

*Obtainable on subscription from the Commonwealth Agricultural Bureaux, Farnham Royal, Bucks.

It also compiles bibliographies, deals with enquiries on weed literature and assists with the preparation of WRO publications.

The Head of the Section is WRO representative on the British Standards Institution Technical Committee PCC/1, which is responsible for the standardization of names of new pesticides. He attended the Seventh Plenary Meeting of ISO/TC81 from 26-29th September 1967, in London, as a member of the United Kingdom delegation and was the representative for the English language on the Editing Committee.

Staff

Miss C. Hasnip took up her appointment as Abstractor (CAB grant) in July 1967, thus filling the remaining abstracting post on the establishment. There were difficulties in filling the post of Indexer (CAB grant) until Mrs. H. J. McArdle was appointed in September 1967, thus releasing Mrs. B. R. Burton, who had been combining the post of Indexer with that of Librarian, for full-time library duties. Unfortunately, Mrs. McArdle resigned in December 1967. Miss E. White, who succeeded her, took up her appointment on 1st March 1968. Mrs. S. Stedman, Typist (CAB grant), resigned in May 1968 and was replaced by Miss L. Coles in July.

Library

There were some 98 additions during the period under review, bringing the number of volumes to about 500. Some 310 periodicals are received, of which 300 are permanently filed. New shelves were provided for the display and easy location of periodicals, which were arranged in alphabetical order. A movable display rack was constructed for material awaiting abstracting, and further matching wall shelves erected for bound volumes.

Index

In order to provide further information for research workers it was decided to include the names of pests, diseases and organisms used for biological control. A guide to the Index was placed on display to facilitate searches by casual enquirers.

Difficulties in filling the post of Indexer inevitably delayed the work of indexing at the beginning of 1968 but by the end of the year the delay had been considerably reduced.

Weed Abstracts

The increasing volume of literature kept abstractors fully occupied but as wide a coverage as possible was assured by regular visits to Oxford libraries and to various Commonwealth Agricultural Bureaux. A total of 2427 abstracts was included in Volume 16 (1967) and 2952 in

Volume 17 (1968), representing an increase of 1547 over Volumes 15 (1966) (which included a double number) and 14 (1965).

The absence of an easy method of checking on the species of crops and weeds mentioned in a given number of *Weed Abstracts* was felt to be a gap that needed filling. With the co-operation of the abstractors a Species Index was compiled for each number and the first of these Indexes appeared in Volume 16, No. 4. Each number of *Weed Abstracts* is now accompanied by an Author and a Species Index.

The printing gap continued despite the fact that on no occasion was copy sent to the printers after the dates agreed with them in October 1965. To remedy this state of affairs a discussion was held in May 1968 and a new schedule was devised whereby copy would be submitted progressively earlier with publication dates unchanged, thus enabling the printers to complete the work in a longer time.

Little improvement resulted and in October 1968 the printers informed the Commonwealth Agricultural Bureaux that they would require increased payment to continue to produce *Weed Abstracts.* The CAB then called for tenders and, as a result, R. G. Baker Ltd. of Farnham Common, were chosen to undertake the printing in future, beginning with Vol. 18, No. 2.

The distribution of *Weed Abstracts* continued to increase. Total subscriptions for Volume 17, No. 6, amounted to 1120, made up of 857 subscriptions and 263 copies on quota or exchange. At the end of 1966 the corresponding figures were 995, made up of 715 and 280. During 1967 the increase in *Weed Abstracts* subscriptions of 72 was the largest of any journal published by the Commonwealth Agricultural Bureaux.

Other Publications

The Head of the Section was the Chapter Manager for Chapter 19, "The organization of research and development in weed control in Britain and sources of published information" of Volume I of the 5th edition of the Weed Control Handbook. He was also responsible, with Mrs. B. R. Burton, Librarian, for compiling the indexes of Volumes I and II of the Handbook.

As a service to members of WRO, notices of forthcoming conferences and meetings were distributed, as they were received or noted in the literature, as from May 1967.

As from 1 October 1967 a weekly *Current Awareness* service was initiated. A list of articles or publications noted during the week is distributed every Friday, to ensure that new developments are immediately brought to the attention of members of the staff.

Bibliographies and Enquiries

Eight annotated bibliographies were compiled together with some ordinary bibliographies. Some 120 written enquiries were dealt with and many more verbal enquiries.

The response of commercial firms to a circular letter sent out in June 1967, requesting all forms of data on herbicides, was quite satisfactory. It was decided, however, that such a letter should be sent annually, in December, to remind them of the interest to WRO of commercial literature.

Overseas Work

The liaison function of WRO supported by the Ministry of Overseas Development (ODM) has continued through correspondence with workers in many overseas countries, through visits of such workers to the Organization and through further visits by staff members overseas. In addition, members of staff have acted as consultants to several bodies requiring specialized advice in the field of weed control or weed research.

Dr. E. C. S. Little was seconded to the United Nations Food and Agriculture Organisation (FAO) for six months in 1967 as a general consultant on weed control matters, and followed this with a special visit to Indonesia to advise on an aquatic weed problem. Subsequently he resigned from WRO and is now with the UNDP/FAO Range Management Project in Kenya. He joins Dr. G. W. Ivens, who is still on secondment from WRO to FAO. Meanwhile C. Parker took over the liaison duties and made a ten-week visit to West Pakistan, India and Ceylon on behalf of ODM to study the problems and establish contacts in this area. He also made a 3-week advisory visit to Africa on behalf of the Commonwealth Development Corporation and an 8-week tour of East Pakistan, Thailand and the Philippines on behalf of the South East Asia Treaty Organisation (SEATO).

As a result of these and previous tours, close contact has been established with a good proportion of weed research workers around the world and valuable exchange of information has resulted.

One of Dr. Little's major activities before he left was the compilation of a valuable review of the literature on all aspects of aquatic weeds, which has been published in summary form in *Weed Research*. He also prepared a comprehensive card index to the literature on weed control in cotton.

Research on tropical species continued to be the responsibility of the Evaluation Section up to the end of 1968 but Dr. Little and I. E. Henson conducted some experiments on tropical aquatic weeds which have been reported in PANS C.

For the future some reorganization is planned and proposals for the formation of an Overseas Section are under consideration. If approved the Section will become responsible for the glasshouse evaluation work involving tropical species and also for liaison and advisory functions of WRO undertaken for ODM.

At present the routine post-emergence selectivity experiments conducted by the Evaluation Section involve 14 tropical or subtropical species including the crops, rice, maize, sorghum, cotton, groundnut and tobacco, the annual weeds, *Eleusine indica* (wild finger-millet), *Echinochloa crus-galli* (barnyardgrass) *Digitaria sanguinalis* (large crabgrass), *Eupatorium odoratum* (Siam weed), *Portulaca oleracea* (purslane) and *Amaranthus retroflexus* (redroot pigweed) and the perennials *Cynodon dactylon* (stargrass) and *Cyperus rotundus* (nutgrass). A smaller range is included in the pre-emergence experiments. The experiments have been conducted over a long period and a report has recently been prepared, tabulating the effects of 174 compounds on *Cyperus rotundus*.

More detailed attention is now paid to the perennial weeds and nine tropical species are included in a special experiment each year with the more promising new herbicides. These species are *C. dactylon, C. rotundus, C. esculentus, Digitaria scalarum* (African couch), *Pennisetum clandestinum* (Kikuyu grass), *Imperata cylindrica* (spear grass), *Paspalum conjugatum* (sour paspalum), *Sorghum halepense* (Johnsongrass) and *Oxalis latifolia* (oxalis). They are grown for several months before treatment, so that they have well-developed perennating systems before spraying. Results of these experiments have now become generally available in WRO Technical Reports.

In 1968 members of a Crop Protection course for "pest control operators" for developing countries run on behalf of ODM at the Imperial College Field Station at Silwood Park spent a day at Begbroke to see WRO and to receive instruction. It is planned that the course should be repeated in 1969 with more time devoted to weed control.

The demand from developing countries for advice and guidance in the sphere of weed control and weed research is steadily increasing. In particular expert help and training are needed in order to get new weed research units established. WRO will not be able to meet all these demands but will be making what contribution it can to the development of herbicide use overseas.

Technical Services

WORKSHOP (*Supervisor*: R. KIBBLE-WHITE)

In January 1968, the workshop and maintenance staff were reorganized following a visit by the ARC Staff Inspector. This reorganization provides three groups—Experimental Requirements, Common Services and Building Maintenance—and has facilitated the work and allowed more effort to be made available for the development of experimental equipment. High priority is being given to the development of herbicide application equipment for glasshouse work and field plots.

PHOTOGRAPHY (H. BYWATER)

The Section was set up in March 1966 after increasing demands for photographic work had made it evident that there was a need for a service of this kind to cater for the specialised requirements of the Organization. The facilities consist of a dark-room, a general work-room/studio and standard photographic equipment.

The work of the Section falls into the following four groups:—

Experimental Recording: Photography is being used to make a permanent record of experimental results. Most of these photographs are taken on colour material. Plants in pots are photographed in the studio, larger plants in the glasshouses. For photography of field plots the equipment sometimes has to travel in rough and dusty conditions and a waterproof metal case with fitted plastic foam interior is essential to protect camera equipment.

For experiments away from Begbroke and technical visits, scientific staff are provided with loan cameras. For photographs needing special techniques the photographer also travels to the site.

Publication, Display, Lectures: Pictures and diagrams have been provided for illustrating articles in the technical trade and general press and for display at careers exhibits, agricultural shows and open days.

A growing slide library is maintained for lecture and reference purposes.

General Photography: Subjects include crops, weeds, equipment, methods, events and copying. A projection service to the station is provided.

Development: Work has been carried out on the use of photographic methods in connexion with the assessment of aquatic weed control in a series of ponds, the production of rapid prints of leaf areas, recording pasture soilage, patternator tube recording, and photometric leaf area measurement.

Ministry of Agriculture, Fisheries and Food

National Agricultural Advisory Service Liaison

P. J. ATTWOOD (Agriculture)

R. F. CLEMENTS (Horticulture)

For a number of years two members of the National Agricultural Advisory Service (NAAS) have been stationed at WRO as liaison officers, one of these dealing with horticulture and the other with agriculture. S. A. Evans left the agricultural post during the summer of 1968 after many years of fruitful work and was replaced by P. J. Attwood. The job of the liaison officers involves reviewing work in progress at WRO and elsewhere and passing on information about herbicides and weed control techniques to their NAAS colleagues. In this way they act as weed control specialists to their service, working largely through crop husbandry, grassland and horticultural specialist advisers. They also collect information about problems occurring in the field and pass information gathered from district advisers and other colleagues back to WRO. In their capacity as consultants to WRO they advise on problems requiring investigation and take part in research discussions.

Each year the NAAS liaison officers undertake the writing or revision of many of the leaflets on weeds and weed control issued by the Ministry of Agriculture, Fisheries and Food. They also lecture at farmers' and growers' meetings and prepare articles for publication in the farming and horticultural press. Members of the NAAS are kept up to date in weed control matters principally by the circulation of notes and papers within the service but colleagues are also addressed at refresher courses and many specific queries from regional specialists are answered.

Collaboration between the two organizations on experimental work has entailed giving help to WRO staff in finding sites for some of their experiments and keeping WRO informed of the results of NAAS trials and investigations. On the agricultural side NAAS regional crop husbandry advisers and county staff undertake a number of national trials, the details of which are usually jointly prepared by representatives of both organizations at meetings of the NAAS/WRO Liaison Group. Some aspects which have been investigated over the past two years are:

Effect of spraying cereals at the "jointing" stage
Dock control in cereal stubbles
Control of couch in potatoes
Efficiency of dinoseb-acetate post-emergence in spring beans
Weed control in swedes and rape
Effect of farm sprays on cereal yields

Most experiments on weed control in horticultural crops are located at NAAS Experimental Horticulture Stations. Small observation studies designed to give further information on local problems or to form the basis of demonstrations are carried out on commercial holdings by field advisers. Close co-operation is maintained with weed control specialists at other centres, particularly the National Vegetable Research Station (NVRS) and subjects for experimental study are formulated in consultation with them. During the past two years a project for the field screening of new herbicides on a range of vegetable and ornamental crops has been operated through co-operation between NVRS, WRO, the Scottish Horticultural Research Institute, Invergowrie, the Horticultural Centre, Loughgall, Northern Ireland, and six Experimental Horticulture Stations. Promising herbicides from these tests have been included in yield trials at several centres.

The Agricultural Chemicals Approval Scheme—Herbicides Liaison

R. J. Makepeace

The Ministry of Agriculture, Fisheries and Food operates a voluntary scheme under which proprietary brands of crop protection chemicals can be officially approved. Labels of approved products bear an Approval Mark which indicates that the Organization is satisfied that the claims and recommendations made by the manufacturers are reasonable and reliable within the limits of normal use. The Approval Organization maintains a liaison officer at WRO to ensure close contact with the work done there and to liaise with the NAAS and other appropriate bodies.

Manufacturers of herbicides are encouraged to inform the Approval Organization of new products as soon as they reach the stage of field testing, and it is the responsibility of the Herbicides Liaison Officer to be familiar with the development work done by both commercial and non-commercial organizations. Although the Organization does not itself conduct field trials, it can sometimes arrange for the NAAS to include treatments in its trials which provide additional information. In this way evidence is collected on which to make an overall assessment of the potentialities of a product. A list of approved products is published annually and currently contains 318 herbicides containing 57 different active ingredients, either alone or in mixtures.

Through the approval scheme it is hoped that advisers can recommend and users select an appropriate product, confident in the knowledge that the recommendations are reliable and have been agreed to by an independent organization.

Ministry of Overseas Development

PANS C (*Editor*: B. Steele)

The Ministry of Overseas Development's quarterly journal on weed control, PANS C, (Pest Articles and News Summaries, Section C), has continued to be compiled at WRO. Together with sections on insects and plant diseases it forms a series on tropical pest control, produced under the Ministry's programme of technical assistance for developing countries. WRO, as part of its support for overseas weed control interests, provides offices and the co-operation of its Information Section and other staff concerned with the tropics for the Editor of PANS C. The result has been an ever-widening group of readers and contributors who both benefit from and add to the current information on weed control which it is the aim of PANS C to provide. Circulation has almost doubled in the last four years and, at the end of 1968, reached 1600 copies.

Towards the end of 1968, changes in the editorial staff of PANS necessitated the transfer of Dr. Steele to London to become General Editor. Also as a result of staff changes a decision was made, for administrative reasons, to combine the three sections of PANS into a single quarterly issue. Future issues of this combined edition will include as much information on weed control as well as other pest control topics as the staff position allows. Liaison with WRO is being maintained and contributors and readers may continue to make contact with PANS through the Organization or its overseas officers.

Visiting Research Workers

The collaborative arrangement in respect of research workers for higher degrees at Reading University have continued. A. M. Hamdoun, from the Ministry of Agriculture Research Division in the Sudan, was awarded an M.Phil. in 1967 for his research on *Cirsium arvense* while at WRO. He has since returned to a research appointment in the Sudan. Currently there are two students working for a Reading Ph.D.—M. Damanakis from Greece is doing research on the availability to plants of paraquat in soil, while R. E. Dhanaraj from India is investigating the response of *Agropyron repens* to dichlobenil and chlorthiamid.

Recently a similar arrangement has been entered into with Bath University in respect of a student, P. Quilt, wishing to work for a higher degree on some aspects of the interaction between herbicides and micro-organisms. He is in receipt of a Science Research Council grant for this work.

Various Sections of WRO have made use of 'sandwich' students during the industrial training portion of their degree course, in order to run small research projects.

During 1967-68 WRO has been pleased to act as host in providing facilities over a period of months for visiting workers who are acknowledged specialists in aspects of weed research. These have included Professor R. A. Peters of the University of Connecticut, U.S.A.; Dr. R. Grover of the Canada Agriculture Research Station, Saskatchewan, and Mr. P. E. L. Thomas from The Henderson Research Station in Rhodesia. Training and research experience was also provided for R. Tamés and Dr. J. Peña, from Facultad de Ciencias, Universidad Santiago de Compostela.

Annotated Bibliographies *

1. Selected references on the control of broomrape (*Orobanche* sp.). 1940-1966. (64 references). Price 8/-.
2. Selected references on the biology of broomrape (*Orobanche* sp.). 1935-1966. (90 references). Price 10/-.

3. Selected references on the mode of action of diquat and paraquat, their fate in plants and soils and their toxicology. 1958-1966. (80 references) Price 19/-.
4. Selected references on minimum cultivation techniques limited to seed-bed preparation and sowing operations in arable and herbage crops, and replacement of mechanical methods of weed control in perennial fruit crops. 1949-1966. (145 references). Price 40/-.
4a. Supplement to Annotated Bibliography No. 4. 1958-1966. (22 references). Price 8/-.
5. Selected references on *Mimosa pudica*. 1946-1965. (21 references). Price 5/-.
6. Selected references on the persistence of picloram in the soil. 1964-1966. (36 references). Price 11/-.
7. Selected references on the control of Asclepiadeae (*Asclepias* spp. 1-31, *Calotropis* spp. 32 and 33). 1957-1965. (33 references). Price 7/-.
8. Selected references on the mode of action of dalapon. 1954-1966. (101 references). Price 38/-.
9. Selected references on the interaction between mineral nutrients and herbicides. 1949-1966. (23 references). Price 8/-.
10. Selected references on wild oats. 1958-1967. (180 references). Price 60/-.
11. Selected references on the control of grass weeds in sorghum. 1956-1967. (60 references). Price 21/-.
12. Selected references on weeds as hosts of pests and diseases. Work in Great Britain 1960-1968. (11 references). Price 5/-.
13. Selected references on the behaviour of simazine in barley, maize and other plants. 1957-1967. (21 references). Price 5/-.
14. Selected references on the behaviour of MCPA in barley and other plants. 1951-1966. (14 references). Price 3/-.

*Obtainable from the WRO Information Section.

OVERSEAS VISITS

A number of overseas visits have been undertaken by members of staff in the last two years as follows:

February-March 1967	C. Parker	Visit to Tanzania and Swaziland on behalf of Commonwealth Development Corporation.
March 1967	G. W. Cussans	International Study Meeting on selective weed control in sugar beet crops—Paris.
May 1967	K. Holly J. Holroyd	To Weed Research Department of IBS and other institutes at Wageningen, the Netherlands.
July 1967-February 1968	E. C. S. Little	On secondment to FAO for various assignments.
September 1967	K. Holly R. J. Hance	6th International Congress of Plant Protection, Vienna.
	K. Holly	Meeting of European Weed Research Council, Vienna.
October 1967	C. Parker	FAO Symposium on Crop Losses, Rome.

October-December 1967	C. Parker	Tour of West Pakistan, India and Ceylon on behalf of Ministry of Overseas Development.
December 1967	D. O'D. Bourke	Columa Conference, Versailles.
May 1968	T. O. Robson	Government Departments, Research Centres and Universities in U.S.A. interested in the use of herbicides in water.
June 1968	G. P. Allen	Visit to Weed Research Department of IBS and other institutes at Wageningen, the Netherlands.
June 1968	J. D. Fryer	Meeting of European Weed Research Council, Yugoslavia.
June 1968	Miss E. Grossbard	Visit to Government Laboratory for Soil & Crop Research, and to Royal Veterinary and Agricultural College, Copenhagen.
July 1968	M. E. Thornton	Meeting of International Association for Mechanization of Field Experiments, Braunschweig, W. Germany.
September-November 1968	C. Parker	Tour of East Pakistan, Thailand and the Philippines on behalf of South East Asia Treaty Organization.
September 1968 to May 1969	R. J. Hance	Visit to Department of Soil Science, University of Saskatchewan, Canada, and University of Wisconsin, U.S.A.
December 1968	T. O. Robson	UNESCO Conference on ecology and control of aquatic weeds, Paris.

List of Publications, 1967-68

ALLEN, G. P. Developments in pasture weed control. *N.A.A.S. q. Rev.*, 1968, (82), 58-62.

ALLEN, G. P. The potential role of selective herbicides in grassland improvement. *Proc. 9th Br. Weed Control Conf.*, 1968 (in press).

ALLEN, G. P. The effect of July applications of dalapon on the growth and botanical composition of an *Agrostis/Lolium* pasture. *Weed Res.*, 1968 (in press).

ALLEN, G. P. and OSWALD, A. K. The response of a permanent pasture to seasonal applications of methyl N-(4-nitrobenzene sulphonyl)-carbamate. *Proc. 9th Br. Weed Control Conf.*, 1968, 471-76.

BLAIR, A. The control of *Rumex obtusifolius* by sulphonylcarbamate herbicides. *Proc. 9th Br. Weed Control Conf.*, 1968, 515-19.

BLAIR, A. and HOLROYD, J. Herbicides to control seedling weed grasses in newly sown leys and pastures. *Proc. 9th Br. Weed Control Conf.*, 1968, 484-87.

CHANCELLOR, R. J. The incidence of dormancy of two-node stem and rhizome fragments of *Polygonum amphibium*. *Weed Res.*, 1967, **7** (4), 323-30.

CHANCELLOR, R. J. The occurrence and growth of re-inhibited shoots and dormant buds on fragmented rhizomes of *Agropyron repens* (L.) Beauv. *Proc. 9th Br. Weed Control Conf.*, 1968, 125-30.

CHANCELLOR, R. J. The value of biological studies in weed control. *Proc. 9th Br. Weed Control Conf.*, 1968 (in press) .

CHANCELLOR, R. J. Road verges—the agricultural significance of weeds and wild plants. *Br. Crop Prot. Coun. Symp. Road Verges*, 1969 (in press).

CHANCELLOR, R. J., DAWSON, J. H. and FURTICK, W. R. Crop losses due to weeds. *FAO Manual*, 1968 (in press).

CLAY, D. V. and DAVISON, J. G. Herbicide evaluation trials on raspberry and rose rootstocks. *Proc. 9th Br. Weed Control Conf.*, 1968, 928-32.

CLAY, D. V. and DAVISON, J. G. The response of dahlias to soil-applied herbicides. *Proc. 9th Br. Weed Control Conf.*, 1968, 965-70.

CLAY, D. V. and IVENS, G. W. Pot experiments on the susceptibility of strawberries to simazine. *Proc. 9th Weed Control Conf.*, 1968, 891-99.

CLAY, D. V. and McKONE, C. E. The persistence of chlorthiamid, lenacil and simazine in uncropped soil. *Proc. 9th Br. Weed Control Conf.*, 1968, 933-38.

CLEMENTS, R. F. Safety first—the aim with herbicide spraying. *Comml Grow.*, 1967 (3752), 907-8.

CLEMENTS, R. F. Herbicides and weed control in strawberries. *Grower*, 1967, **68** (13), 547-8.

CLEMENTS, R. F. Weed control in intensive orchards. *Grower*, 1968, **69** (4), 181-82.

CLEMENTS, R. F. Herbicides in modern crop production. Intensively grown crops. *Proc. 9th Br. Weed Control Conf.*, 1968 (in press).

CUSSANS, G. W. No hope at all for up-and-coming weeds. *Fmr Stk Breed.*, 1967, **81** (18th April), 54 and 59.

CUSSANS, G. W. New ideas on couch control. *Proc. jt Conf., natn., Frms' Un. Eng. Wales and R. agric. Soc. Eng., Kenilworth*, 1967, 23-6.

CUSSANS, G. W. Perennial weed grasses and their control in relation to cereal growing *N.A.A.S. q. Rev.*, 1968 (81), 7-12.

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Glossary of herbicides mentioned in this Report

An asterisk (*) signifies a common name approved by the British Standards Institution.

aminotriazole*	3-amino-1,2,4-triazole
asulam	*N*-(4-aminobenzenesulphonyl)methylcarbamate
atrazine*	2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine
barban*	4-chlorobut-2-ynyl *N*-(3-chlorophenyl)carbamate
Bidisin	2-chloro-3-(4-chlorophenyl) propionic acid methyl ester
bromacil*	5-bromo-6-methyl-3-(1-methylpropyl)uracil
chlorflurecol*	2-chloro-9-hydroxyfluorene-9-carboxylic acid
chloroxuron*	*N'*-4-(4-chlorophenoxy)phenyl-NN-dimethylurea
chlorpropham*	isopropyl *N*-(3-chlorophenyl)carbamate
chlorthal*	2,3,5,6-tetrachloroterephthalic acid
chlorthiamid*	2,6-dichlorothiobenzamide
CP 50144	2-chloro-2,6-diethylphenyl-*N*-methoxymethylacetamide
2,4-D*	2,4-dichlorophenoxyacetic acid
dalapon*	2,2-dichloropropionic acid
dicamba*	3,6-dichloro-2-methoxybenzoic acid
dichlobenil*	2,6-dichlorobenzonitrile
dinoseb*	2-(1-methylpropyl)-4,6-dinitrophenol
diquat*	9,10-dihydro-8a, 10a-diazoniaphenanthrene-2*A*
diuron*	*N'*-(3,4-dichlorophenyl)*NN*-dimethylurea
endothal*	7-oxabicyclo[2,2,1]heptane-2,3-dicarboxylic acid
EPTC*	*S*-ethyl *NN*-dipropyl(thiocarbamate)
fenuron*	*NN*-dimethyl-*N'*-phenylurea
fluometuron*	*N'*-(3-trifluoromethylphenyl)-*NN*-dimethylurea
lenacil*	3-cyclohexyl-6,7-dihydro-1*H*-cyclopentapyrimidine-2,4-(3*H*,5*H*)dione
linuron*	*N'*-(3,4-dichlorophenyl)-*N*-methoxy-*N*-methylurea
Glenbar	*O,S*-dimethyl tetrachlorothioterephthalate
M & B 8882	methyl N-(4 nitrobenzenesulphonyl)carbamate
MCPA*	4-chloro-2-methylphenoxyacetic acid
metobromuron*	*N'*-(4-bromophenyl)-*N*-methoxy-*N*-methylurea
monolinuron	*N'*-(4-chlorophenyl)-*N*-methoxy-*N*-methylurea
monuron*	*N'*-(4-chlorophenyl)-*NN*-dimethylurea
paraquat*	1,1'-dimethyl-4,4'-bipyridylium-2*A*
picloram*	4-amino-3,5,6-trichloropicolinic acid
prometryne*	4,6-bisisopropylamino-2-methylthio-1,3,5-triazine
propachlor*	2-chloro-*N*-isopropylacetanilide
propanil*	*N*-(3,4-dichlorophenyl)propionamide
R 2063	*N*-cyclohexyl-*N*-ethyl-*S*-ethyl(thiocarbamate)
R 7465	2-(α-naphthoxy-*N*,*N*-diethylpropionamide)
simazine*	2-chloro-4,6-bisethylamino-1,3,5-triazine
2,4,5-T*	2,4,5-trichlorophenoxyacetic acid
TCA	trichloracetic acid
terbacil	5-chloro-6-methyl-3-t-butyluracil
tri-allate*	*S*-2,3,3-trichloroallyl *NN*-di-isopropylthiolcarbamate

PRINCIPLES GOVERNING ACCEPTANCE OF NEW HERBICIDES FOR EVALUATION BY THE WEED RESEARCH ORGANIZATION

The Weed Research Organization is faced with an ever-increasing number of new herbicides under development by the agricultural chemical industry, which need to be considered for possible inclusion in its own research programmes. The Organization has, therefore, found it necessary to formulate certain principles regarding the acceptance or otherwise of such compounds for investigation in its programme of new herbicide evaluation and development. These are as follows:

1. WRO is not under obligation to accept chemicals from other organizations or commercial firms for evaluation purposes.

2. Chemicals will only be accepted if the following conditions are agreed to (information to be provided, if necessary, in confidence):
   (a) Composition of chemical and details of concentration and type of formulation must be stated.
   (b) The suppliers must agree to provide the information, as far as it is available, asked for in a standard questionnaire covering physical and chemical properties, toxicology and phytotoxic properties.
   (c) The suppliers must have carried out adequate preliminary tests that indicate the chemical has herbicidal properties.
   (d) There must be a reasonable prospect of the herbicide being developed commercially if promising uses are found, and the suppliers must have arranged to give priority to the chemical in their evaluation and development programmes.
   (e) The suppliers must agree to comply with the terms of the Pesticides Safety Precautions Scheme and to keep WRO fully informed of their action, where relevant.
   (f) The suppliers must be agreeable to a two-way interchange of information between themselves and WRO during the period of development of the herbicide and to giving prior information concerning the nature of their future development programme.

3. Acceptance of a herbicide by WRO does not imply any obligation on the part of the Organization to carry out work on the herbicide or to report the results of any work that may be carried out.

4. WRO retains the right to publish the results of its work on publicly disclosed compounds without consulting the suppliers. In the case of herbicides disclosed confidentially, some indication of the period for which confidential status is requested must be given. Material cannot be withheld from publication indefinitely, though WRO will always try to be co-operative in relation to specific patent situations.

5. Any information given by WRO to the suppliers must not be reproduced in published documents without specific permission and in no circumstances must it be used in advertising.

6. If there is an agreed programme between the firm and WRO involving application to field plots of an edible crop, the firm must agree to accept financial liability in the event of the produce not being allowed to go forward for human consumption.