AGRICULTURAL RESEARCH COUNCIL

WEED RESEARCH ORGANIZATION

Second Report 1965–1966

BEGBROKE HILL, KIDLINGTON, OXFORD

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A.R.C. WEED RESEARCH ORGANIZATION

Staff as at 1st January 1967

Director

J. D. Fryer, M.A.

Secretary

B. A. Wright

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EVALUATION SECTION

Head: K. Holly, Ph.D.

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Experimental Staff:

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Mrs. A. K. Wilson, B.Sc. I. E. Henson, N.D.H.

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A. J. Dunford Miss J. M. Laughton
D. J. Poulton K. R. Taylor M. P. Thompson

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Head: R. J. Hance, Ph.D.

Experimental Staff:

C. E. McKone

Assistants:

Miss J. Barrett C. J. Briscoe

BOTANY SECTION

Head: R. J. Chancellor, M.A.

Assistant: Miss A. Glozier

MICROBIOLOGY SECTION

Head: Miss E. Grossbard, Ph.D.

Experimental Staff: D. L. Jones, B.Sc.

Student: K. Brans

Assistant: Mrs. P. Moore*

* Part time

DEPARTMENT OF WEED CONTROL

Head: J. G. Elliott, M.A.

AGRONOMY SECTION

Head: J. G. Elliott, M.A.

Scientific Staff:

G. P. Allen, B.Sc. G. W. Cussans, B.Sc.
D. J. Turner, Ph.D. (Grasshoppers Club Grant)

Experimental Staff:

A. K. Oswald B. J. Wilson, B.Sc.

Assistants:

P. J. Ayres J. Capel J. Nash
P. D. Smith T. J. Woodward

HORTICULTURE SECTION

Head: J. G. Davison, Ph.D. (from 1st April 1967)

Experimental Staff: D. V. Clay, B.Sc.

Assistants:

W. H. Bell J. I. Green Mrs. N. Slater
Mrs. G. Young* Mrs. C. Cockram*

SPECIAL PROJECTS

Aquatic Weeds: T. O. Robson, B.Sc.

Long-term herbicide project: K. Kirkland

Assistant: G. G. Hawkins

EXPERIMENTAL RECORDS

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Farm Manager: F. Barnes

S. Crossley F. A. Penfold
S. M. Purple P. Rusher

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Information Staff:

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J. L. Mayall Mrs. E. M. Young, M.A.*

Librarian: Mrs. B. R. Burton

* Part time

OVERSEAS SECTION

Head: E. C. S. Little, M.B.E., D.Phil.

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Seconded to F.A.O.: G. W. Ivens, D.Phil.

VISITING RESEARCH WORKERS

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P. E. L. Thomas (Rhodesia)

ADMINISTRATION

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R. Kibble-White (*Workshop Supervisor*)

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A. Gardner F. J. Bowerman H. E. Peacock

Stores: H. A. Wilkinson

Cleaning Staff:

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Mrs. J. Martin* Mrs. H. Thomas* Mrs. D. Tutte*
Mrs. O. Walker*

ATTACHED STAFF

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

National Agricultural Advisory Service Liaison:

S. A. Evans, B.Sc. (Agriculture)
R. F. Clements, N.D.H. (Horticulture)

Agricultural Chemicals Approval Scheme Liaison: J. G. Davison, Ph.D.

MINISTRY OF OVERSEAS DEVELOPMENT

Editor PANS (C): B. Steele, Ph.D.

* Part time

A Review of Progress by the Director

J. D. Fryer

The First Report of the Weed Research Organization (W.R.O.) was published in April 1965, five years after the acquisition of Begbroke Hill Farm by the Agricultural Research Council (A.R.C.). The origins of W.R.O. in the A.R.C. Unit of Experimental Agronomy and its evolution into a fully fledged research institute were described. The present report is concerned with progress during 1965 and 1966, years which have been notable as a period of intense activity by the agricultural chemical industry in discovering and developing new herbicides. In 1965 the sales of herbicides by British manufacturers exceeded for the first time the total combined sales of all other pesticides and allied products. It has also been a period in which there has been an increasing realization that chemical methods of weed control have come to stay in countries which already have a developed agriculture; and that they will tomorrow play an equally important role in assisting developing countries to produce more food and fibre. It is estimated that in Britain about half the arable land is now being sprayed for weed control each year.

As far as W.R.O. is concerned it has primarily been a period of consolidation following the establishment and early growth of the Organization. As will be seen from the staff list on pp. iii–v further development has also taken place and in status W.R.O. is becoming increasingly recognized as the leading centre for applied research and information on weeds and their control. Public interest was highlighted by the 1500 or more visitors who attended the Open Days held at Begbroke in May 1966.

Although primarily set up to serve agriculture and horticulture in the United Kingdom, W.R.O. has many connections with overseas countries and has willingly accepted a responsibility to do what it can to assist developing countries in making use of the revolutionary chemical tools now available for controlling weeds.

THE RESEARCH PROGRAMME

There has been one major change and one important addition during the period under review.

The change has been the reorganization of the research work of the Station into two departments, namely 'Weed Science' under Dr. K. Holly, and 'Weed Control' under J. G. Elliott (see pp. 12 and 27). This step has greatly assisted in the integration of the work of the individual research Sections.

The Department of Weed Science

This Department has as its task the study of the interaction between herbicides, plants and soils, with a view to: (a) finding new weed control techniques, (b) improving reliability of existing methods, (c) detecting, and where possible helping to overcome, problems which might arise from the practical adoption of a new technique. Apart from the continuing need to find new herbicides to increase the efficiency of weed control in many different crops, the already very intensive usage of herbicides in much of the cropped land of Britain is giving rise to some anxiety about the possible development of consequences which might in the long-term be inimical to future crop production or to the environment as a whole. The research required is not the kind which can be left to the chemical industry and official research institutes and Universities must play the major part. The decision of the A.R.C. to support a research project at Begbroke to study the effects of herbicides on soil micro-organisms was, therefore, welcomed. Dr. Erna Grossbard joined us from the Grassland Research Institute (G.R.I.) on 1st April to lead the new *Microbiology Section*, and has already built up an energetic programme of systematic studies with a wide range of herbicides. W.R.O. is much indebted to Dr. E. K. Woodford, Director, G.R.I., for agreeing to release Dr. Grossbard for this work. Dr. Grossbard has had to contend with an improvised laboratory in the new controlled environment building which was completed in 1965 but plans are well in hand for the construction of a new laboratory for microbiological work.

Apart from this there have been no major changes or additions to the Sections comprising the Department of Weed Science. Credit must be given to S. D. Hocombe for maintaining a full programme of herbicide evaluation experiments under very difficult conditions caused by problems in the recruiting of supporting staff, also for designing and supervising the construction by the W.R.O. Workshop of a pair of controlled environment rooms, which will be complementary to the three N.I.A.E.-designed standard controlled environment cabinets to be installed during 1967.

Mr. Hocombe also very capably took care of the laboratory and glasshouse work of the *Evaluation Section* during a six months' absence of Dr. Holly in the United States as a visiting professor at the University of North Carolina. Dr. Holly also undertook an extensive tour of weed research centres in the States, an experience proving a great asset to W.R.O.

The Evaluation Section has continued its self-inflicted but important task of developing a systematic programme of appraisal of all new herbicides coming from industry. With no fewer than some 50 chemical firms in Europe and North America, and several more in Japan, all actively searching for new herbicides, a continuing flow of chemicals for evaluation under the conditions of the U.K. seems assured. During 1965–66 about 60 new commercial herbicides under development by industry were received by W.R.O. It may be asked why a research institute such as W.R.O. should concern itself with what might be considered the task of an official testing station or of industry. The short answer is that in Britain the official Approval and Safety Schemes of the Ministry of Agriculture are not set up to undertake research or testing, and that industry has but limited funds, experience and facilities for evaluating the herbicides it produces. An independent assessment by W.R.O. of the phytotoxic properties, mode of action, and persistence of new compounds of potential importance to British and tropical agriculture provides valuable guidance to all concerned with their practical use and possible consequences.

Nevertheless, with so many new herbicides it is a difficult problem to decide how the available resources should best be deployed to study them. At the present time particular emphasis is being given to herbicides showing toxicity to grasses since these the world over are of ever-increasing importance as weeds. Several acres of many different grass species are now grown at Begbroke by J. Holroyd and his team to allow study of effectiveness and selectivity of herbicides under field conditions; also a variety of tropical species are studied in the glasshouses. Another particularly interesting project is concerned with establishing the relationship between soil type as judged by a simple chemical test, and the dose of individual herbicides required to kill weeds. Studies of persistence of herbicides in soil are given high priority.

The *Chemistry Section* under Dr. R. J. Hance has continued to contribute original research on herbicide-soil relations and has greatly developed its residue analysis service to the other W.R.O. Sections since the purchase in 1965 of gas chromatograph equipment. To operate the latter, the Section was fortunate in recruiting C. McKone whose experience with similar equipment at the Tropical Pesticide Research Unit in Tanzania has proved most valuable.

The remaining Section of the Weed Science Department is the *Botany Section* under R. J. Chancellor whose task is to contribute studies on the biology of weeds which may throw light on weaknesses in their life history and survival pattern and hence suggest methods of control. The Section also provides assistance in weed identification and Mr. Chancellor's latest book on the subject (Chancellor, 1966) is likely to prove of much value to advisers and research workers throughout Europe and North America. During the period under review the Section continued its studies on the periodicity of germination of seeds of annual weeds as affected by cultivation, a subject of topical importance in view of the trend in many crops towards reduced or minimum cultivation. In addition further light has been shed on the ability of fragments of two important perennial weeds to survive under prescribed conditions. The last six months of 1966 were spent by Mr. Chancellor working at the Institut für Pflanzenschutz, Hohenheim, Germany, in the team of Professor B. Rademacher, renowned for its research contributions to weed ecology.

The Department of Weed Control

This Department has as its prime concern the weed problems of the farmer and horticulturalist, the problems posed by the control measures currently being used and the revolutionary changes in crop production practices made possible by the ability of herbicides to provide weed-free crops without disturbance of the soil. There is no rigid dividing line between the two research departments at Begbroke, but the emphasis of the work is different and the outlook and qualifications of the experimental staff have special requirements. Since weed control is an integral part of crop production, research staff in this part of W.R.O. needs an intimate knowledge of the technical and economic problems confronting the farmer and grower in the different agricultural areas of the country. The herbicide or other control method being studied is but a link—albeit a vital one—in the chain of cropping and land management practices which go to make up a whole crop rotation—or at least a several years' cropping cycle for one field.

In this area of research, weed control experiments blend into crop research and then into development studies and finally into advisory and educational work. There are no barriers and few clear-cut responsibilities. Co-operation all along the line is essential—between the weed research worker and research workers in other institutes in the agricultural research service, in University Departments or in the research stations of industry; between the weed research worker and the specialist of the National Agricultural Advisory Service (N.A.A.S.) and the staff of the N.A.A.S. Experimental Husbandry Farms and Experimental Horticultural Stations; between the weed research worker and the crop protection specialists of the agricultural chemical firms, of agricultural merchants and of spraying contractors; between the weed research worker and farmers, growers and nurserymen who are prepared and anxious to help in pioneering the revolutionary methods of weed control now available. The task is a difficult one but its importance is well understood by members of the Weed Control Department of W.R.O., who, realizing the need, are resolved to accept the challenge aided by the two N.A.A.S. liaison officers stationed at Begbroke—S. A. Evans and R. F. Clements. The job involves much more than research: travelling, talking, planning, attending meetings, inspecting possible trial sites offered by growers, participation in farmers' discussion groups are all necessary but take up a great deal of time at the expense of a directly productive research effort.

The Agronomy and Horticulture Sections form the hub of the Weed Control Department. The *Agronomy Section* is led by J. G. Elliott who manages with calm and competence to keep on top of his many and diverse responsibilities. He not only supervises the work of his Department and his Section, but also acts as Chairman of the Field Experiments Committee and Director of the 280-acre farming enterprise; the latter provides land for experiments and serves as a test-bed for new ideas, under the capable management of F. Barnes. The arable team of the Agronomy Section has been much strengthened by the appointment of G. W. Cussans, in October 1965, well known for his work on weed control in the sugar beet crop at the Norfolk Agricultural Station.

After several years working intensively on weed control in potatoes and kale, the arable team is now concentrating on the perennial grass weed problem of intensive cereal production. Couch-grass (*Agropyron repens*) and common bent grass (*Agrostis gigantea*) have in recent years come to be regarded as limiting factors of major importance in the intensive production of barley and wheat in this country. Existing control measures are neither economically nor technically efficient where it is desired to grow a succession of cereal crops. The present intense interest in break-crops for cereals is in no small measure due to the need to control couch. There are no promising new herbicides on the horizon and the time has come for an intensive research effort to find out how these weeds grow, what makes them so successful and how they can best be attacked, both in individual crops and in the long-term.

This is the present major objective of the arable team of the Agronomy Section, an objective which is likely to be reached all the sooner through the generous grant given to W.R.O. by the Grasshoppers Club, and which resulted in the appointment of Dr. D. Turner at Begbroke, in March 1966, to work for two years on the biology of couch, with reference to its control.

Another crop that is securing much publicity at the present time is grass, as the key to more home-produced beef and to the release of land for cereal growing. All the signs point to a steady intensification of production through more efficient management, conservation and utilization. This, in turn, will lead progressively to the attitude that all but the sown or desired grass species in the sward must be considered as weeds. Since there is no reason to suppose that leys of the future will resist invasion by weed grasses any better than they do today, the problem will be how to control one grass growing in another. The major part of the research programme of the grassland team of the Agronomy Section under G. P. Allen is devoted to this end. Essentially a long-term and forward-looking project, considerable progress has already been made and future prospects are exciting.

The work of the *Horticulture Section* has continued to centre, during the past two years, on weed control in fruit crops. Whilst the commercial use of herbicides in fruit plantations is already very extensive and growers are rapidly turning to systems of management based on no soil disturbance (non-cultivation) relatively little research has been undertaken into these practices under conditions in Britain. The demand for information was recently stressed by the enthusiastic attendance by some 300 delegates at the one-day Symposium on Herbicides in British Fruit Growing which took place in London under the sponsorship of the British Weed Control Council on February 24th, 1966.

The horticultural work at Begbroke is split between (i) basic studies on factors influencing the persistence of simazine in soil, (ii) the evaluation of new herbicides for strawberries and certain other crops, and (iii) long-term field trials on herbicide usage in soft fruit crops grown under a variety of systems based on minimum cultivation.

With the present small size of the Section, horticultural crops other than fruit can only be given scant attention. Weed control in vegetables is not within the terms of reference of W.R.O.; close liaison is, however, maintained with the Weeds Section of the National Vegetable Research Station.

A small exhibit demonstrating the role of weedkillers in the garden was provided for the Chelsea Flower Show in 1965, at the request of the Royal Horticultural Society. The interest shown by the public amply rewarded the effort involved.

SPECIAL PROJECTS

The project described in the previous Report to investigate the possible long-term effect of herbicides in the soil has continued, and K. Kirkland is to be complimented on carrying out a task involving hard, routine and often uninteresting work with care and enthusiasm. The results continue to be largely negative and hence satisfactory. Visitors to Begbroke are unanimous in their approval for work of this kind, a view that gives encouragement to those concerned not only to maintain the existing experiments, but to start others involving a wider range of herbicides.

Another project is that concerned with aquatic weed control. The increasing cost and shortage of labour are forcing modern methods of vegetation control onto those responsible for maintaining the complex system of rivers and dykes which form the drainage system of the agricultural land of this country. Herbicides offer many advantages but are only acceptable if the wider implications of their use are well understood. Most watercourses have several functions, the relative importance of each varying from one to another. In some, efficient drainage may be the sole purpose for their existence, but in the majority they also serve to provide recreation in the form of angling, swimming or boating, and serve as a vital habitat for wild life. Weed control cannot be considered in isolation and research is needed not only to develop control measures, but also to assess the consequences of the treatments on the ecology of the drainage channels in the widest sense. T. O. Robson who undertook the survey of aquatic weeds described in the last report was appointed to the permanent staff of W.R.O. in November 1966.

Aspects of weed control which are not the present concern of W.R.O. include: weed control in vegetables; non-selective or 'industrial' weed control; weed and vegetation control in ornamental, recreational and amenity areas, including roadsides.

AID TO DEVELOPING COUNTRIES AND INFORMATION

The Ministry of Overseas Development (O.D.M.) has continued financial assistance for W.R.O. through a grant to A.R.C. with the object of helping developing countries wishing to obtain the benefit of the many new weed control methods now available. The grant provides for the Overseas Section and contributes to the research and information activities at W.R.O. relevant to weed control in the tropics.

Two new senior research appointments concerned specifically with overseas aid have been made under an agreement between A.R.C. and O.D.M. Dr. G. W. Ivens who had been Head of the Horticulture Section at Begbroke since its inception decided to revert to the research field in which he had specialized prior to joining W.R.O., and is now on a four-year secondment to F.A.O. as a bush control specialist attached to Katumani Experimental Farm in Kenya. For the second post we were pleased to welcome on to the permanent staff of W.R.O., C. Parker, an old colleague of the Unit of Experimental Agronomy. Dr. E. C. S. Little, Overseas Liaison Officer, has continued to establish new contacts through visits to Central America, South America and the Caribbean, one result of which has been aid from Britain to the official weed research team in Mexico in the form of a consignment, sponsored by O.D.M., of the latest types of herbicide application equipment for experimental work. Dr. Little has also assisted British manufacturers of agricultural chemicals to keep in touch with developments in weed control in the areas he has visited, and hence in the potential market for British herbicides and application equipment.

Playing a key role in the efforts of W.R.O. to assist, in addition to its own staff, people concerned in weed research overseas is the journal *Weed Abstracts* prepared by the Information Section at Begbroke and published by the Commonwealth Agricultural Bureaux (C.A.B.). The welcome decision taken by the C.A.B. Council in 1965 to give financial support to the journal will enable the already comprehensive coverage of the world literature on weeds to be further extended and to include publications in Slavonic languages. Much of the credit for building up *Weed Abstracts* to its present high standard and its international acceptance must be given to P. J. Boyle who resigned from W.R.O. in July 1966 to take up appointment as Assistant Director of the Commonwealth Agricultural Bureau of Pastures and Field Crops at the Grassland Research Institute, Hurley. D. O'D. Bourke, formerly Assistant Director of the Inter-African Soils Bureau in Paris, has succeeded him as Head of the Information Section.

This brief review of the overseas role of W.R.O. would be incomplete without mention of the tropical weed control journal *PANS*, sponsored by the O.D.M., which has flourished since it came under the editorship of Dr. B. Steele in 1964; also, of the research work on tropical crops and weeds undertaken by the Evaluation Section which continues to provide a stimulus to workers in other countries and which lends authority to advice emanating from W.R.O.

In many developing countries, weed research is non-existent. In others it is getting under way but often with negligible staff and facilities. W.R.O. can assist not only in giving advice, and where possible sending a specialist for a visit, but also in providing training. During 1965–66, weed research workers from Sudan, Ceylon, Rhodesia, Spain and Greece were attached to W.R.O. for training and participation in the research programme.

OTHER ACTIVITIES

Members of W.R.O. have continued to play an active part in strengthening the fabric of voluntary collaboration for which weed control work in Britain is renowned. Work for the British Weed Control Council (B.W.C.C.) has continued to place heavy demands on many of the senior staff. W.R.O. members have played a major role in the following:

(i) production of the *Weed Control Handbook*, of which a completely new two-volume and much enlarged edition will be published at the end of 1967;

(ii) organizing the programme and editing the Proceedings of the 8th British Weed Control Conference held in November 1966; nearly 800 delegates attended the Conference; there were 20 Sessions and the Proceedings extend to some 1100 pages; T. O. Robson deserves special mention for his part as Programme Secretary and Editor of the Proceedings;

(iii) organizing the programme and editing the Proceedings of the Symposium 'Herbicides in British Fruit Growing' held in London in February 1966;

(iv) organizing the B.W.C.C. Annual Review of Herbicide Usage in collaboration with S. A. Evans;

(v) active participation on the Council and on its Committees, including the Recommendations Committee, the Handbook Committee, the Application Committee, the Conference Organizing Committee and the Publication Committee.

Members of W.R.O. appreciate the value of these enterprises and are only too pleased to lend voluntary support to the Council. However, the amount of work undertaken by W.R.O. on behalf of B.W.C.C. has become disturbingly heavy, particularly that connected with the biennial British Weed Control Conferences, and the Council has been asked to consider ways of spreading the load.

W.R.O. is also an active supporter of the European Weed Research Council (E.W.R.C.) and its Director, who edited the international journal *Weed Research* until the end of 1965, is the Council member for the U.K. During the years under review E.W.R.C. held two very successful meetings, one in Paris in December 1965, together with the 2nd E.W.R.C. Symposium on New Herbicides, the other in Portugal in June 1966, in association with a Symposium on Weed Problems of the Mediterranean Area.

Other Committees of which W.R.O. staff were members during 1965–66 include the Scientific Advisory Committee of the Agricultural Chemicals Approval Scheme, the Tropical Pesticides Research Committee, the N.A.A.S./W.R.O. Liaison Committee, the British Standards Institution Technical Committee PCC/I, the A.R.C. Working Party on Potatoes, and the Herbicides Working Party of the A.R.C. Research Committee on Toxic Chemicals. Evidence was provided by W.R.O. for the Crops Panel of the Agricultural Advisory Council.

In collaboration with A.R.C. Headquarters a Symposium on Weed Control in Potatoes was organized by W.R.O. at Worcester College, Oxford, in January 1966.

W.R.O. members are also much in demand for providing papers and lectures for meetings of all kinds, including research symposia and conferences for scientists, farmers, growers or the general public. Courses were organized at Begbroke for the N.A.A.S. Regional Crop Husbandry Officers (December 1965) and N.A.A.S. Regional Horticultural Specialists (September 1965), and W.R.O. staff participated in a Weed Control Refresher Course organized by the Institute of Corn and Agricultural Merchants held in Oxford in January 1966.

Visitors are very welcome at Begbroke but, as in many other institutes, have become a problem through their numbers. The majority are technical people actively concerned with weed control and are often the purveyors of new information, and assist to keep the organization in touch with recent developments. Many come from overseas and no fewer than 25 Commonwealth and 29 foreign countries have been represented in the last two years. An increasing number of parties of farmers, growers, University undergraduates and biology students from schools are being received. A notable visit during the period under review was one by 40 members of the Pesticide Group of the Society of Chemical Industry in June 1965. Another was a three-day visit made by a BBC television team to make a half-hour feature film on W.R.O. which was subsequently shown in August 1965 on the B.B.C. 'Farming' programme.

On May 27th, 1966, W.R.O. held its first major Open Day into which a very considerable effort was put by the entire staff, the object being to explain to visitors the role of the Institute 'as a service to agriculture'. The large Dutch barn was converted into an exhibition hall and each Section prepared exhibits demonstrating its activities. A field conveniently near to the buildings was used as a demonstration area and provided a comprehensive range of demonstrations specially laid down by the field teams to show some of the experimental methods used by W.R.O. and results of special interest to weed control specialists, farmers and growers. Tours of the farm were arranged and a weed control question-and-answer forum was held. More than 1200 visitors came on May 27th. It was particularly pleasing to be able to welcome to a lunch, provided by some W.R.O. wives, a number of old friends of W.R.O., including Sir Harold Sanders and Mr. Frank Rayns to whom special thanks are due for their support during the early days at Begbroke Hill.

The Open Day was preceded by a gathering of some 300 specialists in weed control from the agricultural industry, the Ministry of Agriculture, other research institutes and Universities. Attendance was by invitation only and the idea was to provide a better opportunity than would be possible on the Open Day itself for those particularly interested in W.R.O.'s activities to see the exhibits and have discussions with members of the staff. In addition to this a Press Day was held a few days earlier at which some 20 correspondents from the local and national press were entertained at Begbroke.

NEW FACILITIES

With the completion of the new cattle yard at Parker's Farm, the large Dutch barn became vacant apart from the section occupied by the grain drier. It has now been converted into an admirable building for housing equipment for field work and as a storage and processing area for produce from field experiments.

A new building to provide controlled-environment facilities and a horticultural work-room was constructed adjacent to the glasshouse block. The architects, Messrs. Brian and Norman Westwood, Weybridge, Surrey, managed once again to design a modern structure to harmonize with the old buildings.

Further improvements to the road system and herd standings have been carried out.

ADMINISTRATION

This review would be incomplete without a tribute to the Secretary, B. A. Wright and the supporting staff of W.R.O. who do so much to 'oil

Equipment for spraying fence lines based on two "Vibrajet" drift-free nozzles.

View of some of the indoor exhibits demonstrating work of W.R.O. Sections.

Perennial grass weed exhibit.

Basic equipment used by field teams.

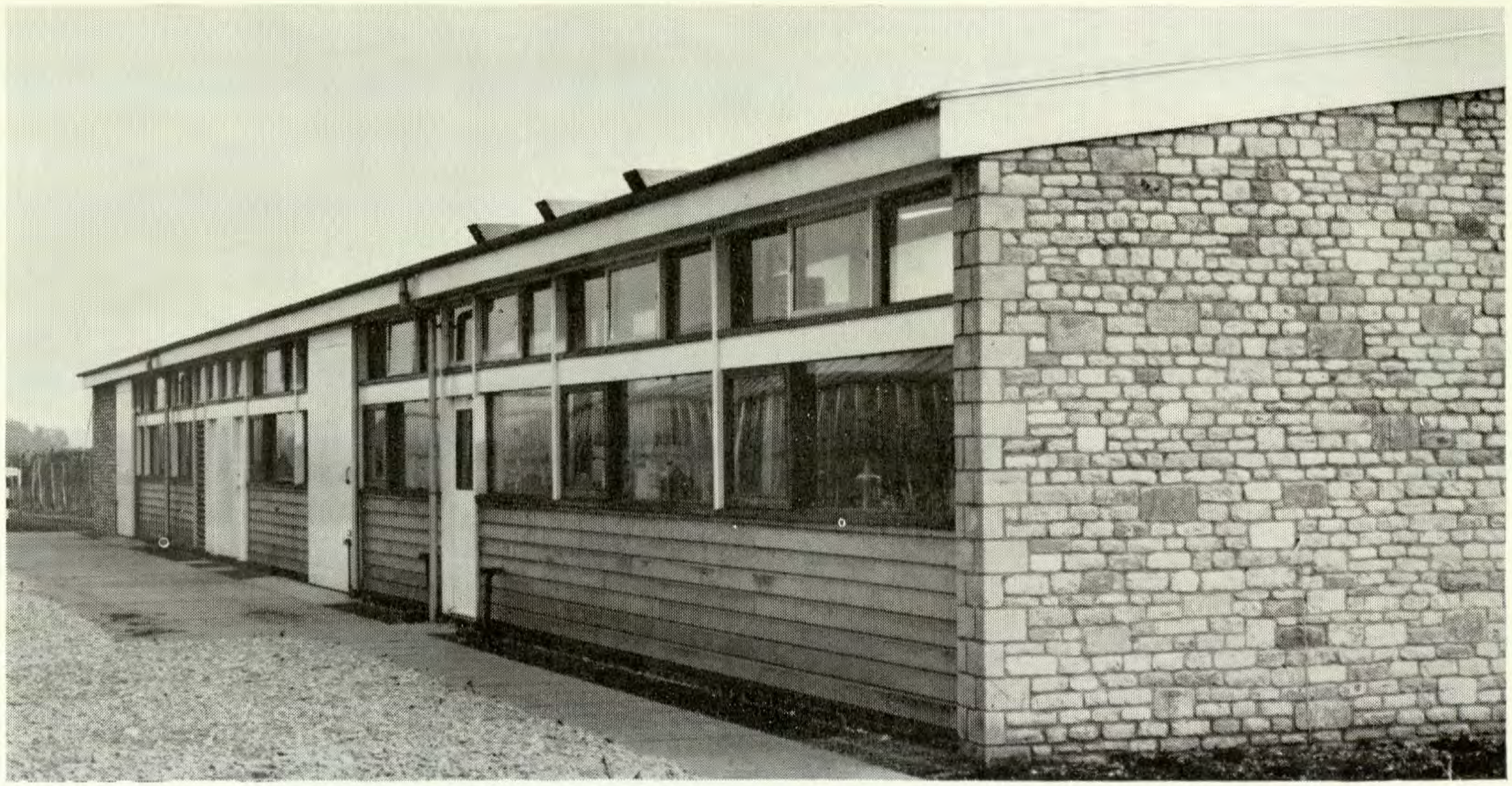
The Director (centre) and Dr. E. C. S. Little with a visitor from West Africa.

Part of the field demonstration of the Horticultural Section.

Open Days—May 1966

General view of the old buildings from the South.

The controlled environment laboratory and horticultural workroom constructed during 1965.



the wheels', and ensure that the technical work of the Organization is supplied with the facilities that are necessary. Members know that their interests and personal affairs are in good hands. Recruitment of staff at all levels has been a major problem during the two years under review and since the publication of the First Report at the end of 1964 there has been a total of 72 new members of staff in all grades, and 53 resignations. This has involved everyone in a great deal of adjustment, time and training. Situated near to Oxford, competition by the University and the motor industry is particularly severe.

The changes have included the following:

NEW APPOINTMENTS

		Section	
A. M. Blair	AEO	Evaluation	1.9.65
I. E. Henson	AEO	Evaluation	22.9.65
G. W. Cussans	SSO	Agronomy	1.10.65
C. E. McKone	EO	Chemistry	6.12.65
F. Barnes	Farm Mgr.	Farm	1.3.66
D. J. Turner	Temp. Res. Offr.	Agronomy	15.3.66
Miss E. Grossbard	PSO	Microbiology	1.4.66
C. Parker	SSO	Evaluation	1.5.66
D. O'D. Bourke	PSO	Information	7.7.66
B. J. Wilson	EO	Agronomy	1.8.66
Mrs. A. K. Wilson	AEO	Evaluation	15.8.66
D. L. Jones	AEO	Microbiology	2.8.66
P. J. Kemp	EO	Information	1.10.66

RESIGNATIONS

			Left
Miss J. Archer	AEO	Evaluation	31.3.65
P. T. Bridgman	AEO	Evaluation	30.8.65
J. D. Parker	EO	Agronomy	7.1.66
H. J. Cunnington	Farm Mgr.	Farm	28.2.66
Miss J. M. Hartridge	AEO	Agronomy	28.2.66
P. T. Atkey	AEO	Evaluation	7.4.66
T. I. Cox	EO	Agronomy	8.6.66
P. J. Boyle	PSO	Information	31.7.66

Finally it is a great pleasure to acknowledge the continuing support and interest of our colleagues in the A.R.C. Head Office. Their ready willingness on all occasions to assist in the problems of W.R.O. has been very much appreciated.

Department of Weed Science

Evaluation Section

Head: K. HOLLY

CHARACTERIZATION OF HERBICIDES

The objectives of the Evaluation Section are (1) to examine new herbicides which seem likely to become available commercially, for their potentialities for helping in the control of weed problems both in Britain and in sub-tropical and tropical parts of the world (the latter under an arrangement with the Ministry of Overseas Development); (2) to obtain an understanding of the factors influencing the performance of herbicides, both new and established, so that guidance may be given on their more effective and reliable use; (3) to investigate whether certain undesirable effects could arise following the introduction of new herbicides. These objectives are pursued through a variety of experimental techniques in the laboratory, greenhouse and field.

Many changes in this diverse programme have been initiated in the past two years in order to meet changing circumstances. The flow of new herbicides from the agricultural chemical industry throughout the world has continued unabated. During this period 54 new herbicides have been taken into various parts of the experimental programme of the Section. Fuller investigation by the commercial sponsors of these herbicides has become commonplace. Hence some of the changes have been directed towards avoiding needless duplication of effort. However, great scope remains for discovery of ancillary uses of new herbicides, for defining the appropriate conditions for their use, and for scientific studies to understand their vagaries in behaviour. On the field side the trend has been to concentrate on particular weed problems and crop situations. Unfortunately these changes have been hampered by difficulties in staffing the Section and there has been an almost complete turnover of all but the senior officers during the two years covered by this Report, with considerable time lags before successful recruitment of replacements.

Assessment of activity

During 1965 and 1966 an Initial Activity Test has been evolved, to which all new herbicides reaching the Organization are subjected. This has been designed to provide some initial experience of the types of effect produced by each new chemical and to act as a guide to subsequent experimentation. Nearly 50 herbicides have now received this greenhouse test. Four methods of application are used: a post-emergence foliar spray under conditions which preclude contact with the soil; a post-emergence drench to the soil avoiding contact with the shoots of the emerged plants; a pre-emergence spray to the soil surface; and a pre-planting spray incorporated through the full depth of soil in the pots. These four application methods are contrasted on three grassy and three broad-leaved species. Of these, two are small-seeded (kale and ryegrass), two are large-seeded (dwarf bean and *Avena fatua* (wild oat) and two are perennials (*Polygonum amphibium* (amphibious bistort) and *Agropyron repens* (couch-grass). The results are useful in indicating whether selectivity should be examined both pre-emergence and post-emergence and provide helpful leads on the groups of plants which respond. Activity against perennial weeds is indicated. By showing whether a compound acts primarily through the root or the shoot it is possible to decide whether the influence of soil or climatic factors deserve investigation. Guidance is also obtained as to whether a soil-acting herbicide should be incorporated into the soil to give maximum performance.

Assessment of selectivity

The selectivity of new herbicides is investigated in detail on a very wide range of pot-grown plants of agricultural, horticultural and tropical crops, and term-perate and tropical annual and perennial weeds. During 1965–66 30 herbicides, including several established materials used as standards, have been included in post-emergence selectivity experiments while 23 herbicides have been included in the corresponding pre-emergence selectivity experiment. The handling of results from these experiments has been much simplified by the adoption of direct recording of the data on punch cards as the plants are assessed, followed by computer-processing of the results. Through the co-operation of the Department of Statistics at Rothamsted Experimental Station, the ORION computer is now used to convert the data for plant kill and effect on plant vigour into percentages, relative to untreated control plants, which are printed out directly in both digital and histogram form on to stencils. These are then duplicated for inclusion in experiment reports. These reports were originally intended for use within W.R.O. for the planning of further work. However they are now exchanged with other selected official research organizations in the United Kingdom and overseas who are also concerned with the evaluation of new herbicides and the development of weed-control methods. During the past two years the number of such organizations participating in this exchange has risen from 14 to 24, distributed all over the world. Appropriate parts of the reports are also sent to the manufacturers of each herbicide tested.

Toxicity to perennials

Initial Experiments. Because the selectivity experiments are of relatively short duration they are not completely suitable for examining the susceptibility of perennial species to herbicides, for the time required to exhibit phytotoxic effects and to recover from sub-lethal damage may be longer. This difficulty has been met both by keeping some of the perennial material for much longer periods for additional observations and by the initiation of a series of pot experiments specifically to examine the response of perennial species.

In a separate pre-emergence and post-emergence test which is being developed the susceptibility of perennial herbaceous weeds to those herbicides which have shown promise on perennials in earlier stages of the greenhouse evaluation is examined. About 30 species are being used of which approximately one-third are of tropical or sub-tropical origin. In a recent experiment with compounds which primarily act on perennial weeds by inhibition of sprouting of buds on the underground portions of the plant, the permanency of the effect was investigated. Planting material whose sprouting had been inhibited by chlorthiamid showed few signs of sprouting after transfer to clean untreated soil. With other compounds such as EPTC and α-chloro-6-t-butyl-*o*-acetotoluidide recovery on replanting was generally rapid, suggesting that the inhibitory effects last for only as long as these herbicides persist in the soil.

Agropyron repens (couch-grass). Of all the perennial weeds in British agriculture today *Agropyron repens* is the most troublesome in arable land. In consequence, this species has been given the greatest attention in both the greenhouse and the field portions of the programme.

In an arable rotation, after a cereal crop has been harvested, there is generally a period of 5–6 months when the land is free of crops. This is the ideal time to use some types of herbicides for the control of *A. repens* for there is an adequate period for any herbicide residues to disappear from the soil before crops are planted in the spring and there is the opportunity for any associated cultivations which may be needed. Thus there is a possibility of using herbicides which would not normally be acceptable due to their inadequate selectivity.

Experimental work in the field has therefore tended to be concentrated on this autumn period. Natural infestations and specially planted areas of the weed have been used to test both foliar and soil-acting herbicides. Special attention has been paid to mixtures of foliar herbicides and a useful technique has been developed in which a series of treatments are applied in strips at right angles to one another in a plaid design, to give all possible combinations. However, no treatments have shown themselves to be superior to the standard applications of dalapon and activated aminotriazole.

Volatile herbicides which can be either mixed with the soil or applied below the soil surface seem a particularly promising line of research and to this end a joint project with the National Institute of Agricultural Engineering (N.I.A.E.) at Silsoe is in hand, to develop equipment for the precision application of this type of herbicide below the soil surface.

In pots a range of new soil-acting herbicides has been examined and several were found to be almost as effective on *A. repens* as EPTC, dichlobenil and chlorthiamid, but none were markedly superior. With some of the photosynthetic inhibitors such as the various triazine and urea herbicides, even those such as monolinuron which are markedly water-soluble, it was found that no appreciable toxicity could be found when applied to the foliage under conditions which prevented spray from reaching the soil. Uptake from the soil seemed to be of paramount importance. If a soil-acting herbicide is to be incorporated within the soil for *A. repens* control, then it is necessary to know where to position it in the soil to secure maximum effectiveness. Pot experiments have investigated whether the best results can be obtained with the herbicide above or below the rhizome. Results suggest that entry both through the roots and through the emerging shoot may be important.

Rumex obtusifolius (broad-leaved dock). Detailed field experiments have been concerned with two major broad-leaved perennial weeds. On *Rumex obtusifolius* the work begun in 1963 has been continued and numerous herbicides and herbicide mixtures have been tested for their effectiveness. Picloram and dicamba continue to be two of the more effective herbicides used either alone or in mixture with 2,4-D. Unfortunately both are highly lethal to clover and picloram has a long residual life in the soil. Asulam and another related benzene sulphonyl carbamate are almost as effective and have the added advantage of being much less damaging to clover. Maleic hydrazide has proved very effective at a dose of

4 lb/ac and although it checks the grasses severely, they recover subsequently and clover, if present, is unaffected and benefits very much from the reduction in competition. All these herbicides are more effective if applied in the early autumn.

Cirsium arvense (creeping thistle). The other species, *Cirsium arvense*, is mainly a weed of grassland and one of the major stumbling blocks in its control by spraying is the preservation of clover in the sward. In a limited experimental programme several herbicides have given good control of creeping thistle. These include picloram, dicamba and mixtures of these herbicides with 2,4-D but all the treatments eliminated clover from the sward. Picloram was particularly effective on this weed and a dose of 12 oz/ac gave almost complete control for over 12 months, but it is a very persistent herbicide and particularly toxic to clover.

Woody plants. A small amount of work has been started to evaluate the activity of new herbicides on woody plants. Potted plants of *Populus gelrica* have been utilised in this test. Two methods of application have been used, one to simulate spray application to the upper portion of the shoot and the other to simulate band application to the base of the stem. These techniques have proved adequate for demonstrating the local and translocated effects of standard materials such as 2,4,5-T and picloram. So far none of the newer compounds have compared favourably with these standards.

SCIENTIFIC STUDIES ON HERBICIDES

A considerable proportion of the laboratory and greenhouse work of the Evaluation Section during 1965–66 has been directed at studying various aspects of herbicide performance. Subjects receiving attention included the persistence of herbicides in plants and soil, mobility in soil, the relationship between soil type and phytotoxic activity, and the effect of herbicide treatment during the early stages of seed germination. Possible techniques to examine the mobility of foliage-applied herbicides within the plant and their resistance to removal from leaves by rainfall have also been tested.

Residues in soil

Much interest is attached to the possibility of significant amounts of herbicide remaining in the soil for long periods of time. Continued use has been made of the standard technique developed earlier to examine the persistence of new herbicides in soil, in which moist samples are aged on the greenhouse bench and receive a simple bio-assay at intervals to indicate the presence or absence of residual phytotoxicity. One disadvantage of the method is the abnormally long periods of persistence which are observed as compared with what has happened with the same herbicides in field situations. This is discussed in a recent paper from W.R.O. (Hocombe, Holly & Parker, 1966) which summarizes the results of five years' work with the technique, involving 62 herbicides.

Two recent experiments have examined a possible alternative method in which the soil samples are aged under more uniform conditions of soil moisture and temperature and with microbiological nutrients added in the hope of accelerating breakdown. Evidence so far suggests that the persistence period can be reduced by this method but there may be problems through the addition of the microbiological nutrients itself inducing phytotoxicity which interferes with the bio-assay of the herbicide residue.

Mobility in soil

The extent to which herbicides move in soil is of great practical importance because of the possibilities of movement out of the surface layers of soil where germinating weeds may pick up the herbicide readily and movement into areas where deeper rooted crops may take up larger amounts or where breakdown may not be so rapid. Artificial soil columns have been used to study the movement of several triazine herbicides following the application of simulated rainfall to the top of the column. Mobility appeared to decrease in the order prometon, atrazine, simazine, propazine, prometryne, indicating an inverse correlation with published data on the adsorption of these herbicides.

Toxicity to germinating seeds

Little is known about the absolute amounts of herbicide required in the vicinity of the germinating seed in order to kill the individual plant. A small amount of experimental work has been done with atrazine to determine the amount required to kill a seedling turnip at what is probably the most susceptible stage of development. It appears that plants which emerge from seeds which have taken up more than a microgram of atrazine have a poor chance of survival.

SPECIFIC WEED AND CROP PROBLEMS

Annual grass weeds in cereals

The control of annual grass weeds in cereal crops is one of a number of problems on which the resources of the Section for field experimentation have been concentrated. Annual broad-leaved weeds in cereals are now, for the most part, controlled successfully but annual grass weeds are an increasing problem in Great Britain, aggravated by the intensification of cereal growing. Most troublesome are *Alopecurus myosuroides* (blackgrass) in winter cereals and *Avena fatua* and *A. ludoviciana* (wild oats) in winter and spring cereals. There are two herbicides, barban and tri-allate, already commercially available for their control, which can be used successfully, but both have their limitations, and there appears to be no diminution in the importance of these weeds.

During the 1965–66 season a programme of experiments was organized to examine the potentialities of 15 herbicides for controlling *Alopecurus myosuroides* in winter wheat. Factors investigated were dose levels, time of application and combinations of herbicides. Out of a total of 30 different treatments a new triazine herbicide GS 14260, applied pre-emergence soon after sowing, was the most promising. Doses of 2 to 3 lb/ac gave good control of the weed with a wide margin of safety in respect of the crop. This chemical, which is now available commercially, has the added advantage of controlling a number of autumn-germinating broad-leaved weeds.

If weeds are to be controlled intelligently and economically it is important to know how weeds and crop interact with each other. Such information is lacking in the case of *A. myosuroides*. The effect of crop competition and nitrogen level on the growth of this weed was therefore investigated in one experiment. The results indicate that increasing the sowing rate of winter wheat from 1 to 2 cwt/ac or reducing the row spacing of the crop reduces both the number of surviving weeds and the number of inflorescences which they produce. Increasing the level of nitrogen increased slightly the number of plants but not the number of inflorescences. None of the treatments appeared to influence the size of the inflorescences.

Susceptibility of cereal varieties

In the past important differences have been found between varieties of the same crop in their liability to damage from herbicides. For many years the National Institute of Agricultural Botany (N.I.A.B.) has undertaken the routine testing of the susceptibility of new cereal varieties to the various groups of herbicides currently available for use on cereals, but this has now been discontinued. Therefore in the spring of 1966 an experiment was conducted in collaboration with the Welsh Plant Breeding Institute in which 52 different cereal strains and varieties were treated at two stages of growth with double the recommended dose of 10 different herbicides. The objective was to develop a suitable technique which could be used both by manufacturers of herbicides for testing new products on a range of cereal varieties and by plant breeders for testing new varieties for their response to a range of herbicides.

Selective control of grass weeds in grassland

Grass weeds such as *Agrostis* and *Poa* species, *Holcus lanatus* (Yorkshire fog) and *Festuca rubra* (creeping or red fescue) are a problem in much of the permanent pasture of England and Wales. Management and fertilizer treatment can often reduce the weed grasses and improve productivity but it is generally a slow process. Ploughing and reseeding will of course achieve a rapid and positive improvement but this is expensive and often inconvenient or impossible. Similarly, killing the sward with a herbicide before reseeding is expensive and has difficulties such as those posed by broad-leaved perennials during the establishment phase.

A herbicide which would selectively control the weed grasses might speed up the improvement of a permanent pasture provided the desirable crop grasses were there in sufficient quantity and adequately distributed to take over from the weed grasses. Therefore the studies on possible herbicides for the selective control of different grasses which were begun in 1961 have been continued. Two of the benzene sulphonyl carbamates have shown promise for the control of *Holcus lanatus* and *Poa* spp, and work is continuing with various urea herbicides for the control of *Holcus lanatus* and *Festuca rubra.* The search continues for new herbicides showing selectivity between established grasses and an attempt is being made to understand the underlying reasons for the selectivities already discovered. This involves a programme of both greenhouse and field experiments. Close liaison is maintained with the grassland team of the Agronomy Section (see p. 29).

Recently more effort has also been devoted to finding herbicides for the control of grass weeds during the establishment phase of sown pastures. This may be a technique which will be more readily accepted in grassland farming at the present time. The benzene sulphonyl carbamates, amongst a number of other herbicides, again look promising for the selective control of seedlings of *Holcus lanatus*, *Agrostis* spp. and *Poa* spp., in newly sown swards. Much lower doses of herbicide are required at this stage than when the plants are more mature.

Potatoes

Investigation of the resistance of this crop plant to herbicides has continued. Experiments involving both pre-emergence and post-emergence treatments are carried out initially in pots, but this provides only a preliminary guide as to what the situation may be in the field. A number of closely related urea herbicides has come forward for use in this crop and these have been compared, along with some other candidate herbicides, in field experiments in respect of potential risk of crop damage. It has been demonstrated that the position reached in the soil by the herbicide may be of importance in this connection. It has also been shown that there may be an interaction between the earlier application of certain urea and triazine herbicides and the speed of action of bipyridyl desiccating agents.

Fen soils

Weed problems in the Fens pose particular difficulties in respect of their control. Because of the high organic matter content in fen soils, most soil-acting herbicides are adsorbed and inactivated to a large extent. In 1965 and 1966 experiments were conducted at the Arthur Rickwood Experimental Husbandry Farm with a number of soil-acting herbicides, old and new, on two differing fen soils to assess their weed control performance in these circumstances. The herbicides had been selected as being those least likely to be inactivated. Among the more promising were some of the older compounds such as fenuron, propham and chlorpropham and some of the new such as medinoterb. It had been hoped to intensify work on weed problems in the fens by appointing an officer to work on them full-time. Financial arrangements had been approved but, unfortunately, no suitable recruit has yet been found.

APPLICATION OF HERBICIDES

There is a pressing need for research on the effect of methods of application of herbicides on their biological performance. In recent years there has been an increasing need to use more precision in application. The older type of growth regulator herbicide such as MCPA had a much greater margin of selectivity than many of the newer herbicides. Some herbicides may persist unduly long in the soil if overdoses are applied. Farmers are becoming more critical and sensitive to any suggestion of crop damage. There are many possibilities through changes in formulation and method of application, to influence accuracy of application, biological effectiveness and selectivity.

A joint project has recently been established with the N.I.A.E. to investigate the many factors concerned with application which influence the biological activity of both soil-applied and foliage-applied herbicides. A 'Vibrajet' has been modified for use on the laboratory pot sprayer, in addition to the conventional fan nozzle, so that new herbicides may be compared when using sprays of widely different characteristics. This equipment will allow preliminary studies to be made on factors such as drop size and distribution and consequent spray retention by plants. There will also be investigations in the field and a preliminary experiment has compared the biological performance of some contrasting forms of spray application, the drift therefrom, and the biological consequences of this drift.

The potentialities of many soil-acting herbicides for the control of perennial weeds are not being exploited to the full by using conventional methods of application. Considerable advances might be made by appropriate direct positioning of the herbicide in the soil, adjacent to roots or rhizomes. As has been mentioned, another joint project has been started with the N.I.A.E., which involves the construction and development of experimental equipment to apply herbicides in bands or as continuous layers at various positions below the soil surface. Such an underground applicator may be able to utilize quite different formulations of herbicides from those in use through conventional spraying machines. This project is in a very early stage and much work will be needed in the workshop, the field, the laboratory and the greenhouse before results applicable to farming practice emerge.

FLAME CULTIVATION

A number of W.R.O. sections have collaborated in a preliminary investigation of the potentialities of flame cultivation, using propane as fuel, and in comparison with contact herbicides. Flame cultivation at slow tractor speeds gave effective control of seedlings of a number of annual weeds. The efficiency of control decreased markedly with increasing tractor speeds. This form of weed control cannot be expected to give a lasting effect on perennial weeds such as *Agropyron repens*.

NON-RESEARCH ACTIVITIES

The Section has been heavily involved in assisting in the activities of the British Weed Control Council. Members of the Section staff are on the Handbook, Recommendations, Herbicide Application and Conference Programme Committees of the Council. Preparatory work for the next two-volume edition of the Weed Control Handbook has taken up a lot of time.

The Section is very closely concerned with developments in the agricultural chemical industry and has a constant need to be well informed on the potentialities of new herbicides being developed by industry and the progress that is being made with them by the firms concerned. Therefore much attention and time is given to liaison with commercial firms and the exchange of information with their research staffs. In consequence the Section also deals with a large number of requests for help and information on herbicides to assist in the planning of research programmes and kindred problems from both within and outside W.R.O.

Chemistry Section

Head: R. J. Hance

In addition to its research function, the Chemistry Section provides an analytical service for the other sections of the Organization. This service activity has greatly increased during the period of this report, the number of service analyses having risen from about 200 in 1965 to over 700 in 1966. This increase is largely due to the appointment of an Experimental Officer and an additional Scientific Assistant to the staff and to the acquisition of gas chromatographic equipment.

Such analytical work was, for the most part, concerned with determinations of herbicide residues, most frequently in soil, but also in crops and water. In addition, a number of estimations were made of carbohydrate fractions in plant tissues. The herbicides most commonly encountered were simazine, atrazine, 2,4-D, linuron and tri-allate, but occasional samples containing other herbicides were handled. During the course of this work a method was devised for the determination of tri-allate in soil, straw and grain, and work is currently in progress on the development of a new method for the determination of the substituted ureas.

The research programme of the Section continued to be concerned with studies of the interactions between herbicides and the soil. In particular, interest was maintained in problems associated with the sorption of herbicides by soil colloids.

Measurements were made of the time taken for adsorption and desorption processes to attain equilibrium. Monuron, linuron, atrazine and chlorpropham were studied using soils and other adsorbents under aqueous slurry conditions. With adsorption processes, it was assumed that equilibrium was attained when no further change in the distribution of herbicide between soil and solution occurred with time. On this basis, equilibrium was reached in 4 hours in many cases and in only one of the 18 herbicide-adsorbent systems studied was it not attained in 24 hours. With desorption processes, equilibrium was considered to be established when the distribution of herbicide between soil and solution was the same as that calculated from a Frendlich adsorption plot previously established for the system under consideration. Using this criterion, desorption appeared to be a slower process than adsorption as in most cases 24 hours or longer were required to attain equilibrium and in 7 systems more than 72 hours were required. In fact, with 2 systems it seemed likely that the sorption process was not completely reversible. It has not so far been possible to explain fully these results. It appears possible, however, that in some cases more than one type of adsorption site was involved. If the differences in energies of adsorption associated with different sites are sufficiently large, it should be possible to detect them by means of measurements of heats of adsorption. Efforts were made to make such measurements directly by microcalorimetric methods but they were unsuccessful. Attention has now been turned to indirect methods.

In view of the influence of adsorption on many aspects of the behaviour of herbicides in the soil, it is necessary to know, at least approximately, the extent of adsorption of a soil-applied herbicide if estimates are to be made of its field performance. However, the direct measurement of adsorption is tedious. There have been suggestions in the literature that the coefficient of partition of a herbicide between water and a non-polar solvent might give a useful indication of the extent of its adsorption by soil. Unfortunately this is a parameter which can also be tedious to determine and may be inaccurate in cases where the solute distributes greatly in favour of one solvent. However, estimates of this distribution may be obtained by partition chromatography. A reverse phase thin-layer system in which the stationary phase was liquid paraffin and the mobile phase was aqueous ethanol proved to be satisfactory for this purpose. Correlations were found between chromatographic movement in this system and adsorption by a number of soils for a group of 31 herbicides which included ureas, triazines, carbamates and uracils. It is suggested, therefore, that such a simple chromatographic test may be useful for the prediction and classification of herbicide behaviour.

It is generally considered that a possible source of loss of herbicides from the soil is by non-biological chemical reaction. Experiments have been carried out to assess the importance of such processes. Slurries of soils and clay made with aqueous herbicide solution were sealed in glass tubes and heated at 85°C, 95°C or 107°C. It was assumed that at these temperatures, no biological action would occur. Tubes were taken at intervals and their contents analysed to determine the amount of unchanged herbicide. Hence the velocity constants of the decomposition reactions at each temperature could be calculated on the corresponding velocity constants at 20°C estimated by extrapolation. The results obtained with atrazine, chlorpropham, diuron, linuron, paraquat and picloram indicate that as far as these chemicals are concerned, non-biological chemical degradation is unlikely to be an important source of loss from the soil as the half-lives at 20°C would be in the range 9–116 years.

A visiting research worker, Mr. R. S. Tamés who is attached to the Section has recently commenced an investigation of some aspects of herbicide-root relationships.

Botany Section

Head: R. J. CHANCELLOR

The Botany Section is currently concerned with the regenerative ability of perennial weeds, especially those with rhizomes. The plants that have been selected for study are *Agropyron repens* (couch-grass) and *Polygonum amphibium* (amphibious bistort). They contrast in life-history and importance for the former, one of the most important weeds of arable land, has over-wintering shoots, while *P. amphibium*, which is widespread although much less important, shoots which can be killed by frost.

Investigations were initially concentrated on the occurrence of dormancy in the lateral buds of rhizomes. With both species there is only one bud formed at each node and the main dormancy of these buds is due to 'apical dominance'. It is estimated in North America that 95 per cent of all *Agropyron* buds remain dormant indefinitely in undisturbed stands. In addition work in North America has shown that lateral buds of *Agropyron repens* and *Polygonum coccineum* acquire dormancy during the summer which is evinced even when apical dominance is broken by fragmentation. No definite dormancy of this type has been demonstrated in *Agropyron repens* and *Polygonum amphibium* in England during two years of testing nor in southern Germany during the latter half of 1966 (research by the Section Head while the recipient of a scholarship from the Alexander von Humboldt-Stiftung) and absence of this type of dormancy is obviously of great importance in various methods of control.

Other tests on the regeneration of rhizome fragments under greenhouse conditions have investigated the depth from which small fragments can reach the soil surface, the smallest fragments capable of re-establishing a new plant and the relative rates of regrowth under various conditions. Deep burial of *Agropyron repens* by ploughing is a traditional way of reducing regrowth. Studies of the ability of small fragments to emerge from depth have shown that complete control by this method alone is hardly feasible; it was found that when 2-node rhizome fragments of *A. repens* were buried at 86 cm depth in long tubes of soil they produced shoots averaging 21 cm in length with a maximum of 40 cm, while *Polygonum amphibium* fragments similarly planted averaged 30 cm with the longest reaching 70 cm (27 in.).

Under favourable conditions and planted at 0·5–11 cm depth *Agropyron repens* has been found to be capable of producing new plants from 0·12 cm lengths of rhizome, with an attached bud, and *Polygonum amphibium* from 0·25 cm pieces.

Limited work is continuing on annual weeds and this is concerned principally with the periods of germination of common species in conjunction with the effects of different frequencies of cultivation upon their emergence. This subject is of considerable importance in view of developing minimum-cultivation techniques, which could in turn have great influence upon the development of weed populations and hence on the weed flora. Studies of seedling emergence of common wild plants that are not weeds have shown that they are not necessarily prevented from being weeds by the effects of cultivations upon germination as had been expected; but the germination of very few is undoubtedly discouraged by them.

The Botany Section also maintains a weed seed bank, a weed garden and a weed seedling identification service, on which subject a comprehensive book for the British Isles was prepared and published in 1966 (Chancellor, 1966). In addition the Section carried out a yearly survey of weeds occurring in arable fields on the farm by counting 1 sq ft quadrats positioned on a 20-yard grid covering the whole of each field. The results are useful in field experiments on herbicides and provide interesting data on the changing weed flora.

Microbiology Section

Head: Miss E. GROSSBARD

In the spring of 1966 a small section was initiated in the Department of Weed Science to study the effect of herbicides on the micro-organisms of the soil. The Section did not become fully operational until late summer.

The need for such an investigation arises from the fact that many herbicides by virtue of their chemical properties can at appropriate concentrations either inhibit the growth of micro-organisms or kill them. This is borne out by the results of experiments in which herbicides have been applied to certain species of micro-organisms (in pure culture) under artificial laboratory conditions.

The soil microflora is responsible for many essential chemical processes in the soil such as the conversion of nitrogen into plant food, and, in conjunction with the smaller soil animals, for the transformation of complex organic plant and animal residues into nutrients which can be absorbed by plant roots. Soil micro-organisms thus perform an essential function of scavenging and purification of the soil. Furthermore, many types of soil micro-organisms are among the most important agents in the detoxification of herbicides themselves. Any use of herbicides, or for that matter of any other agricultural chemical which would substantially interfere with these beneficial activities might affect soil fertility. Thus a study of the interaction of herbicides with soil micro-organisms is essential.

The terms of reference of the new Microbiology Section are:

1. To investigate the effect on soil micro-organisms of repeated applications of herbicides in the field over a long period of time by appropriate studies made on soil samples taken from the long-term experiments undertaken at Begbroke or elsewhere.

2. To investigate, as part of the overall evaluation programme of W.R.O., any possible effects of all the more important herbicides on the soil microflora, from as many aspects as personnel and other facilities permit.

INVESTIGATION OF SOIL SAMPLES FROM FIELD EXPERIMENTS

Long-term applications

The design of this experiment is described on p. 14. The contribution of the Microbiology Section has so far consisted of the collection of soil samples, three to four times yearly, and subsequent investigations into the differences in respiration of soils that had received long-term (three–four years) treatment with the four herbicides (MCPA, tri-allate, simazine and linuron) as compared with untreated controls. Carbon dioxide production was used as a criterion for soil respiration and breakdown of organic matter. Mineralization of nitrogen was investigated by the determination of ammonia and nitrate nitrogen. The soils were not supplemented with specific substrates.

This work had already started in 1965 when the Head of Section was still on the staff of the Grassland Research Institute. The results of 1965 in respect of both carbon dioxide and nitrate production were analysed statistically. For 1966 the data available at the time of writing this report refer to carbon dioxide production only, and the statistical analysis is not yet available. Work on mineralization of nitrogen is in progress. In 1965 the non-cropped weed-free plots receiving three or four times the normal rate of herbicides applied over three years were examined. The studies in 1966 included, in addition, one sampling of the cropped plots receiving the standard application rate at the end of the season.

Results for 1965—uncropped plots

The results for 1965 showed that there was no statistically significant reduction in carbon dioxide production on the plots treated with each of the four herbicides, as compared with controls. At one sampling 17 days after spraying a highly significant stimulation was noted with linuron. Similarly, the mineralization of nitrogen was not affected adversely. In fact, at the last sampling at the end of September a small but significant stimulation in nitrate formation occurred on the MCPA and linuron treated plots.

Results for 1966—uncropped and cropped plots

The interpretation of the data for 1966 is based on the means of the replicates of the three samplings, pending availability of the statistical analysis. On the uncropped plots receiving MCPA an increase in CO_2 production was noted one month after spraying. This fits in with the findings of Kirkland and Fryer (p. 37) on the accelerated breakdown of MCPA on soils pre-treated with this herbicide. The means for the tri-allate treatment were similar to those for 1965, indicating a slight reduction in CO_2 production after spraying, which was later followed by an increase to above that obtained with the controls. In both years the stimulation occurred at the end of the season, i.e., in September.

Samples taken from the linuron-treated plots in 1966 showed a small but consistent depression in CO_2 output following the summer application, as compared with the negative results of 1965. Chemical assays are now revealing a build-up of residues of linuron on the plots receiving annually three times the normal dose.

Soil from simazine-treated plots gave similar results in both years, the CO_2 output being somewhat lower than those of the controls. However, in 1965 these differences from the controls were not significant statistically. On the cropped plots receiving one application per year at the normal rate the differences between treated and control plots were so small that it is unlikely that a statistical analysis will reveal any significant effects.

The effect of simazine at different rates of application

A randomized field experiment consisting of small plots was laid down in 1964 and simazine was applied in 1963 and again in 1964 at rates ranging from 1–16 lb/ac. Neither carbon dioxide production nor nitrification was inhibited significantly in 1965. The 1966 results are not yet available.

LABORATORY EXPERIMENTS

Evaluation of herbicides

Eight herbicides were investigated as a first step in a rather large screening programme. The chemicals were mixed with one type of soil in the first place at 500 ppm and incubated. Samples were removed at intervals and analysed. 500 ppm is a high concentration unlikely to be encountered under field conditions. Assuming a typical field application rate, appropriate for many herbicides, of 2 lb/ac and an acre-inch of soil to weigh 400,000 lb (which is a generalization based on a density approaching 2), then even distribution of the herbicide through this one-inch surface layer would give a concentration of 5 ppm. Of course, soils vary greatly in density, herbicides are not uniformly dispersed in practice and there may be local concentrations exceeding this figure, but it is most unlikely that a concentration of 500 ppm would ever be reached in the field. However, this concentration was chosen in order to eliminate harmless herbicides with a large margin of safety. It was hoped to find chemicals which even at this high concentration would not affect appreciably microbial activity and which consequently could then be classified as being innocuous and excluded from further tests.

The chemicals selected were endothal, propanil, simazine, prometryne, linuron, dinoseb, paraquat and picloram. Preliminary results, requiring further confirmation and statistical analysis, have shown that while seven of the eight herbicides did interfere with carbon dioxide production, reduction was comparatively low, ranging from 20–39 per cent. In many cases the extent of reduction decreased with time. For instance with propanil, after three weeks incubation the reduction was 39 per cent but after fourteen a stimulation, which may or may not be statistically significant, was noted. Endothal, on the other hand, showed a rise in CO_2 production of well over 100 per cent in the first three weeks after application, but the extent of stimulation then decreased with time until CO_2 output eventually reached a similar level to that of the control. This suggests that the endothal molecule was degraded rather rapidly and the breakdown products utilized as nutrients by the soil microflora. The usefulness of the preliminary screening scheme at high concentration is demonstrated in this case, since it is unlikely that endothal would exert any injurious effects when applied at field rates, and it may now be eliminated from follow-up tests at lower concentrations to which the other herbicides are now being submitted. Figures on mineralization of nitrogen will be available at a later date.

The utilization of simeton by the mould Aspergillus fumigatus

It was demonstrated in a small scale experiment, involving two isolates, that the mould *A. fumigatus*, found in many soils, uses simeton successfully as a source of both carbon and nitrogen. When cultured in a solution containing minerals but without nitrogen and a source of carbon no growth occurred, but on addition of as little as 10 ppm of simeton the fungus formed both mycelium and spores, and on addition of 100 ppm of simeton the growth almost equalled that in a complete standard medium.

A technique of autoradiography to observe the fate of simazine in individual soil particles

Radioactive simazine was applied to the surface of soils in small containers. After various pre-treatments soil particles were removed from the surface and from the profile at successive depths of 1 cm and a thin smear prepared. This was placed in contact with an X-ray film and exposed for two months in view of the low radioactivity of the simazine. The images obtained showed that the movement of simazine was very slow, only 3 cm in four days. The effect of microbial breakdown of the simazine was indicated by the lower density of the images obtained from soil incubated for one month as compared with frozen soil. The method shows promise for the study of the fate of herbicides at the level of the microhabitat.

List of Research Projects

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

The activities of this Section involve a closely integrated programme of laboratory, greenhouse 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 greenhouse:

1. Preliminary investigation of the activity and pre-emergence and post-emergence selectivity of new herbicides: Mrs. A. K. Wilson.

2. Detailed investigation of properties and potentialities of new herbicides.

(a) Soil-acting herbicides—their mobility and persistence in soil and the effect of soil type on activity: S. D. Hocombe, Mrs. A. K. Wilson, and with the collaboration of Chemistry Section.

(b) The response of perennial weeds and woody plants to herbicides: S. D. Hocombe, C. Parker.

(c) Dormancy in perennial weeds and the effect of chemicals thereon: C. Parker.

(d) The effect of environmental factors, particularly temperature and light on herbicide performance: S. D. Hocombe.

(e) Detailed elucidation of factors influencing interesting selectivities: S. D. Hocombe, Mrs. A. K. Wilson.

3. Bio-assay of herbicide residues: S. D. Hocombe, C. Parker, Mrs. A. K. Wilson.

II. Projects predominantly in the field:

1. The response of perennial weeds, notably *Agropyron repens* and *Rumex obtusifolius*, to herbicides: J. Holroyd, M. E. Thornton, A. M. Blair.

2. Herbicides for the control of *Alopecurus myosuroides* in cereals: J. Holroyd, M. E. Thornton.

3. Early field evaluation of new sugar beet herbicides: J. Holroyd.

4. The response of potato to herbicides: J. Holroyd.

5. The activity of soil-applied herbicides on different soil types: M. E. Thornton.

6. Varietal differences in response to herbicides: J. Holroyd.

7. The influence of method of application on the biological performance of foliar and soil-acting herbicides: J. Holroyd.

8. Development of experimental application equipment: M. E. Thornton.

9. 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: C. E. McKone.

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

1. The germination behaviour of weed seeds in soil.
2. The biology and regenerative capacity of perennial weeds.

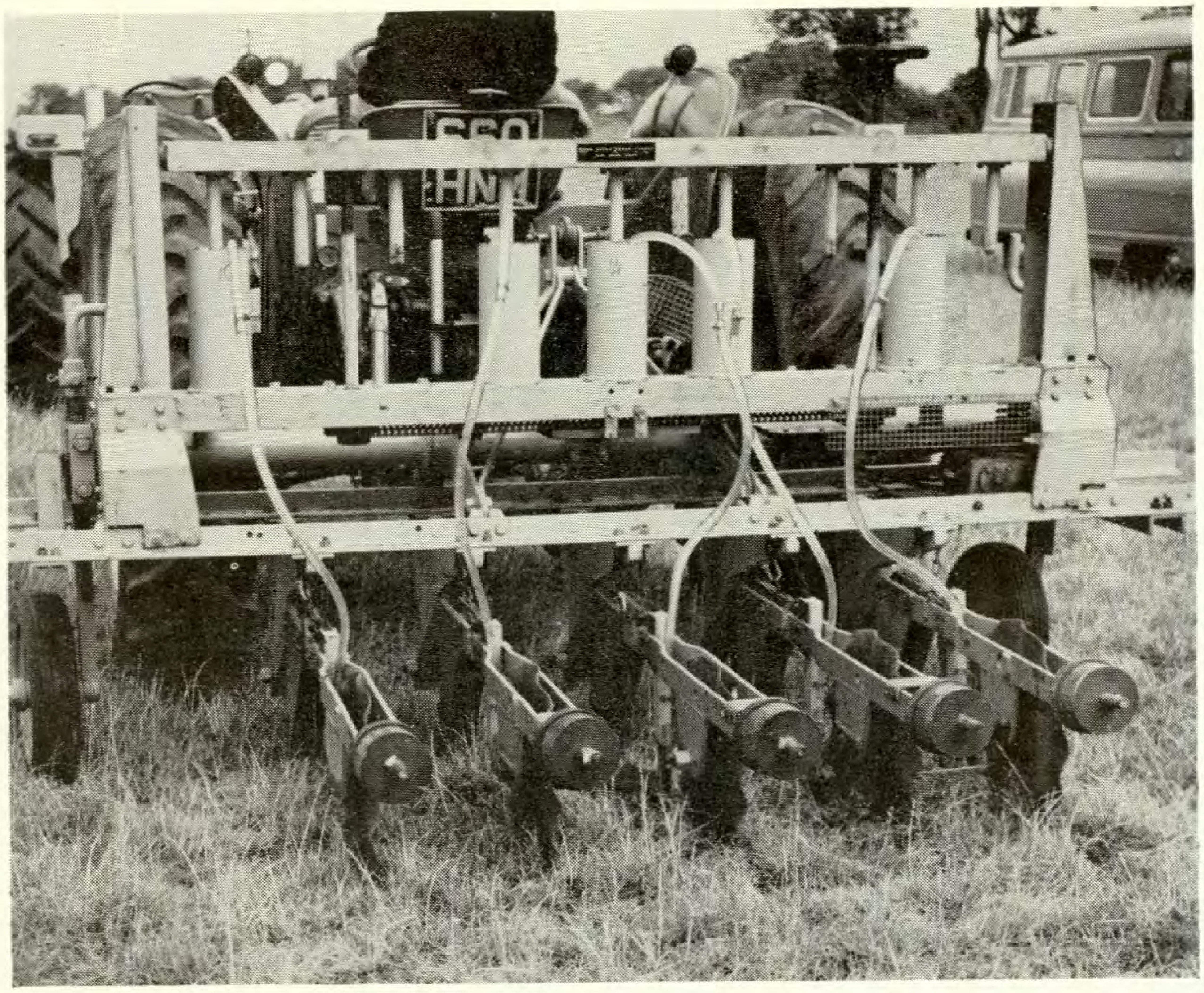
MICROBIOLOGY SECTION (*Section Head:* Miss E. GROSSBARD)

1. The effects of herbicides on the soil microflora in long-term field experiments in which there is repeated herbicide application: Miss E. Grossbard.

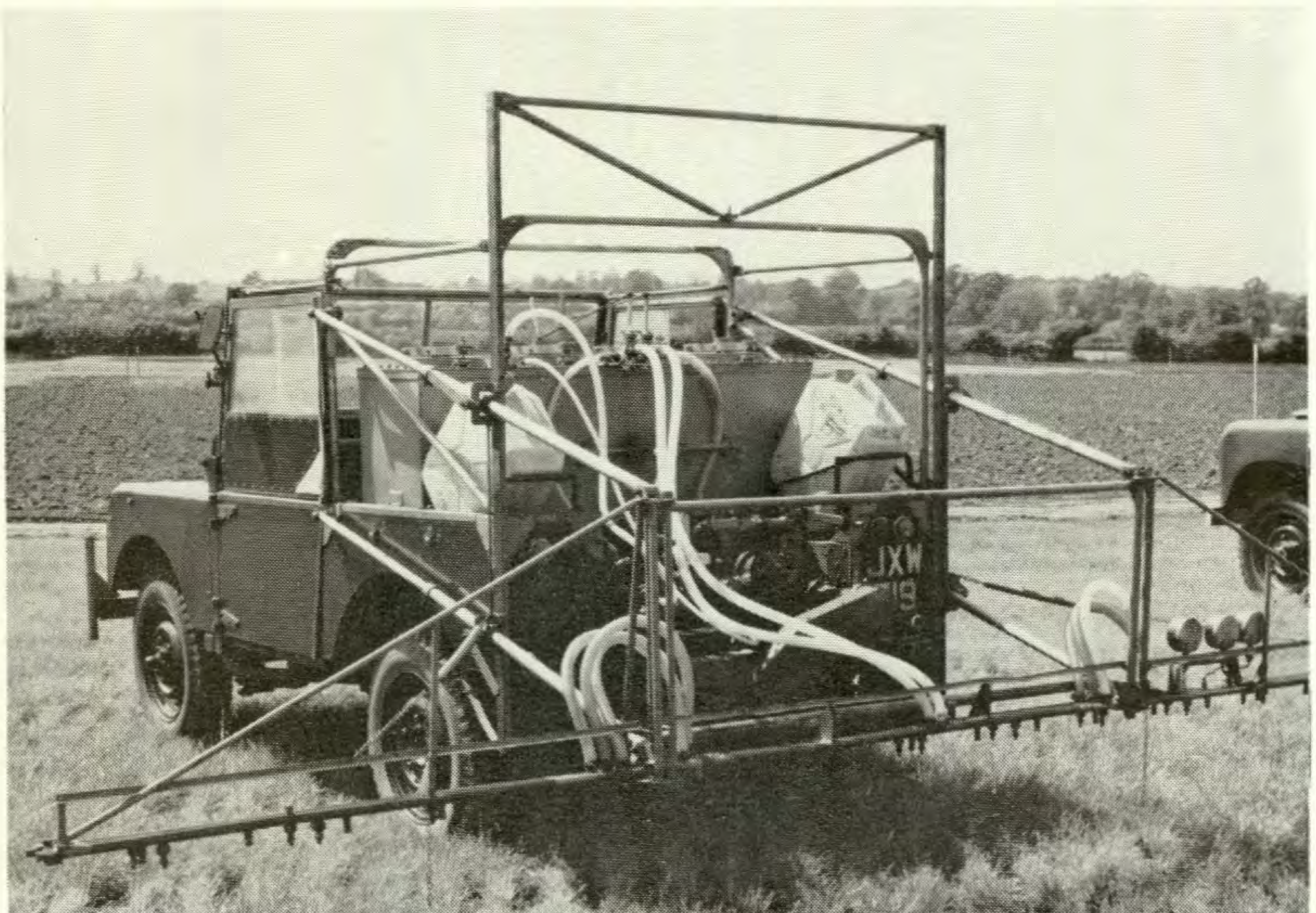
2. Evaluation of herbicides for possible effects on soil micro-organisms: Miss E. Grossbard, D. L. Jones.

OVERSEAS SECTION (*Section Head:* E. C. S. LITTLE)

This is predominantly a liaison Section, but performs a small amount of research on the following topics:

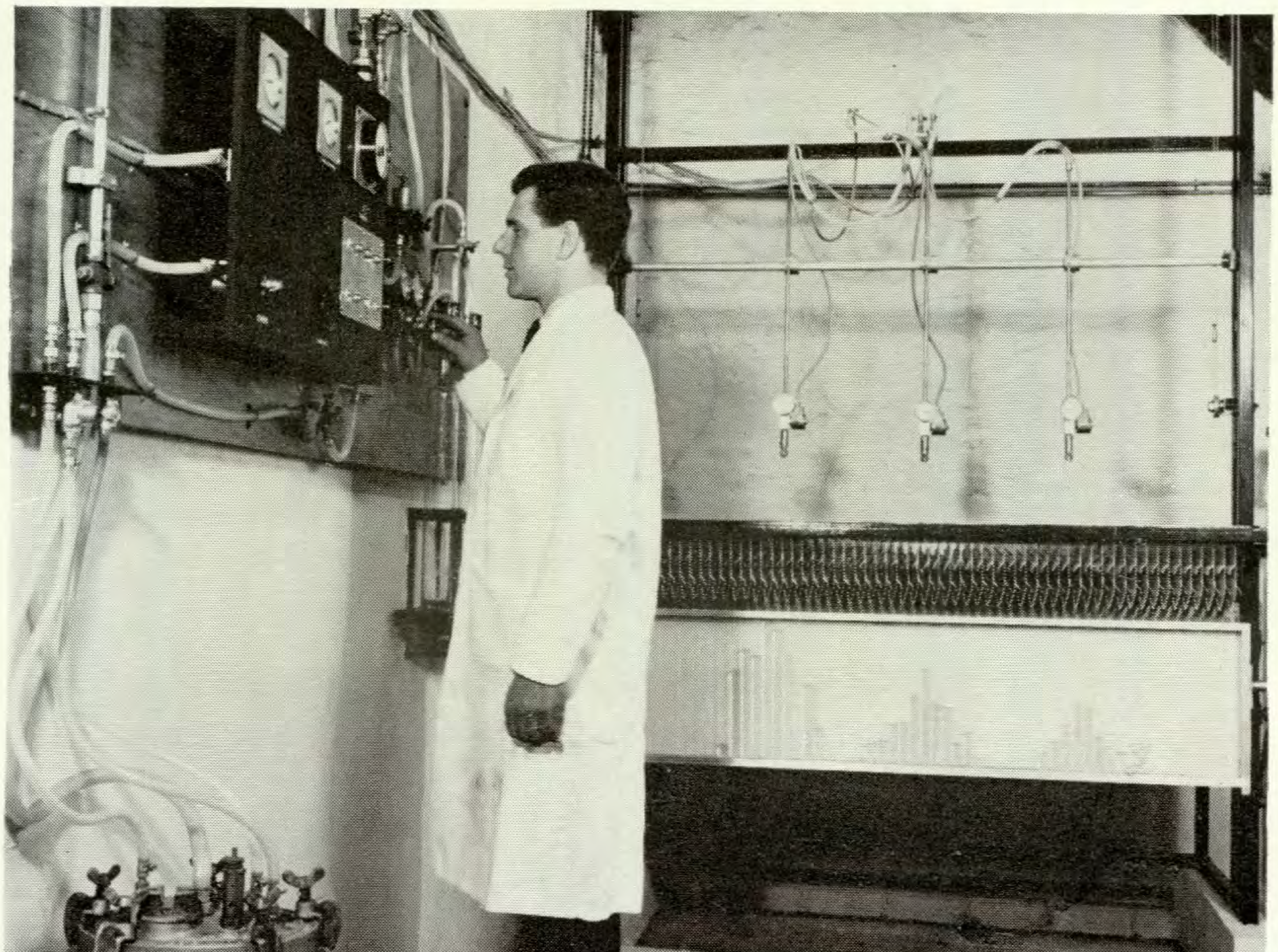


A prototype "fluid drill" for injecting seeds suspended in an aqueous fluid into cultivated or uncultivated soil.



A versatile field plot sprayer.

Work in the new microbiology laboratory.



Nozzle testing equipment designed and built by W.R.O.

1. Translocation of herbicides.
2. Water losses from surfaces covered with tropical water weeds.
3. Aerial application of herbicides.

RESEARCH STUDENTS

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

2. A. M. Hamdoun (attached to Botany Section): the biology of *Cirsium arvense* and its response to MCPA.

3. R. Tamés (attached to Chemistry Section): behaviour of herbicides in root systems.

Department of Weed Control

The Agronomy Section

Head: J. G. Elliott

The particular interest of the Agronomy Section is the conduct of research of immediate practical value to the farmer. This is research that may be aptly described by the words 'problems' and 'possibilities': the problems that farmers encounter through their inability to control particular weeds or through their use of herbicides or other methods for weed control; the possibilities in husbandry ensuing from the revolutionary development of herbicides.

Much of the Section's work is carried out on commercial farms, at other Research Stations or at the Experimental Husbandry Farms. Because of this the teams are trained and equipped on a mobile basis. In agriculture itself, the major division in crop husbandry is between arable and grassland, and this has dictated the specialization within the Agronomy Section. Although primarily a research section, the staff is inevitably drawn into educational activities which, provided they are not too time-consuming, are welcomed as opportunities for the exchange of views and experiences.

The work on the various projects is described in the paragraphs that follow.

ARABLE CROPS

Potatoes

During the past two years the emphasis has been on the control of perennial grass weeds, and on studies of the emergence of annual weeds in potato seedbeds.

Methods of controlling *Agropyron repens* and *Agrostis gigantea* both during the autumn and in the spring prior to cropping were investigated. At two sites rotary cultivation twice in the autumn gave very good control during the following year and was slightly superior to aminotriazole applied in the autumn. At two further sites, an early spring application of TCA gave a substantial reduction in shoot numbers throughout the following season; this was also the case with EPTC incorporated in the seedbed before planting, both at Begbroke Hill and in experiments in co-operation with Bridget's Experimental Husbandry Farm. Neither of these chemicals adversely affected the crop and it is proposed to continue trials with them.

The emergence of weeds in potato seedbeds was studied on the sandy loam at Begbroke Hill and on the fen soil of the Arthur Rickwood Experimental Husbandry Farm. On both soils and in both years (1965/66) the emergence of annual weeds occurred in a distinct flush shortly before the emergence of the potatoes (unchitted seed). When the soil was left undisturbed after planting, few weeds emerged after the main flush, but disturbance encouraged further emergence. The weed control achieved by paraquat was poor if application was made before or during the main flush but good when all the weeds had emerged. Linuron applied between potato planting and emergence gave good control of annual broad-leaved weeds but not of perennial grasses. The experiments confirmed the desirability of using mixtures of foliar and residual herbicides pre-emergence. Flat seedbeds showed a greater speed and density of weed emergence than ridged land; with ridges orientated east-west, emergence was more rapid on the southern than the northern face.

Chemical weed control has made it possible to study the growth of potatoes planted in unconventional arrangements. Different densities have been obtained by using a constant seed rate and varying seed size and thereby plant population; the tubers were spaced in either two or three rows in 60 in. beds. With each population beds with two rows tended to outyield those with three. As the seed size increased, so did the proportion of harvested tubers in the larger grades; however, the total yield tended to fall, and the highest yield of marketable tubers was given by the medium-sized seed.

Perennial grasses in cereal land

This is a new project started in October 1965. The initial approach has been to study the biological performance of the weeds against a background of cereal cropping so as to understand the factors aiding the weeds' success in this environment.

One aspect of the work is being aided by a grant made by the Grasshoppers Club to support a research worker in a programme of biological investigation on *Agropyron repens* (couch-grass) and *Agrostis gigantea* (common bent). Work has been carried out on the regeneration of rhizome fragments of *Agropyron repens* and on exhaustion of rhizome reserves by defoliation as they are influenced by the size of rhizome fragments, depth of planting and the nitrogen status of the soil. Preliminary results have indicated that to achieve a quick exhaustion of the rhizome reserves, *A. repens* must be defoliated whenever regrowth attains a height of about 2 in. Short fragments of rhizome are more readily exhausted than long fragments except in the presence of high levels of soil nitrogen when the longer fragments are equally sensitive to defoliation.

A field experiment is in progress to determine the rate of production of aerial shoots and rhizomes by plants established from short rhizome fragments at various seasons of the year in the absence of a crop. This information will serve as a background to the observations made in crops where the effect of competition is added to the basic life-cycle.

Competition has two effects which are inseparable in field experiments: the effect of weed on crop growth and vice-versa. The competition between barley and natural or artificially established populations of *A. repens* has been studied. Preliminary results suggest the time of planting of barley may affect its competitive ability against *A. repens*, early planting being preferable; nitrogen accentuates success in competition.

The Section has assumed responsibility for a collection of clones of *A. repens* which had previously been built up by the A.R.C. Unit of Experimental Agronomy. Some of these clones have been multiplied in the field so as to provide sources of uniform material for experiments.

Crop production by minimum cultivation

The Section has a research project concerned with the performance and control of weeds in new systems of crop production, based on minimum cultivation, but it has in addition been co-operating with the N.I.A.E. on methods of cereal establishment by direct drilling into uncultivated soil.

It may be expected that the very different degree of soil disturbance associated with direct drilling on the one hand and ploughing on the other will give rise to differences in the weeds associated with the two systems. Weed performance has been studied in some detail on five long-term experiments in progress at the Ministry of Agriculture's Experimental Husbandry Farms. The changes in weed populations will be recorded over the years as the experiments proceed, but already marked changes in weeds have been recorded after one or two years. The species that are developing on the direct-drilled plots are annual and perennial grasses, broad-leaved perennials normally associated with grassland and certain arable annuals, namely *Matricaria* spp. (mayweeds), *Stellaria media* (chickweed) and *Capsella bursa-pastoris* (shepherd's purse).

The most critical time for a crop plant drilled directly into untilled land appears to be the early phase of germination and establishment, and the efficiency of sowing is clearly important. The Section has co-operated with the N.I.A.E. in recording the performance of the available drills and measuring some of the factors governing their performance in sowing cereals.

Five machines were tested, all of which are designed to cut slits in uncultivated soil and to place seeds in the slits. Two were power-driven with a rotary cutting action and three used direct draught. On the light soil at Begbroke Hill which was rather dry at the time all showed variation in the depth of drilling but the power-driven drills came nearest to achieving the required planting depth of 1½ in. These machines also placed the highest proportion of seed in the slits and gave the highest plant establishment. Seed coverage was generally poor with all the drills under these conditions. An improvement in establishment might well be achieved if more soil cover over the seeds could be provided.

GRASSLAND

The selective control of weed grasses in pasture

The object of controlling weed grasses in pasture stems from the belief that the suppression of the undesirable species will lead to the dominance, and therefore increased production, of the better species.

In an experiment in 1963, dalapon at 5 lb a.e./ac applied in July to a permanent pasture, selectively reduced *Agrostis stolonifera* (creeping bent) and *Poa trivialis* (rough meadow-grass) and allowed perennial ryegrass to increase. White clover was unaffected. Subsequent experiments have confirmed that the differences between ryegrass and these weed grasses in their response to this chemical are repeatable and are at a maximum in the period from late June to mid-July. The lowest effective dose on the weed grasses has been 2–3 lb a.e./ac; and at this dose the effect on the ryegrass is transitory. Nitrogen at 60–120 units/ac applied within a day or two of spraying leads to a good regrowth.

While a number of experiments have demonstrated increased yields of ryegrass during the year following treatment an increase in total sward growth has not as yet been recorded. Present experiments are seeking to clarify the effect of treatments and subsequent management on herbage yield as related to botanical composition.

In this context the herbicide is suppressing the undesirable species and thereby creating vacant spaces in the sward. The treatment will be agriculturally desirable only if desirable species fill the spaces. Observation suggests that the performance of ryegrass in this respect is limited by its tufted habit and poor capacity for lateral spread. Ryegrass needs a uniform distribution with a spacing between plants of not more than 6–9 in. if a complete canopy is to be formed quickly. White clover is a much better colonizer. Broad-leaved weeds are not controlled by dalapon but where they are likely competitors for space the majority can be controlled with the growth-regulator herbicides. Results indicate also that soil-acting chemicals may have a place in this technique, for controlling the emergence of seedling weeds.

The botanical composition and output of grassland is particularly affected by drainage, lime status, fertility and management. This implies that although herbicides may be used to alter the balance of a species in a sward, the changes induced will not be permanent unless the underlying environmental factors are modified to support them. It is within these limitations that the experiments are being carried out. The use of dalapon in this technique is a fore-runner of other herbicides with selective action on grasses.

The control of creeping thistle in pasture

During 1965 and 1966 a study was made of the timing and pattern of growth of *Cirsium arvense* in Begbroke grassland. Equipped with some experience of the plant's growth pattern it is proposed to re-examine the performance of MCPA in controlling shoot emergence at different seasons.

Thought is also being given to the investigation of the ability of this species to interfere with grazing.

Sward destruction and reseeding

This project is concerned with the development of herbicides which will provide sufficient kill of the established grass sward and associated broad-leaved species to allow reseeding without resort to deep or power-consuming cultivations. Most of the work in the past two years has been carried out on the long-established *Agrostis/Festuca* pasture at Begbroke. This sward type consists mainly of species resistant to the herbicides that are available and offers a difficult testing ground for sward-killing chemicals. It also has a thick root mat on the soil surface.

The investigation falls into 3 parts:

1. The effects of the chemicals on the sward. Particular attention is paid to the speed of kill, the duration of the destructive effect and the speed of recoloniza-

tion in the absence of crop competition. Studies have been made on the dose-response and the time of application of chemicals alone or in mixture, and as single or split applications. Dalapon, activated aminotriazole and paraquat perform best when the main application is made in the autumn and followed by a low dose of paraquat in the spring. Where broad-leaved weeds are a problem control is better attempted prior to or subsequent to grass control. The current programme is concerned with obtaining a wider spectrum of control and a greater duration of kill. The treatments include mixtures of linuron, atrazine, bromacil, dalapon and paraquat with aminotriazole.

2. The more promising treatments are further examined in the presence of a crop which has been direct-drilled into the sprayed sward. Sown in this way the treated plots allow the examination of the interaction between the crop and the regenerating weeds.

When a direct-draught slit-drill has been used under the conditions at Begbroke, weeds have re-established rapidly where small seeded grasses have been sown, less quickly with winter cereals and least when a crop which quickly produces a thick canopy, such as oats and vetches, has been sown. This indicates that the value of a herbicidal treatment can be strongly modified by the properties of the crop that is sown afterwards.

3. Investigations are made of problems arising from the activities outlined above. In a new technique such as this the failure of a crop to establish may be only indirectly connected with the actual method of sward destruction. Other factors include the efficiency of the drill in placing the seed in the soil, the presence of pests particularly suited to the environment of the killed sward, the inability of the seedling to emerge through a dead root mat.

It has been the experience of the past two years that a pioneer crop can be most useful for establishing a thick canopy that will suppress any weeds unkilled by the herbicide, and for allowing time for the decay of the surface root mat. It can pave the way for the kinder surface conditions that are necessary for the direct drilling of small-seeded grasses. It is best if the pioneer crop is harvested green because there is then no ripening period during which the ground is without a foliar canopy, a situation in which weeds can flourish.

The sowing of seeds in aqueous fluid

The idea of sowing seeds suspended in an aqueous medium arose from the investigation of the use of herbicides to kill grass swards prior to reseeding. It was apparent by 1961 that conventional agricultural implements were not suitable for working on killed swards, and that some new form of sowing was required. A fluid technique appeared attractive because it would allow incision of the seed into slits and would provide water for germination and early growth, and thereby enhance the chance of seedling establishment.

No staff was available at W.R.O. to work full-time on this project, and an approach was made to the National Research Development Corporation (N.R.D.C.) for financial support. The Corporation agreed to provide a sum for the employment of an experimental officer for two years at Begbroke Hill. As a result, J. D. Parker was appointed in February 1964.

(a) The development of the drill.

Four experimental drills have been constructed, three by N.I.A.E. and one in the workshop at W.R.O. The three N.I.A.E. machines represent a progression in development, the second and third incorporating modifications and improvements thought appropriate in the light of experience gained by testing the previous model. They all differed from the W.R.O. machine in that they were designed to work on uncultivated soil or dead sward, while the W.R.O. machine was built specifically to sow parallel rows of dry and fluid seed into an arable seedbed prepared in a conventional way. The early prototype used a squeeze-pump to propel the seed and fluid, but this action was discarded in favour of the positive volumetric displacement obtained by a plunger working in a cylinder, which has proved to be accurate and trouble-free. In all other machines, the seed and fluid are ejected from the cylinder at a controlled but variable speed through plastic tubing to a normal coulter unit when used on arable seedbeds or to a knife-coulter when used on uncultivated surfaces.

(b) The physical properties of the fluid.

The ideal fluid should be based on a stable and non-toxic substance that is cheap, easy to handle and to mix. When constituted it should support various sizes and densities of seeds in suspension, yet move easily through narrow-bore tubing. Since a second object of the fluid is a carrier vehicle for nutrients and crop protection chemicals, the fluid should be physically compatible with such compounds.

The material selected for the fluid was a commercial grade of sodium alginate. If an 0·5 per cent w/v solution is acidified to pH 4·5, a thixotropic gel is formed which has good support and flow characteristics. Phosphoric acid has been used in the acidification process at a concentration of 0·05 per cent v/v of alginate solution. Most of the biological testing has involved this gel which has a material cost of approximately £2 per 100 gallons.

(c) The performance of seeds in the fluid.

The greatest advantage in speed of seedling emergence has been achieved by pre-germinating the seed in damp sand in a controlled environment and then transferring it to the fluid for sowing. In this method the fluid acts as a carrier for the seed which permits its movement without mechanical or biological damage. An appreciable advantage has been obtained over dry seed with sugar beet, kale and perennial ryegrass even when the soil has contained ample moisture for the germination of the dry seed, and when normally prepared arable seedbeds are used. When dry seed has been placed in the fluid and sown immediately, no advantage has been obtained in soil containing adequate moisture for germination, but where moisture has been limited the fluid has provided an advantage.

Although considered promising the project has been abandoned, it is hoped only temporarily, owing to lack of financial support.

OTHER ACTIVITIES.

The activities described above are those wholly concerned with the research projects in progress. However, the Section has been involved in other activities, some intimately connected with research, others less so, and some which are purely educational.

The co-operation with the Ministry of Agriculture, Fisheries and Food Experimental Husbandry Farms, which was described in the First Report of the

W.R.O., has continued to flourish particularly in the potato and minimum cultivation projects. The basis of the co-operation is mutual interest in a subject. There is an agreed division of responsibility, each organization working on those aspects of the co-operative programme appropriate to its expertise.

The need for research workers of different disciplines to pool their experiences and to co-ordinate their efforts is increasing. The Weed Research Organization now makes many contacts with other organizations. The Head of the Agronomy Section is a member of the A.R.C. Working Party on the Development of Chemical Weed Control in Potatoes. Annual meetings are held with the Crop Husbandry and Grassland specialists, the N.A.A.S., with the Grassland Research Institute, the Pea Growing Research Organization, the Norfolk Agricultural Station, and Messrs. Unilever Ltd., at which research information and intentions are exchanged.

With the growth of the Computer Service at Rothamsted, it is now possible for the Section's field data to be summarized and analysed by computer. With the Grassland Team leading the way, the Section is moving progressively to a computer-processing of results.

The British Weed Control Council continues to make substantial and welcome claims on the time of the Section. The Review of Herbicide Usage is now an annual event. The Weed Control Conference was held at Brighton in November and members of the Section acted on the Programme Committee and as Sessional Organizers. The year has also seen the majority of the work done for the Section's contributions to Volumes I and II of the new edition of the *Weed Control Handbook*. All the Scientific Officers in the Section have been involved in these tasks.

There is an increasing demand for lectures, talks, and participation in discussion groups. These vary from those at the technical level required for a winter school organized by the Institute of Corn and Agricultural Merchants at Oxford in February, 1966, to numerous talks of a general nature to farming audiences.

Horticulture Section

Head: G. W. Ivens

The Section's duties have included the development of new techniques for control of weeds in fruit and ornamental crops and investigation of problems arising from the use of herbicides in horticulture. Implementation of plans to expand the work on orchard fruit and bulbs continues to await the appointment of additional staff.

Because of the increasingly important role of herbicide persistence work in the research programme, the main projects into which the work has been divided have been changed slightly and are now as follows:

PERSISTENCE OF SOIL-APPLIED HERBICIDES

Simazine is now used extensively in a number of fruit crops and is the most important of the residual chemicals as far as perennial horticultural crops generally are concerned. It is also one of the more persistent herbicides and for these reasons it remains the principal subject of the persistence studies.

Experience is now available from a number of experiments. In the raspberry non-cultivation experiment where simazine at 2 lb/ac has been applied each March since 1962, the residues the following autumn have varied from non-detectable to 0·19 lb/ac. In plots mulched with straw residue levels have been consistently lower than in unmulched plots. There is no evidence of a build-up of simazine residues during the five years that treatments have been applied.

Residues were considerably smaller after the wet summer of 1965 than after the previous dry summer, and the effects of soil moisture on persistence have also been shown in irrigation experiments. On plots watered to field capacity at 0·5 in. soil moisture deficit the rate of disappearance was greater than on plots receiving normal rainfall, while on covered plots, once the soil had dried out, residues remained unchanged over long periods (e.g. no change in six months during the summer of 1965).

The more rapid disappearance of simazine from moist soil is thought to be due to greater activity of soil micro-organisms. Microbiological activity is also influenced by soil fertility and an experiment was started in the summer of 1966 to determine whether persistence under field conditions can also be influenced by the addition of inorganic fertilizers.

Until recently simazine residues have been determined by a lengthy bio-assay technique, using turnip as a test plant. A more rapid method would have great advantages, and a study has been made of the possibility of estimating triazines and substituted ureas by Parker's method (Parker, 1965),* involving the inhibition of the effects of paraquat by pre-treatment with these chemicals. Using *Lemna minor* and turnip seedlings as test plants, the method has been found adequately sensitive for simazine, but reproducible results are very dependent on uniform lighting, so that it is only likely to be successful under constant environment conditions. In the latest persistence experiment simazine residues are being estimated by the Chemistry Section, using a spectrophotometric method.

SELECTIVE ACTION OF SOIL-APPLIED HERBICIDES IN PERENNIAL CROPS

In the field, strawberries are more sensitive to the effects of simazine in spring than later in the year and a series of experiments has been started in the glasshouse to investigate some of the factors concerned. With freshly dug runners planted in soil mixed with varying doses of simazine at intervals from March to September sensitivity to simazine has been found to decrease as the season progresses, a change associated with an increase in size of runner. There is also evidence of a decrease in sensitivity as the ratio of shoot to root increases. Cold-stored runners were consistently more sensitive, but, although remaining constant in size through the season, again showed decreased sensitivity with the later treatments.

Experiments have also been conducted in the glasshouse in an attempt to obtain confirmation of the stimulation of growth by simazine claimed to occur with certain fruit crops in the field. With apple root-stocks and strawberry no such evidence has been obtained, but with blackcurrant there has been some evidence of stimulation of shoot growth.

* Parker C. A rapid bio-assay method for the detection of herbicides which inhibit photosynthesis, *Weed Res.* 1965, 5, (2) 181–4.

(a) *Non-cultivation trials*

In raspberries grown without cultivation since planting in 1962, simazine being used to control weeds, yields have been no lower than with inter-row cultivation, and in 1966 were significantly higher where simazine was used. In the same experiment the use of a straw mulch, with or without simazine, greatly reduced the number of canes produced in the spring, but increased yield. On plots which have received no cultivation for five years slight capping of the surface develops in summer, but weathering and the activity of earthworms prevent this from becoming serious. Penetration of rain-water appears to be unimpeded. Assessments of microfauna have been carried out periodically in this experiment by the Nature Conservancy and a slight reduction in the mite population has been recorded on simazine-treated plots. The numbers of *Collembola* species have not been affected.

In a second experiment on raspberries started in 1963 comparisons are being made between the long-term effects of a residual herbicide (simazine) and a contact material (paraquat), and between non-cultivation and a single, annual, inter-row cultivation. Neither the cane growth nor the yields have differed significantly in 1965 or 1966, but the simazine-treated plots have been easier to manage than those treated with paraquat, where it is proving difficult to maintain weed-free conditions in the rows.

A strawberry non-cultivation experiment is also in progress in which cultivation is being compared with weed control by means of residual herbicides (chloroxuron and simazine) and a contact treatment (directed application of paraquat). In the same experiment a comparison is also being made between straw-burning after harvest and no burning. In the first two fruiting years of the plantation cultivation without straw-burning (foliage mown off after harvest) has given significantly higher yields than any other treatment, suggesting that both types of herbicide treatment and burning have caused damage. Unfavourable soil conditions at the time of the first chloroxuron treatment soon after planting, drift of paraquat on to the plants in the rows and the need to use extra straw to achieve a burn during the wet weather following harvesting in both years have probably all contributed to the yield reductions observed. It is evident, however, that the successful adoption of non-cultivation techniques in strawberries is more difficult than in raspberries.

(b) *Evaluation of herbicides*

Strawberry. Observation trials noted in the previous report showed that lenacil (Du Pont 634) was promising, and this chemical again gave the best results of four herbicides compared with chloroxuron as spring treatments in a yield trial. A dose of 2 lb/ac compared favourably with the standard dose of chloroxuron in degree of weed control afforded and caused no damage over two years.

Blackcurrant. Simazine has been claimed to interfere with the rooting of blackcurrant cuttings. In an experiment in which doses up to 4 lb/ac were applied in April to November-planted, unrooted cuttings, however, no effect could be detected, even when 2 in. of irrigation water was applied after spraying.

Dalapon has also been tested on blackcurrants to determine whether overall application in the dormant season for couch control is liable to cause damage. Doses of 6 and 9 lb/ac in January caused no damage. After application in early March damage developed on the basal leaves as the shoots developed, but the remainder of the shoot was normal and fruiting was not affected.

Apple. A series of experiments has been started to obtain information on which of the growth-regulator herbicides, effective against *Convolvulus arvensis* and *Calystegia sepium* (bindweeds), are likely to cause the least damage when parts of the tree are sprayed. The response of different varieties is also being studied. The first treatments were applied to single shoots in mid-August 1965, and the preliminary results suggest that 2,4-D caused less damage to four varieties than MCPA, MCPB or mecoprop. 2,4-DB was also relatively non-toxic on Lord Lambourne, but dichlorprop was more damaging while 2,4,5-T was the most damaging of all. Bramley's Seedling showed greater sensitivity to 2,4-D than Cox's Orange Pippin, Lord Lambourne or Worcester Pearmain, and only with Bramley's Seedling was there evidence of movement of herbicide out of the treated shoot.

Dahlia. Work in previous years has shown simazine to be a possible treatment, but of marginal safety. In 1965 it was compared with chloramben, and under the prevailing wet conditions caused much damage, while chloramben, although not damaging, was relatively ineffective.

In 1966 several chemicals which had shown promise in an earlier observation trial were included in a replicated experiment. Prometryne and linuron were very effective and caused no damage when kept off the foliage, while lenacil gave good results as an overall spray. Trifluralin (unincorporated) failed to give adequate control of weeds.

Nursery stock. Simazine is extensively used in woody-plant nurseries, but is damaging to many herbaceous species. An experiment was carried out with the assistance of Jackman's Nursery in 1965 to investigate the potentialities of steam-activated charcoal as a root dip at planting, prior to simazine application. The 26 types of plant included representatives of many of the more sensitive genera (such as *Erigeron*, *Potentilla* and *Veronica*), but the charcoal gave sufficient protection for the majority to grow normally under wet conditions conducive to injury. A second trial in 1966 gave very similar results on a different range of species and lenacil has also been shown to have possibilities for herbaceous perennials.

Special Projects

AQUATIC WEED PROJECT (T. O. ROBSON)

The survey of the problem of aquatic weeds in England and Wales was completed with the submission of a report to the Agricultural Research Council in September 1965.

The main conclusions of this report were that:

1. There is an increasing need for new labour-saving methods of aquatic weed

control to enable river authorities and drainage boards to meet their commitments for the maintenance of efficient land drainage.

2. The most pressing problems occur in the smaller channels and on the steep banks where mechanized cutting is impossible and also in channels where filamentous algae prevent the use of boats. It is in these situations that herbicides are most likely to be the only solution.

3. The use of herbicides in aquatic situations is regulated not only by their effect on fish, other important forms of aquatic life and water use. The development of new herbicidal techniques must therefore include observations on their possible side effects as well as on their ability to control weeds.

Work continues on the accurate aerial application of herbicide to drainage ditches in collaboration with the Tropical Pesticides Research Unit at Porton, the Kent River Authority and the Littleport and Downham Drainage Commissioners, near Ely. The 1964/65 results were published in *Weed Research* in September 1966 (Robson, Little, Johnstone and Hill, 1966). A further trial to test reduced volumes and doses of dalapon on *Phragmites communis* (common reed) was started in August 1965.

Two other projects have also received attention. The Fisheries Division of the Ministry of Agriculture, Fisheries and Food started studying the Chinese grass carp (*Ctenopharyngoden idella*) and T. O. Robson is assisting with the assessment of the effect of the fish on aquatic weeds.

The second project is concerned with investigating the rate of 2,4-D breakdown in natural surface waters and the factors affecting this breakdown. A series of experiments has been completed but more work is needed.

During the latter part of 1965 and the whole of 1966, T. O. Robson served as Secretary to the Programme Committee of the British Weed Control Council in respect of the 8th National Conference, a task which occupied a great deal of time. He also served on the B.W.C.C. Recommendations and Handbook Committees.

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

This consists of a single field experiment started in 1963 (First report W.R.O. 1960–1964, p. 47) as an attempt to investigate the possible effects on the properties and biology of soil of the repeated long-term application of four representative herbicides applied: (a) annually to crops as selective treatments, and (b) to uncropped weed-free land at higher rates and at more frequent intervals.

The herbicides under examination are MCPA, tri-allate, simazine and linuron.

The experimental lay-out consists of paired field plots. One plot of each pair receives the appropriate herbicide, the other plot is never sprayed. As far as is possible, all other factors are the same for both types of plot.

The same crops are grown on the same plots each year. Routine assessments of crop yields and disappearance of herbicides from the plots are carried out at the Weed Research Organization. Herbicide residues are detected by bio-assay and chemical methods.

Other assessments have aimed to measure the effect of the treatments on soil microflora and fauna and also on the chemical properties of the soil.

The Microbiology Section at W.R.O. has investigated CO_2 and nitrate production as indicators of microbial activity in soil taken from the plots.

A study of the effects of the herbicides on specific soil bacteria and on the numbers of bacteria in the plots has been undertaken by the N.A.A.S. Regional Bacteriologist, Coley Park, Reading. Measurements of nutrient status and pH of the soil have been carried out by the N.A.A.S. Soil Chemistry Department at Coley Park.

Some assessments of the microfaunal population in soil taken from the plots have been made by the Entomology Department at Rothamsted but this work has been discontinued.

A study of the viable weed seed population in the soil under the various crops is being undertaken by the National Vegetable Research Station, Wellesbourne, Warwick.

The investigation of the growth of *Ophiobolus graminis* (take-all) and other soil fungi in the plots that have received the higher doses of herbicides, which was carried out by Miss V. Wilkinson at the University Department of Agriculture in Oxford, has now been terminated.

Statistical analysis of yield results is carried out by the Department of Statistics at Rothamsted.

During the first four years of the experiment, there have been no significant differences between the yields of crops from treated plots versus untreated, which could be attributed to long-term herbicide application. The coefficients of variation have ranged between 2·8 and 18 per cent for barley, 0·9 and 7·8 per cent for carrots (fresh wt.) and 1·6 and 8·8 per cent for maize (total fresh wt. cobs and foliage). Neither the numbers of specific bacteria nor the total bacterial count has been adversely affected by the herbicides.

There has been no build-up of herbicide residues on any of the cropped plots, and only slight build-up of simazine and tri-allate residues on the small uncropped plots, after annual applications of four times the normal dose. A residue of 32 oz a.i. of linuron was present on the small uncropped plots as sampled on June 20th, 1966, before the first application for that year. This is a build-up of 1·3 times the amount sprayed in a single application. MCPA has consistently disappeared at a much faster rate than expected from the literature, a dose of 3 lb/ac having regularly proved to be undetectable within three weeks of application to the soil. Convincing evidence has been obtained that a population of micro-organisms capable of detoxifying MCPA at a much enhanced rate has built up in the MCPA-treated plots receiving the higher dose (Kirkland and Fryer, 1966).

It is proposed to initiate some new long-term experiments in spring 1967 in addition to the work already described. These will investigate the persistence and movement in soil of paraquat, picloram, prometryne, lenacil and pyrazon applied at different rates and frequencies year after year to the same plots.

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 line and connected by a level crossing. 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 3 silage cuts and a hay crop in 1966. 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 near the railway line is stocked with beef cattle, no fertilizer is applied and the tall weeds 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 by 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.

In respect of the role of the farm as a test-bed for new ideas, topics being currently studied on a whole-field scale include:

1. The control of weeds in paddocks with herbicides as an alternative to cultivation.
2. The factors affecting a farmer's decision as to whether a cereal crop should be sprayed.
3. Cereal production by minimal cultivation.
4. The control of grasses in lucerne.
5. The performance of beef steers in a paddock grazing system.

List of Research Projects

The Department is responsible for research on practical problems in weed control, and for research on the consequences of herbicide use on the land.

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

The Agronomy Section is divided into two specialized teams that are responsible for weed research in the two main branches of crop husbandry, arable and grass land.

I. The Arable Team (G. W. Cussans, T. I. Cox and B. J. Wilson) has during the past two years been concerned with the following projects:

(a) Studies of the emergence and control of weeds in maincrop potatoes grown in conventional and novel systems.
(b) Cultural and chemical methods of controlling weeds in agricultural kale.
(c) The control of *Agropyron repens* and *Agrostis* sp. in land being cropped with cereals.
(d) The control of weeds in cropping systems involving minimum cultivation.

II. The Grassland Team (G. P. Allen, Miss J. Hartridge and A. Oswald) has carried work on:

(a) The selective control of *Agrostis* sp. in long leys and permanent pasture.
(b) The use of herbicides for sward destruction prior to surface reseeding.
(c) The control of *Cirsium arvense* (creeping thistle).

HORTICULTURE SECTION (*Section Head:* G. W. IVENS until October 30th, 1966, and J. G. DAVISON as from April 1st, 1967, assisted by D. V. CLAY)

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

I. The persistence of soil-applied herbicides, when used repeatedly in perennial horticultural crops.

II. Selective action of soil-applied herbicides in perennial crops. A greenhouse study of the factors affecting the response of fruit crops to herbicides, and a study of root systems in relation to herbicide uptake.

III. The evaluation and development of new herbicides for horticultural crops.

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

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

AQUATIC WEEDS PROJECT (T. O. ROBSON)

This project has been operated on a temporary basis during the period under review.

FARM (*Manager:* F. BARNES)

I. The prime responsibility of the farm is to provide fertile land for field experiments and to provide the field experimenter with the various services on the land that he requires.

II. The land not in experiments is farmed commercially. The farm acts as a working test-bed for new techniques of weed control and for the study of weed problems.

Information Section

Head: D. O'D. BOURKE

The Information Section is responsible for the provision of library and information facilities for the research staff, and for the preparation of *Weed Abstracts** which is published by the Commonwealth Agricultural Bureaux (C.A.B.). It also compiles bibliographies, answers enquiries on weed literature and assists with the preparation of W.R.O. publications. The Head of the Section is the chapter manager for Chapter 19 of the new edition of the *Weed Control Handbook*. He is also the W.R.O. representative of the British Standards Institution Technical Committee PCC/1 which is responsible for the standardization of names of new pesticides.

Staff

An increase in staff was made possible by a C.A.B. grant to A.R.C., approved at the Quinquennial Review Conference held in London in August 1965. The amount of the grant is £33,000 over six years, i.e., £5500 per annum, to finance the new posts of deputy to Head of Section, Abstractor, Indexer and Typist. The post of deputy was filled by W. L. Millen. Mrs. S. Stedman was appointed as a typist.

P. J. Boyle, Head of the Section since September 1960, left in July 1966 to become Assistant Director, Commonwealth Bureau of Pastures and Field Crops. He was succeeded by D. O'D. Bourke, formerly Assistant Director, Inter-African Soils Bureau, Paris. In October 1966 P. J. Kemp, formerly of the N.I.A.E., took up his appointment as an Abstractor.

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

Library

The library is one of the most important ones in Britain specializing in weed literature. There were some 60 additions during the period under review and it now contains about 400 volumes. It receives some 260 periodicals, 230 of which are permanently filed. It also maintains the proceedings of major weed conferences, technical reports, bulletins and commercial literature.

Index

The Index was kept up to date despite the fact that the post of Indexer had to be combined with that of Librarian. It provides a cumulative key to *Weed Abstracts* and since it is based on a rapid visual system it facilitates the checking of references by members of the W.R.O.

Weed Abstracts

Until the end of 1966 there was no possibility of abstracting literature in Russian and Slavonic languages. This problem was solved by the appointment of P. J. Kemp. His arrival also made it possible to resume regular visits to Oxford libraries to consult journals not taken by the W.R.O.

It was not possible to abstract Japanese literature but contact was made with the editor of *Zasso Kenkyu* ("Weed Research") and with Japanese firms in order to obtain as much Japanese literature as possible with English summaries.

Delays in publication made it necessary to combine the last two numbers of Volume 15 (1966) into a double number. A C.A.B. questionnaire confirmed that readers set great store by the topicality of abstracts.

The circulation of *Weed Abstracts* continued to increase. Total subscriptions for Volume 15, Number 4 amounted to 970, made up of 691 subscriptions and 279 copies on quota or exchange. At the end of 1964 the corresponding figures were 900, made up of 629 and 271.

Bibliographies

Up to April 1966, the Information Section had prepared some 130 bibliographies in the form of lists of titles. In order to provide additional information it was decided whenever possible to prepare annotated bibliographies instead. Subjects may be selected because of a general demand or as the result of specific requests. Completed bibliographies are offered for sale. Seven were produced by the end of the year.

Overseas Section*

Head: E. C. S. LITTLE

Throughout the world there is an increasing realization that traditional methods of weed control are, or soon will be, inadequate to cope with the demands of more intensive agriculture. As yet, many countries are not sufficiently advanced to provide the technical staff for the research necessary to exploit modern methods of weed control, in particular techniques based on the revolutionary herbicides now available. The Ministry of Overseas Development (O.D.M.) in 1963, recognizing the possibilities of giving useful aid in this direction, financed, through a grant to the Agricultural Research Council, the appointment to W.R.O. of an Overseas Officer and assistant to form the Overseas Section.

The formation of this Section enabled the existing contacts between W.R.O. and overseas workers to be greatly expanded.

This expansion has been effected partly by correspondence but mainly by visits abroad, sponsored by the O.D.M., which have enabled a large number of personal contacts to be made.

Since 1963 a major journey of about three months has been undertaken annually. The first (1964) was round Africa (13 countries), the second (1965) through the Caribbean, Central America and parts of the U.S.A. (12 countries) and the third (1966) round South America (8 countries).

In addition visits have been made to a number of European countries in connection with international conferences. Visits have also been made to the United Nations agencies, FAO in Rome and UNESCO in Paris.

An important feature of this travel was to establish contacts with research officers at the Tropical Pesticides Research Institute at Arusha in Tanzania, and at the Herbicide Section of the University of the West Indies in Trinidad and Jamaica. These officers are engaged in important research into weed control in the tropics. They are kept fully informed of the latest information from the evaluation and screening work at W.R.O. with new herbicides on tropical species.

The opportunity has also been taken to draw attention to many people around the world to the journals *Weed Abstracts* and *PANS* (see also pp. 41 and 47) which provide so much valuable information from international sources.

One useful result of the numerous contacts made has been the increasing numbers of overseas visitors to W.R.O. (76 people from 33 countries) with consequent valuable exchanges of information. A steadily increasing flow of enquiries by correspondence is also being experienced as a result of the personal contacts made. In 1966 some 44 enquiries for information were received from 26 countries.

In order to promote interest in the international aspect of weed control problems regular articles are contributed to *PANS* describing aspects of general interest arising from the tours. Nine such articles have been published.

In addition to liaison work, the Head of the Section has undertaken some research studies at W.R.O. These have included: (1) investigations into the

* This Section is attached to the Department of Weed Science in respect of its research activities.

reduction of drift from aerial applications of herbicides; (2) the evapo-transpiration characteristics of some tropical water weeds; and (3) the translocation of some herbicides in test plants such as cotton.

A review of the world literature on brush control in tropical grasslands was prepared in collaboration with Dr. G. W. Ivens.

A study is being carried out in collaboration with Imperial College Field Station and the National Institute for Agricultural Engineering on the important features of knapsack sprayers for herbicidal applications, especially in the tropics.

Following a visit to Mexico in 1965 arrangements were made with O.D.M. to supply research workers of the National Institute of Agriculture with top quality British-made spraying equipment to help them in their experimental work.

During a visit to the Congo in 1964 the presence of the important water weed *Salvinia auriculata* was discovered and this was reported to West African countries so far free of it (Little, 1965).

After three years of operation there seems to be a clear indication that the Overseas Section can perform a useful function as a means of providing assistance abroad on weed control problems. The existence of the Section also promotes a flow of information inwards to W.R.O. much of which is valuable and stimulating.

Ministry of Agriculture, Fisheries and Food

National Agricultural Advisory Service Liaison

S. A. Evans (*Agriculture*)

R. F. Clements (*Horticulture*)

Two members of the National Agricultural Advisory Service, one dealing with agriculture and the other with horticulture, are stationed at the W.R.O. Their function is to act as specialists in weed control to their Service, in which capacity they utilize the research findings and information available from W.R.O. and from other sources. In turn W.R.O. obtains through the liaison officers information on aspects of farm and market-garden practice and on field problems.

HERBICIDE TRIALS

Agricultural crops

Each year the N.A.A.S. regional crop advisers and country staff undertake a number of national trials, the details of which are usually prepared jointly by representatives of the N.A.A.S. and the W.R.O. Results are summarized by the N.A.A.S. Liaison Officer (Agriculture).

Some of the aspects which have been dealt with in the past two years are as follows:

Pre-emergence herbicides in cereals. It is known that the sooner weeds are controlled by post-emergence sprays the better is likely to be the crop yield. This series of experiments was an attempt to discover whether even better yields might be expected where pre-emergence sprays were used to keep the crop weed-free from the time of drilling. Results so far obtained in eight trials over three years suggests that yield benefits are likely to be marginal compared to those obtained after post-emergence spraying carried out whilst the weeds are still small.

New herbicides in cereals. Twenty-one trials have been conducted with ioxynil, picloram, morfamquat and chlorflurazole applied on a range of weeds in cereals. The weed control was generally good, but a striking feature of the trials was the variability in results sometimes obtained, indicating a need for closer study of how application and other factors may influence the efficiency of herbicides.

Effect of spraying on cereal yields. About 170 trials either unreplicated or with duplicated treatments only, carried out over two years, suggest that yield increases as a result of spraying cereals for the control of broad-leaved weeds are not frequent. Whilst other factors can justify the expense of spraying, this work has shown the need to be more critical of herbicide usage in cereal crops.

Other agricultural work has included the control of couch in stubbles and in potatoes, the use of pyrazon in sugar beet, the use of herbicides in kale, the use of GS 14260 for blackgrass control in cereals and the control of docks and bracken.

Horticultural crops

Investigations on herbicides in relation to horticultural crops are located principally at the Experimental Horticulture Stations. Small observation studies are also carried out on commercial holdings by horticultural advisers. Studies of this kind are designed to give further information on local problems and also have a demonstration value. Subjects for study are put forward by the N.A.A.S. Liaison Officer (Horticulture) who collates results, interprets them in an advisory context and reports back to the field advisers. Subjects recently investigated include the use of chlorthiamid and dichlobenil in top and soft fruit and ornamentals, the use of charcoal dipping to prevent simazine injury to freshly planted strawberries and chloroxuron for weed control in chrysanthemums.

Herbicide experiments on the E.H. Stations are conducted under the aegis of the various commodity Sub-Committees of the Experimental Horticulture Committee. The N.A.A.S. Liaison Officer (Horticulture) acts as consultant and co-ordinator of these experiments which cover fruit, vegetables and flowers. The results are written up annually in the reports of the various stations concerned.

OTHER ACTIVITIES

The N.A.A.S. Liaison Officers undertake the writing of many of the leaflets on weeds and weed control issued by the Ministry of Agriculture, Fisheries and Food. They lecture also at farmers' and growers' meetings and prepare articles for publication in the agricultural and horticultural press. Information and instruction are provided to members of the N.A.A.S. by means of lectures at refresher courses, papers and notes circulated within the service and by answering specific queries from regional specialists.

The N.A.A.S. Liaison Officers are members of the British Weed Control Council and have duties in connection with a number of the Council's committees.

The Agricultural Chemicals Approval Scheme—Herbicides Liaison

J. G. Davison

The Ministry of Agriculture, Fisheries and Food operates a voluntary scheme under which proprietary brands of crop protection chemicals can be officially approved. The Scheme is supported by the Association of British Manufacturers of Agricultural Chemicals, the National Association of Corn and Agricultural Merchants and the National Associations and Unions of Farmers and Growers in the United Kingdom. Labels of approved products bear an Approval Mark, an 'A' surmounted by a crown, which indicates that the Organization which operates the Scheme 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 the W.R.O. to ensure close contact with the work done there and to make use of other facilities, such as the Library and Information Section. As the centre for official research and development in weed control in the United Kingdom, the W.R.O. also attracts many visitors, contact with whom is important for the close liaison which must exist between the Approval Organization, independent workers and industry.

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 National Agricultural Advisory Service 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.

As the Scheme is voluntary, manufacturers are under no obligation to get approval for their products before marketing them. In practice, however, most of the products now on the market in the U.K. are approved. Precise figures are not available, but so far as herbicides are concerned, it is estimated that about 90 per cent of the products at present available are approved and these account for more than 90 per cent of the acreage sprayed.

Each year, the Approval Organization publishes a list of approved products. The current farmers and growers' list for 1967 includes about 780 products of which 354 are herbicides. Between them, the herbicidal products include 50 different active ingredients. Of these, 37 are available as products containing one active ingredient only and the remaining 13 are available only in mixtures of, in most cases, two, but in some cases three or even four active ingredients. In addition there are a further 40 or so products available for garden use based on 10 active ingredients. There are virtually no herbicidal recommendations for use in the U.K. for which an approved product is not available.

In the last three years, the numbers of approved herbicide products for farmers and growers have increased by approximately 40 per year, 16 of which contain more than one active ingredient. During the same period there has been an average of four new active ingredients per year. This trend looks like continuing. Through the approval scheme it is hoped that advisers can recommend and users select an appropriate product, confident in the knowledge that the recommendations have been agreed to by an independent organization. This is especially true in the early commercial life of a product when farmers and growers have no practical experience. Early approval of products containing such recently introduced chemicals as ametryne, benazolin, bromacil, lenacil and pyrazon has encouraged farmers and growers to take advantage of the most recent additions to the ever-increasing number of chemicals available for the continuous fight against weeds.

Ministry of Overseas Development*

PANS, Section C (Editor: B. Steele)

The Ministry of Overseas Development finances three quarterly journals under the title *PANS* (Pest Articles and News Summaries). Their object is to keep workers in developing countries, and others who co-operate with them, in touch with the latest developments in pest control, especially under tropical conditions. Sections A and B deal respectively with insects and plant diseases. Section C, on weed control, is produced at Begbroke Hill as the main centre for information on this subject.

The first two years for which *PANS* (*C*) has had a full-time editor were 1965 and 1966. This has facilitated many improvements in the appearance and presentation of material. The abstracts section, which consisted of a selection reprinted from *Weed Abstracts*, has been replaced by reviews and articles on

* See also p. 7.

special topics. Surveys are undertaken, with overseas readers in mind, on such subjects as new machinery, herbicide suppliers and new chemicals. Close attention can now be given to layout; photographs and illustrations are a feature of every issue and the aim is to produce a journal which is attractive as well as informative.

As a result of efforts made by the editorial committee, by the Overseas Liaison Officer, with whom close co-operation is maintained, and through contacts made with frequent overseas visitors to W.R.O., the circulation of Section C has increased during this period by some 50 per cent. It now reaches almost 100 different countries throughout the world.

A wide variety of information is presented to cater for weed control interests at all levels. There is a consistent demand for more basic details of commercially produced weed control products. The assistance of manufacturers in making these available is much appreciated. The view that contributions to *PANS* (C) are a means of encouraging the exchange of news and ideas round the world is increasing among weed control workers overseas. Towards the end of 1966 countries contributing information included Australia, Borneo, Japan and Ceylon; Swaziland, Sudan, Gambia and Israel; Mexico and the Philippines.

Visiting Research Workers

Post-Graduate Work

The arrangement with the University of Reading has continued, whereby post-graduate students who wish to work on a thesis on some aspect of weed control may do the necessary research at W.R.O. and submit it to the University for a higher degree. Supervision is provided jointly by W.R.O. and the University Department of Agricultural Botany.

As a result P. J. Davies was awarded a Ph.D. for a thesis submitted in June 1966, entitled 'The basis of the differential phytotoxicity of 4-hydroxy-3,5-di-iodobenzonitrile'. In this work the response of white mustard, pea and barley to ioxynil was investigated in detail in relation to retention by the plants, entry into the foliage, movement within the plant, and ultimate degradation by the plant. The results obtained provide possible explanations for the selectivity shown by this herbicide. Dr. Davies has now taken up a research post in the Department of Biology, Yale University, U.S.A.

D. T. Wettasinghe of the Tea Research Institute, Ceylon, was awarded a Ph.D. for a thesis submitted in October 1966, entitled 'Studies on the relative toxicities of substituted *s*-triazines'. The response of the cereals and a selection of broad-leaved species to simazine, propazine, methoprotryne and 4-allylamino-2-chloro-6-isopropylamino-1,3,5-triazine was investigated. The influence of depth of germination on toxicity, the exposure of the whole or part of the root system to the herbicide and the route of entry of the herbicide into the germinating seedling were considered in relation to selectivity. Dr. Wettasinghe has returned to the Tea Research Institute.

A. M. Hamdoun of the Ministry of Agriculture Research Division, Sudan, is currently working for a thesis on the biology of *Cirsium arvense*. The factors affecting regeneration from root fragments, and the effect on the root system of MCPA treatment of the shoot are receiving special attention.

M. Damanakis from Greece, holder of a government scholarship, is at present at the start of a three-year period of research for a higher degree thesis, on some aspects of the behaviour of paraquat in soil.

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3. Mode of action of diquat and paraquat, their fate in plants and soils and their toxicology 1958–1966. (19/-).
4. Selected references on minimum cultivation techniques limited to seedbed preparation and sowing operations in arable and herbage crops, and replacement of mechanical by chemical methods of weed control in perennial fruit crops. 1949–1966. (40/-).
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7. Selected references on the control of Asclepiadeae (*Asclepias* spp. 1–31, *Calotropis* spp. 32, 33). (7/-).

* Obtainable from the W.R.O. Information Section.

OVERSEAS VISITS

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

January–July 1965. K. Holly. Short-term Kellogg Foundation Fellowship to study weed control research in U.S.A. Appointed Visiting Professor at North Carolina State University.

April–July 1965. E. C. S. Little. Tour of the Caribbean, Central America and Southern U.S.A. under the auspices of the Ministry of Overseas Development.

July 1965. G. W. Ivens. Visits to horticultural research stations in Germany and the Netherlands.

October 1965. E. C. S. Little. Conference on the Use of Isotopes in Weed Research—Vienna, Austria.

December 1965. J. D. Fryer & K. Holly. New Herbicides Symposium and French Weed Control Conference—Paris, France.

March 1966. E. C. S. Little. International Agricultural Machinery Exhibition—Paris, France, and International Agricultural Aviation Congress—Arnhem, Netherlands.

June 1966. J. D. Fryer. Meeting of the European Weed Research Council, Lisbon, Portugal.

June–December 1966. R. J. Chancellor. Scholarship from the Alexander von Humboldt-Stiftung, held at the Institut für Pflanzenschutz der Landwirtschaftlichen Hochschule, Hohenheim, Stuttgart, Germany.

July 1966. J. G. Elliott. 10th International Grassland Congress, Helsinki, Finland.

August 1966. G. W. Ivens. 17th International Horticultural Congress, Washington, U.S.A.

September–November 1966. E. C. S. Little. Tour of South America under the auspices of the Ministry of Overseas Development.

GLOSSARY OF HERBICIDES MENTIONED IN THIS REPORT

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

activated aminotriazole	aminotriazole + NH_4SCN
ametryne*	4-ethylamino-6-isopropylamino-2-methylthio-1,3,5-triazine
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
benazolin*	4-chloro-2-oxobenzathiazolin-3-ylacetic acid
bromacil*	5-bromo-6-methyl-3-(1-methylpropyl)uracil
chloramben*	3-amino-2,5-dichlorobenzoic acid
chlorflurazole*	4,5-dichloro-2-trifluoromethylbenzimidazole
chloroxuron*	*N′*-4-(4-chlorophenoxy)phenyl-*NN*-dimethylurea
chlorpropham*	isopropyl *N*-(3-chlorophenyl)carbamate
chlorthiamid*	2,6-dichlorothiobenzamide
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
diuron*	*N′*-(3,4-dichlorophenyl)*NN*-dimethylurea
endothal	7-oxabicyclo[2,2,1]heptane-2,3-dicarboxylic acid
EPTC	*S*-ethyl *NN*-dipropylthiolcarbamate
fenuron*	*NN*-dimethyl-*N′*-phenylurea
GS 14260	2-t-butylamino-4-ethylamino-6-methylthio-1,3,5-triazine
ioxynil*	4-hydroxy-3,5-di-iodobenzonitrile
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
MCPA*	4-chloro-2-methylphenoxyacetic acid
medinoterb*	2,4-dinitro-3-methyl-6-t-butylphenol
methoprotryne*	4-isopropylamino-6(3-methoxypropylamino)-2-methylthio-1,3,5-triazine
monolinuron*	*N′*-(4-chlorophenyl)-*N*-methoxy-*N*-methylurea
monuron*	*N′*-(4-chlorophenyl)-*NN*-dimethylurea
morfamquat*	1,1′-bis(3,5-dimethylmorpholinocarbonylmethyl)-4,4′, bipyridylium-2*A*
paraquat*	1,1′-dimethyl-4,4′-bipyridylium-2*A*
picloram*	4-amino-3,5,6-trichloropicolinic acid
prometon*	4,6-bisisopropylamino-2-methoxy-1,3,5-triazine
prometryne*	4,6-bisisopropylamino-2-methylthio-1,3,5-triazine
propanil*	*N*-(3,4-dichlorophenyl)propionamide
propazine*	2-chloro-4,6-bisisopropylamino-1,3,5-triazine
propham*	isopropyl *N*-phenylcarbamate
pyrazon*	5-amino-4-chloro-2-phenyl-3-pyridazone
simazine*	2-chloro-4,6-bisethylamino-1,3,5-triazine
2,4,5-T*	2,4,5-trichlorophenoxyacetic acid
TCA	trichloroacetic acid
tri-allate*	*S*-2,3,3-trichloroallyl *NN*-di-isopropylthiolcarbamate
trifluralin*	2,6-dinitro-*NN*-dipropyl-4-trifluoromethylaniline

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. The W.R.O. 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 the W.R.O. fully informed of their action, where relevant.
   - (f) The suppliers must be agreeable to a two-way interchange of information between themselves and the W.R.O. 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 the W.R.O. 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. The W.R.O. 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 W.R.O. will always try to be co-operative in relation to specific patent situations.
5. Any information given by the W.R.O. 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 W.R.O. 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.