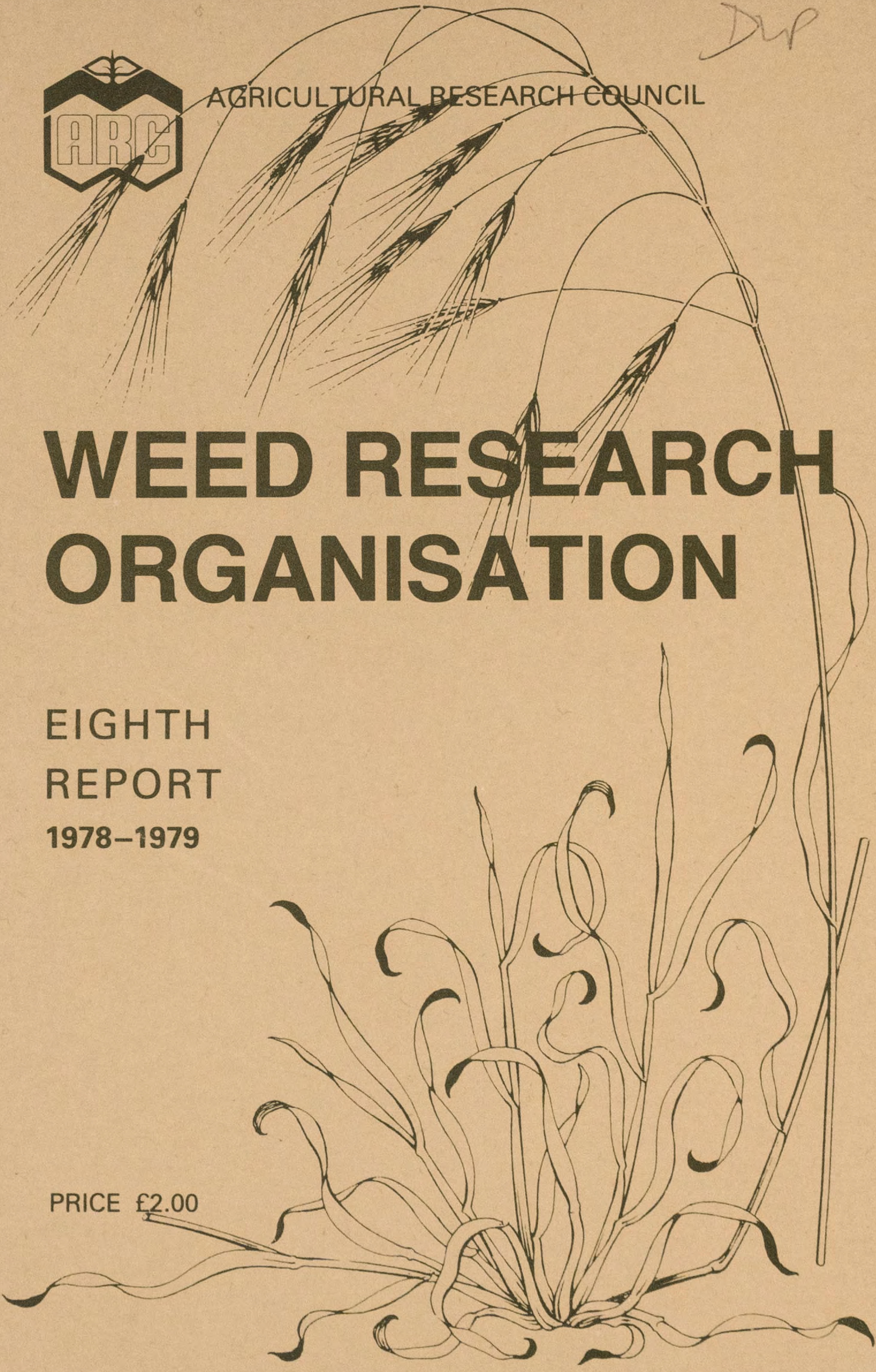
AGRICULTURAL RESEARCH COUNCIL

WEED RESEARCH ORGANISATION

EIGHTH
REPORT
1978–1979

PRICE £2.00



Bromus sterilis L.

WEED RESEARCH ORGANISATION   EIGHTH REPORT 1978–79

SOME FACTS ABOUT THE WEED RESEARCH ORGANIZATION (WRO)

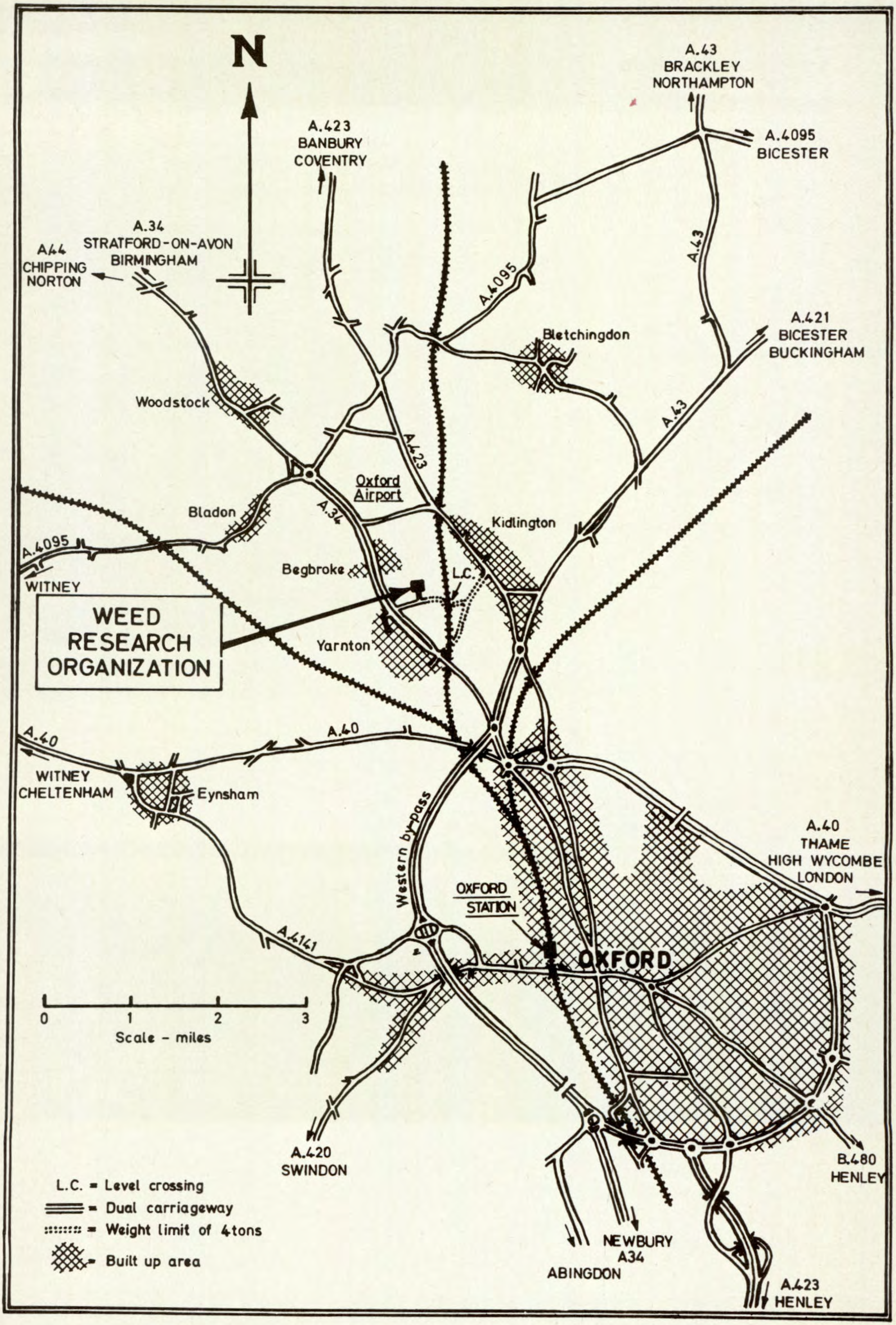
WRO is one of nine institutes belonging to and directly controlled by the Agricultural Research Council. It was set up in 1960 to serve as a national centre for strategic and applied research and information on weeds and weed control, with particular emphasis on herbicides. Its principal aim is to serve British agriculture but from its inception it has played an active role in tropical agriculture in co-operation with the Overseas Development Administration (ODA). Its information role is international and is assisted by the Commonwealth Agricultural Bureaux (CAB). For 1978–79 ODA and CAB together provided about 6% of the institute's funds.
The information provided in this report is necessarily condensed and selective. Readers wishing for more detail, or for an appointment to visit Begbroke, are invited to contact the Information Department.

ABBREVIATED TITLE

The abbreviated title of this report as given in the *World List of Scientific Periodicals New Periodicals Titles* (1960–68) is:
Rep. Weed Res. Org. 1978–79 (1980)

WEED RESEARCH ORGANIZATION

EIGHTH REPORT



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OXFORD
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Scale - miles
A.420
SWINDON
B.480
HENLEY
L.C. = Level crossing
= Dual carriageway
= Weight limit of 4tons
= Built up area
NEWBURY
A34
ABINGDON
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HENLEY

AGRICULTURAL RESEARCH COUNCIL

WEED RESEARCH ORGANIZATION

EIGHTH REPORT
1978–1979

Published July 1980

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Contents

DIRECTOR'S INTRODUCTION

This report differs from those of most of the institutes of the Agricultural Research Service in being biennial rather than annual and in not presenting details of individual research projects. Its aim is to provide an easily read review of the institute's work and progress for anyone who may be interested in what we do. For reasons of space and cost much has had to be omitted. For those wishing to have more detail, a comprehensive list of recent WRO publications is given on p. 87–100. Earlier lists are available on request from the Information Department whose staff will also be happy to answer enquiries concerning the published literature on our subject. Technical enquiries and requests for advice on practical aspects of weed control should be addressed to the Agricultural Development and Advisory Service (ADAS) Liaison Unit attached to WRO or to appropriate research staff.

A RESEARCH STRATEGY FOR THE '80s

It has been estimated that this year (1980) the world sales of herbicides will amount to more than £1750 million. In 1979 the value of herbicides used in the UK for agriculture and horticulture was £94.2 million compared with £15.5 million and £19.5 million respectively for fungicides and insecticides. The major arable and vegetable crops are almost all sprayed nowadays for weed control. Many fields are treated more than once each year (see table). Information of this kind sets the scene for much of the work of WRO. During its 20 years existence the institute has contributed much to the numerous chemical measures which are now available for weed control and which for the most part are extremely efficient. It is no exaggeration to say that the use of herbicides has transformed agriculture and that the latter's economic viability depends heavily on the continuing availability of cost-effective treatments. Whilst herbicides have been one of the success stories of the century their limitations are becoming more widely recognised. They are costing the nation and individual farmers and growers a great deal of money. Their performance does not always match up to the stringent requirements of modern crop production technology. The scale of their use, their efficacy in controlling weed populations and the fact that they are

Opposite. The attractive purple panicle of barren or sterile brome (*Bromus sterilis*). With the increasing trend towards minimum cultivation of winter cereals, this roadside grass has invaded the headlands where its resistance to many grass weed herbicides makes it difficult to control.

Herbicide use in Great Britain

Percentage of national area grown treated with herbicide (1978)

Cereals	103*
Sugar beet	186*
Potatoes	68*
Field beans	98†
Oil seed rape	64†
Fodder roots	55†
Grassland	6*
Vegetable crops and bulbs	103† ϕ
Dessert, culinary and cider apples	217† ϕ
Bush fruit	247†
Cane fruit	153†
Strawberries	215†
Vines	284†

Figures greater than 100 indicate that these crops were treated on more than one occasion

Sources:

* British Agrochemicals Association Annual Report 1978/79
† Ministry of Agriculture, Fisheries and Food Surveys 1972–75
ϕ England and Wales statistics only

applied regularly every year and often several times each year invite critical comment about their ecological impact and the possibility of undesirable side effects on users and the public at large. The concern felt about their safety, whether misplaced or not, is exemplified by the recent adverse publicity in the national media about 2,4,5-T.

The need to reconcile the dependence of economic agriculture on herbicides and other pesticides with the desire to restrict their use to the minimum level that will allow efficient crop production was brought sharply into focus by the Royal Commission on Environmental Pollution in their 7th Report *Agriculture and Pollution*. The conclusion of the Commission that research should point the way to the practical development of cost effective and environmentally acceptable pest (or weed) management systems neatly summarised the research strategy adopted by WRO in recent years. At the agronomic end of the institute's programme much progress has been made in understanding the population dynamics of the important grass weeds wild-oats, black-grass and sterile brome in intensive cereal production, work which has enabled strategies for their rational control by herbicides to be developed for individual farms. The research needed is enormously detailed and time consuming but the results have been of great assistance to farmers and advisers and must surely set a pattern for the future. The role of herbicides and slot seeding as an integral part of grass sward improvement systems is another example from the institute's programme of the advances that are possible by considering herbicides as sophisticated crop management tools rather than as chemical hoes.

Such agronomic and agro-ecological work needs constant feeding by new information and ideas deriving from science based programmes which can shed fresh light on the factors influencing plant and herbicide behaviour. It is the marrying together of agronomy and the scientific disciplines underlying weed control technology which makes WRO unique as a weed research centre and gives it the ability to promote advances in weed control technology far beyond those that are possible by the empirical development of herbicides, so successfully undertaken by the agrochemical industry and by weed scientists working as individuals or in small teams. Thanks to the welcome change in the policy of ARC, which in recent years has lifted its embargo on basic research by WRO, and to the strengthening of the scientific staff which followed the dissolution of the ARC Units of Developmental Botany and Systemic Fungicides (see WRO 7th Report) the institute has at last reached a position when it can make major contributions to the science as well as to the practice of weed control.

VISITING GROUP ENDORSES RESEARCH STRATEGY

This change towards a strengthened science based programme without weakening the vital agronomic work of WRO found favour with the Visiting Group to the institute, made in October 1979 under the Chairmanship of Professor J Heslop-Harrison FRS. Their view was endorsed by ARC Council who also recognised that the institute's changing role created a difficulty in so far as many of the staff were recruited to undertake applied research and may not therefore be ideally qualified for the more basic programmes. As a result Headquarters have given assurance that they will support the recruitment of suitably qualified graduates to those posts which require innovative research workers as and when opportunity offers. The Visiting Group, which in addition to the Chairman consisted of Professor W W Fletcher, Mr J S Martin, Dr J R Corbett and Mr E R Bullen, proved an enjoyable and fruitful experience for the institute staff involved and I should like to acknowledge with gratitude the well informed, helpful and friendly way the group set about its task. In its report the group expressed satisfaction 'that the institute is doing excellent work, both in applied and strategic research relating to weed science and as a national information centre'. In the formal report that WRO prepared for the group a number of problems of staff imbalance were described mainly deriving from the rapid growth of the institute during a period of general stringency in the Agricultural Research Service when funds were limiting. Whilst the group considered these difficulties sympathetically and made appropriate recommendations, the recent curb in government spending and the imposition of cash limits have mitigated against any early solution. At the time of writing (May 1980) it seems clear that the level of funding of WRO by ARC will be inadequate to maintain the staff complement achieved by October 1979. From that time vacancies have had to remain unfilled so that we can keep within the allocated cash limit. Plans are now being made for adjusting the organization of staff which we hope will, in the longer term, result in a smaller but stronger institute and an acceptable ratio of running to staff costs. In the short term the members of those research teams which are under strength are having to do the best they can with the resources available and with the help of other groups. The spirit of co-operation and the determination of staff to meet the challenge of maintaining an effective and happy institute in spite of prevailing difficulties are not only characteristic of those who make up WRO but are very positive features of a generally difficult situation.

ROLE OF THE SCIENTIFIC ADVISORY GROUP

Whilst the role of the Visiting Group is to provide a formal report on WRO to the ARC for each 6-year period and to consider the very detailed report prepared by the institute, the Advisory Group to the Director is a continuing source of informal advice and encouragement. Chaired by Professor A H Bunting the group meets once a year but members are encouraged to visit the institute individually at other times to review those parts of the programme in which they have a special interest. I should like to take this opportunity to thank the group for the time, help and enthusiasm they have devoted to our affairs. I am particularly grateful to Professor Bunting for his continuing support and his willingness to share in our problems.

LIAISON ACTIVITIES

As the research programme has diversified and strengthened over the years it has increasingly provided information of direct relevance and of assistance to herbicide manufacturers and distributors as well as to farmers, growers, advisers and many others. This is as it should be since we have no wish to duplicate the work which industry can do as well or better.

With increased specialization and investment in all sectors of crop production, new high levels of expertise in the use of agrochemicals are called for and there is much scope for enhanced efficiency and economy. In order to promote the communication of WRO experience as well as to keep in touch ourselves with practical problems we have continued to provide two all-day seminars for distributors (Merchants Days: see page 34) and one for herbicide manufacturers (Chemical Industry Day: see page 33) each year in co-operation, respectively, with the United Kingdom Agricultural Supply Trades Association and the British Agrochemicals Association. These events are invariably over subscribed and reflect the intense interest of the industry in the type of work we now do. In 1980 we plan to hold the first Consultants Day catering for the specialist crop protection consultant advising large scale cereal growers. Such meetings provide opportunities for more detailed presentation of results and discussion than are possible with the biennial Weed Workshops aimed at a wider cross section of those connected with crop protection technology. The 1979 Weed Workshop attracted more visitors than ever, some 1300 people over the two-day period (see page 34). Other liaison events which should be mentioned are the annual two-day aquatic weed control meeting which now attracts some 50 participants and a one-day seminar on the management of amenity grassland, planned for 1980, which will be attended by representatives of the Countryside Commission, local authorities and other organizations concerned with research on, and the management of, land put aside for conservation and the enjoyment of the public.

PESTICIDE USE: REGULATION OR RESTRICTION

Whilst it is gratifying that WRO research is of interest to so many at home and abroad (more than 3100 visitors to the institute in 1978–79: see page 34) the fact that it is successful in showing the way to greater efficiency in the use of herbicides can on occasion bring the institute into conflict with commercial and official interests. Both consumer protection legislation and the development of the admirable British Agrochemical Supply Industry Scheme (BASIS) are reinforcing the insistence by manufacturers and distributors that pesticides are used only as recommended on the container label. Such label recommendations, which are the instrument by which official safety clearance of the Pesticide Safety Precautions Scheme is implemented, are influenced both by the manufacturers' marketing policy and a need to ensure an adequate standard of efficacy to satisfy the

Agricultural Chemicals Approval Scheme as well as the *average* user. A specialist user who is competent and anxious to use a pesticide as a finely tuned part of a crop production system may well find opportunities to use the chemical of his choice at lower doses or perhaps at different times to those recommended on the label with a significant increase in cost effectiveness. Such steps towards 'pest management' or 'integrated pest control', advocated so strongly by the Royal Commission on Environmental Pollution, are an anathema to the voluntary regulatory schemes operating in this country. A formula must, however, be found to accommodate such advances or else 'misuse' of pesticides by farmers and growers in the pursuit of greater efficiency and reduction in environmental hazard can only lead either to discrediting what is probably the finest regulatory system for pesticides in the world or the introduction of restrictive and expensive legislation.

RESEARCH COMMISSIONED BY OUTSIDE BODIES

The multi-disciplinary expertise available in WRO, its international reputation and its wide range of facilities for research are resulting in increased opportunities for undertaking work funded by organizations other than ARC and the Ministry of Agriculture, Fisheries and Food (MAFF). Apart from the longstanding arrangement with the Overseas Development Administration and the Commonwealth Agricultural Bureaux, who finance respectively the Tropical Weeds Group and much of the Weed Abstracts Group, work additional to the core programme is currently sponsored by Cyanamid Ltd (tolerance of wheat cultivars to difenzoquat), Imperial Chemical Industries Ltd (the selective control of aquatic weeds by diquat/sodium alginate), the Sugar Beet Research and Education Committee (control of weed beet), the Forestry Commission (herbicide evaluation for special weed problems of forest crops) and the Countryside Commission (feasibility study on the use of herbicides for the management of country parks and picnic sites). This last project and that sponsored by the Forestry Commission are noteworthy in that they form a logical extension of the expertise available at WRO on weed control in agricultural crops to the control of vegetation in non-agricultural land. The Countryside Commission project, which started in late 1979, is exploring the possibility of using selective herbicides as management tools and possible substitutes for the conventional grazing and cutting practices which in many amenity areas are no longer feasible. One of the principles involved is the ability of certain herbicides at very low doses to check coarse grasses sufficiently to prevent them becoming dominant and allowing diverse dicotyledonous plants like primroses, cowslips, orchids and thyme to flourish. This is yet a further example of how much of the institute's programme is now based on an ecological approach to weed control.

ACKNOWLEDGEMENTS

Finally, I should like to acknowledge the innumerable people who help to make WRO what it is: the farmers who are in the forefront of innovation and generously allow us to use their land and crops for experiments; herbicide manufacturers who make available chemical samples for research and co-operate in many other ways; advisers from ADAS and agricultural merchants who help us to keep in touch with practical problems and find experimental sites; university staff serving as supervisors to students at WRO; the Directors and staff at the other ARC institutes with whom we co-operate and many others. To colleagues at ARC Headquarters I express particular thanks for their advice and support. I am grateful to the staff of the Chief Scientist's Group of MAFF for their high level of interest and support for our programme, much of which is commissioned by the Ministry. Above all I wish to thank my colleagues at Begbroke Hill for their unswerving loyalty, enthusiasm and effectiveness and above all for their friendship which makes my task at WRO so enjoyable as well as rewarding.

J D FRYER
Director

PROGRESS REPORT

REVIEW OF RESEARCH

WEED CONTROL IN ARABLE CROPS

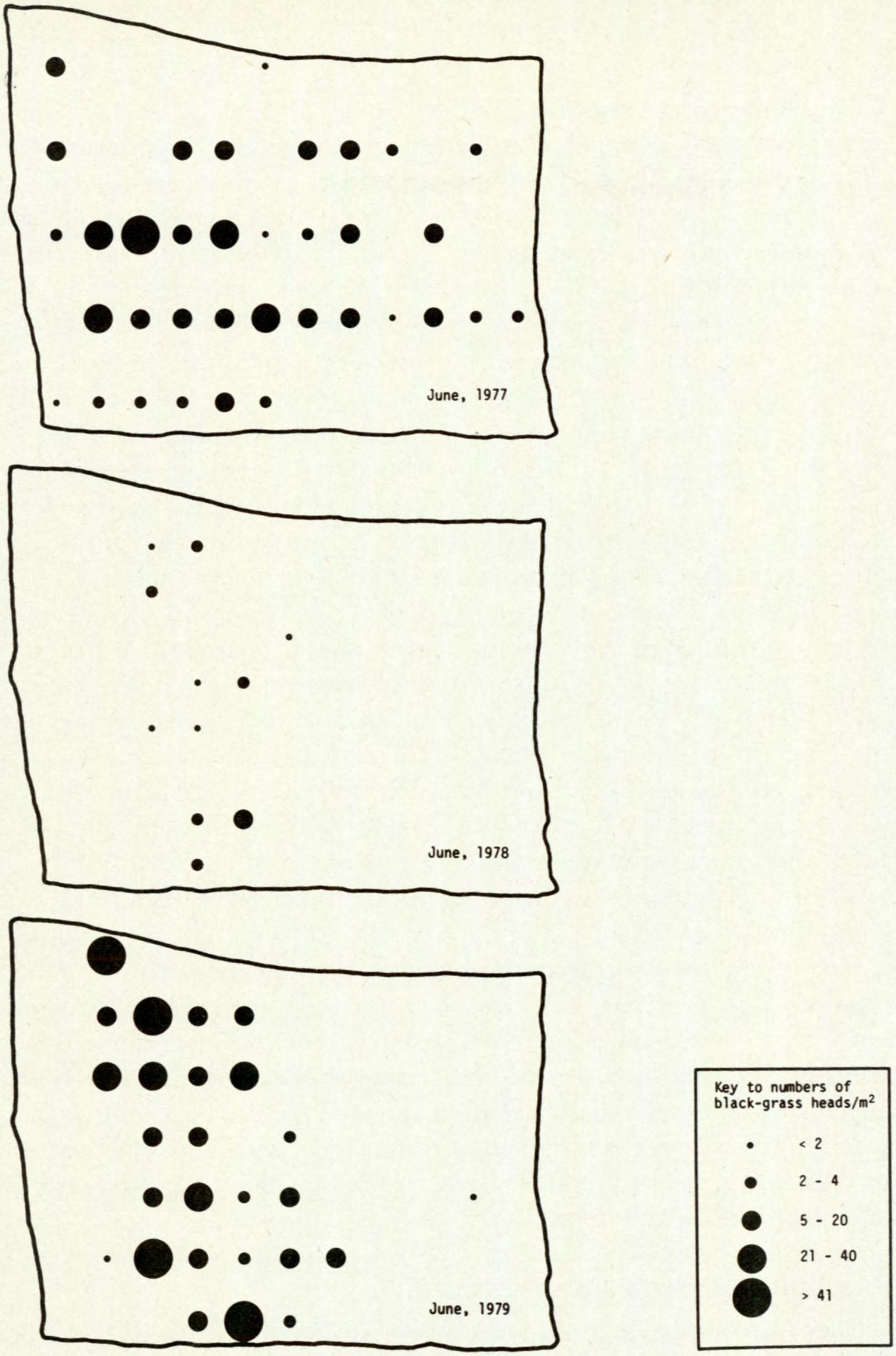
Previous reports have reflected the importance of the annual grass weed problem in modern cereal production and the complex inter-relationship of the many factors which contribute to the effective control of these weeds. A major part of the past research effort of WRO has been successively focussed on wild-oats (*Avena fatua*) and black-grass (*Alopecurus myosuroides*) with the result that various combinations of cultural and chemical measures have been suggested which should enable a farmer to reduce a serious infestation of these weeds to an acceptable level. It is now necessary to demonstrate how effective the various options are in practice, as described below, though there remain many aspects of the biology of these grass weeds requiring research as indicated in the article on the significance of seed dormancy in wild-oat on pp. 52–58. In addition, the development of new herbicide treatments, new measures of application and formulation, and a more complete understanding of the effect of climatic change on herbicide performance must also continue as described below and in the article on the latter topic at pp. 68–75.

Meanwhile, modern intensive methods of winter cereal production have enabled yet another grass weed to increase its weed status with alarming rapidity. Current knowledge of barren or sterile brome (*Bromus sterilis*) and the results of recent WRO research upon this weed are described in the article on p. 43.

Systematic approaches to the control of grass weeds in cereals

Previous work by the Annual Crops Group has shown that, when seed shedding is prevented, populations of wild-oats and black-grass in cultivated arable land decline fairly rapidly. This suggests that their persistence as weeds is only partly due to the survival of seeds already in the soil. Probably the major factor is the present inadequacy of control measures which allow fresh seeds to augment those already in the soil.

This possiblity has, so far, been confirmed by a systematic control project being carried out jointly with the Agricultural Development and Advisory Service on a commercial farm. This is located on heavy clay land farmed in two blocks, 120 hectares in a cereal/ley rotation and 21 hectares in continuous cereals. The land has a history of wild-oat and black-grass



Annual variation in distribution of black-grass heads/m² observed by WRO staff in a field under cereals at Neville's Farm, Wantage, 1977–79. The intensive herbicide use in 1978 reduced the infestation but the reduced use in 1979 allowed the infestation to increase again.

infestations and the two weeds are present on all fields, mostly at moderate to low levels. Weed populations have been mapped and monitored in detail every year since 1977. Weed levels declined in 1978 following intensive herbicide use, most fields having been sprayed twice for black-grass and wild-oats. With less expenditure on herbicides in 1979, poorer control allowed more weed seed to be shed and the weeds reverted to 1977 levels. Thus, once low levels of infestation are achieved, effective control measures must be maintained to prevent a rapid return to former serious levels of infestation.

Varying levels of wild-oat seed return are also a feature of a long-term systems experiment at WRO based on crop rotation, cultivation and herbicide use. Last season (1979), method of cultivation exerted a major influence on the emergence of seedlings. These accounted for only 4% of the estimated viable seeds present in the soil on ploughed plots, compared with 10% of those present in tine cultivated plots. Two levels of weed control were also compared. Difenzoquat* gave almost complete control in both wheat and barley. In contrast, a reduced dose of barban gave useful but poorer control. The estimated seed return from this latter treatment, after ploughing, was $295/m^2$ in wheat and $124/m^2$ in barley whereas, after tine cultivation, it was $459/m^2$ and $434/m^2$ respectively. The same treatments will be re-applied each year and the effect of these different levels of seed return on future populations will be recorded.

The importance of the autumn-germinating plants of wild-oat prompted a long-term study of the pattern of emergence of wild-oats in winter barley. Emergence of seedlings from fresh seeds was much greater in autumn 1979 than in the previous two autumns, possibly because of the wetter conditions. Three times as many seedlings emerged after tine cultivation compared with ploughing, but the reserves of seed in the soil were not affected by method of cultivation. When seed populations were artificially spread on to cereal stubbles in autumn, most seedlings emerged in the second spring even though seed reserves fell by half in the first year. This work continues and will be reported fully at a later date.

Progress with high speed sprayers

Earlier work by the Annual Crops Group, reviewed in the WRO 7th Report, showed that a lightweight, low-ground-pressure vehicle could still be used for spraying when the land was far too wet for the use of conventional

* British Standards Institute common names for herbicides are used throughout this report. The corresponding full chemical name of each compound is given in the glossary at p. 000.

equipment. Since then there has been considerable commercial development of such vehicles.

The other major finding was that this vehicle was much more stable than a tractor and could therefore travel much faster while spraying without excessive boom movement. By travelling at higher speeds, spray volume is automatically reduced without having to resort, as would be necessary at conventional speeds, to smaller nozzle sizes with their liability to blockage and the production of fine drift-prone drops. Recent work has concentrated on these relationships by comparing herbicides applied at volumes ranging from 60 to 220 l/ha and carrier speeds from 5 to 19 km/h using four different nozzle sizes.

The results suggest that low volume, high speed spraying in winter cereals could be successful, but more intensive confirmatory work is needed. Applications of a mixture of ioxynil, bromoxynil and mecoprop and of isoproturon gave high levels of weed control with all treatments. Spring applications of difenzoquat were also very effective at all spraying speeds but marginally better control was achieved with smaller and more numerous drops.

Herbicides for the control of grass weeds

The Herbicide Performance Group has inherited the role of the former Herbicide Group in the evaluation of both new and old herbicides for their potential in solving specific problems as they arise. For example, the recent trend in cereal production towards continuous cropping with winter cereals, earlier drilling and less mouldboard ploughing, has brought about a serious change for the worse in the weed status of a number of grass species. These include common couch (*Agropyron repens*) and black bent (*Agrostis gigantea*) growing from seed, and the two species of *Bromus*, sterile brome (*B. sterilis*) and soft brome (*B. mollis*).

Recent pot experiments have indicated that seedlings of both common couch and black bent can be controlled selectively in cereals by several of the herbicides used to control black-grass, e.g., methabenzthiazuron, metoxuron, chlortoluron, isoproturon, terbutryne and nitrofen. Sterile brome has, however, proved more difficult to control and although, in pots, a limited number of herbicides have shown promise either as pre- or post-emergence treatments, levels of control in the field have proved variable and a reliably effective treatment is still being sought. However, preliminary work on the effect of changes in formulation and application factors has proved promising and these approaches, and the possibility of more active herbicide mixtures, are being pursued further.

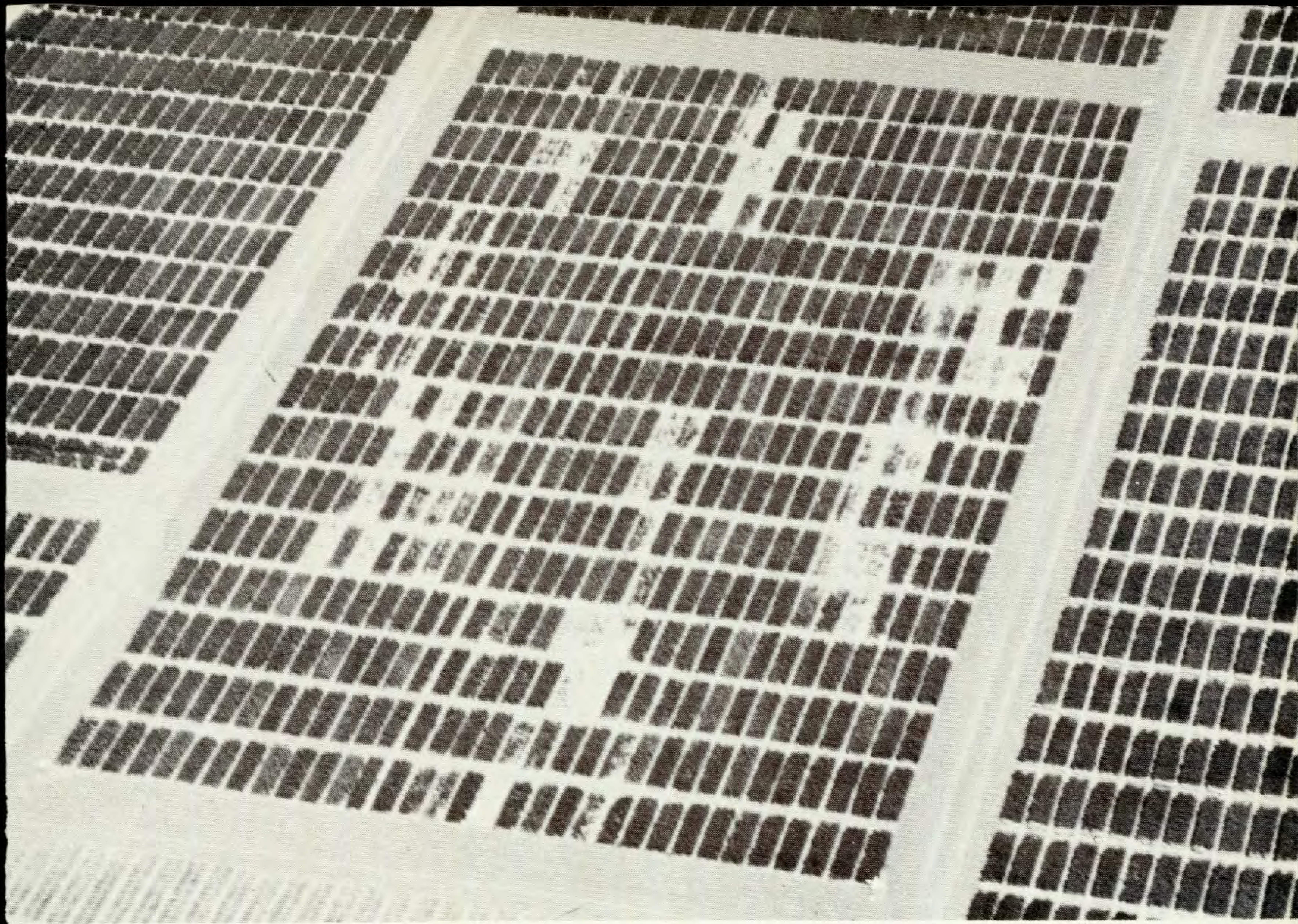
A number of other grass herbicides have also been evaluated recently which, while differing in their chemistry, are all effective on a very similar range of species. Although ineffective against broad-leaved weeds, they can selectively control a wide range of annual and perennial grasses in all broad-leaved crops and in onions. Annual meadow grass (*Poa annua*) is one important grass species which seems to be resistant to all these herbicides. Experiments with two of the compounds, alloxydim-sodium and trifop-methyl, have already shown that both are compatible in mixtures with most of the other herbicides which can be used in broad-leaved crops. Thus, it should not be difficult to extend the range of weeds susceptible to them.

Varietal differences in herbicide tolerance

Varieties of the same crop often differ in their tolerance of a herbicide. In cereals, differential responses to barban, metoxuron, chlortoluron and difenzoquat have been demonstrated. Field tests, in which high doses of herbicides are sprayed across strips of different varieties, enable indentification of the most sensitive varieties but yield effects cannot always be accurately predicted from visual assessments and potentially damaging treatments may escape detection. In collaboration with the Plant Breeding Institute, the Annual Crops Group has conducted two series of yield experiments using herbicide doses up to four times those recommended for weed control. The first trials were also run in association with Ciba-Geigy UK Ltd, and compared the tolerance of the black-grass herbicides chlortoluron and isoproturon by a range of winter wheat varieties. They confirmed the marked differences, previously observed in screening tests, between varieties sensitive to or tolerant of chlortoluron, and showed less obvious but significant varietal differences in tolerance of isoproturon. The second series of trials examined the responses of ten winter wheat varieties at two stages of growth to the wild-oat herbicides, difenzoquat and diclofop-methyl. Some varieties tolerated very high doses of difenzoquat while others were severely damaged at the normal dose. Varieties that showed an intermediate response are included in current field trials studying the interaction between variety and the growth stage at which the herbicide is applied.

The population dynamics of "weed beet"

The presence of weedy, mostly annual, off-types of beet in sugar beet land is causing great concern. Surveys conducted by the British Sugar Cor-



An aerial view of the joint WRO/Plant Breeding Institute/Ciba-Geigy trial in 1978 to determine the tolerance of the black-grass herbicides chlortoluron and isoproturon by a range of winter wheat varieties.

poration indicate that at least 24% of the national beet crop is affected although infestation levels are generally low.

A national committee is co-ordinating work on this problem and the Annual Crops Group at WRO is contributing in two ways. Candidate chemicals for weed control or growth regulation are being screened in the glass houses and an investigation has started into the population dynamics of weed beet.

The work is still at a very early stage but annual weedy types have already been shown to be prolific seed producers and their seed moderately persistent in the soil. Seed behaviour can, however, be modified by cultural factors; many more germinate, or die before germinating, when the seed is left near the soil surface.

WEED CONTROL IN GRASSLAND

As the costs of grass establishment continue to escalate, forcing farmers to accept far longer term leys, so the research of the Grass and Fodder Crops Group has focussed increasingly on the prevention of sward deterioration. Much attention has been given to the full exploitation of new herbicides permitting weed free establishment and preventing later weed ingress.

Survey indentifies re-seeding problems

Each year nearly 500,000 ha of grass are re-seeded in the UK but there is little information on how the grass is sown, what weed problems are encountered or what percentage of re-seeded swards are successfully established. To provide such information the Grass and Fodder Crops Group, in collaboration with the British Grassland Society, carried out a survey of farmers' experiences in Cornwall, Buckinghamshire, Derbyshire, Hampshire, Shropshire and North Devon. This survey involved 95 fields.

In just over half the fields the grass was spring sown and in a third it was established under a cover crop. Broadcasting was more common than drilling, the average seed rate being 29 kg/ha. A third of the fields were sprayed with a herbicide and the most important weeds were chickweed (*Stellaria media*), meadow grasses (*Poa* spp) and docks (*Rumex* spp).

Three months after sowing, one crop in eight was judged to be "thin". Badly drained or acid soils consistently gave poor establishment. Conversely, firm seedbeds and early grazing usually resulted in dense crops. Chickweed and docks were most often associated with dense crops, whereas grass weeds featured more in thin crops.

This survey clearly indicates the need for further research into the pre-requisites of successful re-seeding.

Herbicides ensure cleaner reseeds

Following the favourable indications of earlier glasshouse and small plot experiments, the benefits of early chemical control of grass weeds invading newly sown swards have been investigated in longer term field trials. In one such experiment, a single application of ethofumesate at 0.8 kg/ha to a newly sown autumn re-seed, heavily contaminated with chickweed and meadow-grass seedlings, increased ryegrass yields by some 40% over a three-year period, involving seven harvests. This work by WRO culminated in a commercial recommendation for the use of ethofumesate in re-seeded grassland.

A subsequent two-year experiment demonstrated that weed ingress could be contained using ethofumesate at sowing, followed by an application of methabenzthiazuron in the spring. Currently, a range of grass varieties are being tested for their tolerance of these two herbicides.

Pasture renovation with selective herbicides

The number of herbicides available for selective control of weeds in established swards continues to grow. The most recent addition stems from work at WRO which established the value of asulam for controlling the problem grass Yorkshire-fog (*Holcus lanatus*) in ryegrass swards. Work is now in progress to establish which pasture species are best adapted to colonise the gaps left in a sward after the removal of clumps of Yorkshire fog; preliminary indications suggest that species capable of rapid vegetative spread, e.g. white clover and red fescue (*Festuca rubra*), are most likely to succeed, rather than the more slowly-spreading perennial ryegrass.

The benefits of achieving legume dominance in mixed swards by using grass-suppressing herbicides in winter, are being studied in a 6-year joint experiment ith the Microbiology Group. The object is to find out how frequently propyzamide and carbetamide need to be used to maintain a given proportion of white clover. Early results are confirming that both herbicides increase clover and protein nitrogen yields and that compensatory growth of grass largely offsets the initial check in dry matter production.

Further developments in slot-seeding

The technique of introducing improved species of grasses, clovers and fodder brassicas into old swards, at low cost and minimum disturbance to soil and grazing management, continues to attract farmer and commercial interest. Research on row width, seed rate, band-spray herbicides, fertilizers and sward type have led to the publication of guidelines for slot-seeding. Current emphasis is on legume introduction; detailed competition studies are defining the establishment and survival requirements of white clover. An experiment with GRI is indicating a need to protect seedlings from insect attack.

Encouraging results have followed the slot-seeding of red clover into a ryegrass ley using a bandspray of either paraquat or glyphosate; the placement of phosphate fertilizer 3 cm below the seed has proved advantageous. High yields of good quality forage have been produced without the use of fertilizer nitrogen.

The Gibbs slot seeder; a commercial product built to meet the requirements of the WRO one-pass seeding technique for renovating permanent pasture.

Role of weed seeds in the deterioration of permanent pasture

The numbers and percentage composition of seeds in the soil beneath old indigenous pasture at WRO is being studied by the Weed Biology Group to assess the role of buried seeds in the deterioration of pastures. An initial soil sampling in spring 1978 indicated that there were 100 million seeds per hectare in the uppermost 15 cm of soil and that more than 40 species were present. The incidence of most species in the soil seed bank differed so much from that in the overlying vegetation that there was no close correlation between the two. An extreme example was that of the rushes (*Juncus* species) which, although absent from the above-ground flora, nonetheless made up half the soil seed bank. Seasonal changes in the soil seed population are now being investigated to determine the life-span and persistence of the seed of individual species.

The conditions necessary for seed germination and survival under grassland have also been the subject of laboratory and pot experiments. Results indicate that only a small proportion of seeds of a few grassland species are dormant when shed. Seed survival therefore depends upon dormancy being enforced and the extent to which this happens differs greatly between species. For example, dormancy is much more readily enforced in common bent grass (*A. tenuis*), which is more exacting in its germination requirements, than it is in perennial ryegrass (*Lolium perenne*), which is able to germinate over a wide range of conditions. Studies are now being made in the field on regeneration and seed germination in small areas of sward which have been damaged or killed.

WEED CONTROL IN PERENNIAL CROPS

Growers of fruit and nursery crops are becoming increasingly dependent on herbicides as suitable hand labour becomes more expensive and scarce. However there are certain weeds that cannot be controlled chemically in some crops, and there are still some crops for which there are no herbicide recommendations. The Perennial Crops Group is trying to correct these deficiencies. Work is in progress on the control of specific weeds and to reduce the amount of field testing needed for new recommendations. For some crops black polythene can now be used as an alternative to herbicides.

Pot tests speed search for new herbicides

Recommendations for soil-applied herbicides usually are based on field tests carried out over a period of 2–3 years on a range of soil types, chosen to ensure that the conditions experienced will include the extremes encountered in commercial usage. In practice, reliability of the results, especially in respect of crop safety, is very dependent on the weather and particularly on rainfall, so pot tests with plants grown in sand have been developed to provide more reliable information on crop tolerance.

The limitations of conventional field testing were illustrated by a test involving the use of four soil-applied herbicides in apples. In four years of field testing there was no damage to newly planted apples in the loamy soil at Begbroke, even at doses higher than those recommended. However, in one of those years, high doses of metribuzin and simazine damaged newly planted trees in a sandy soil at Luddington Experimental Horticulture Station. The amount of damage varied with the times of application, all of which fell within the period that a grower would reasonably expect to be able to treat newly planted trees.

In the fifth year the same high doses of metribuzin and simazine also caused damage at Begbroke. But it was confined to trees in their second year after planting whereas newly planted trees, which are normally considered to be more sensitive, were unharmed. The amount of damage was also influenced by the method of pruning which altered both the ratio of leaves to roots and the period of maximum leaf expansion.

It thus took five years and ten field tests to demonstrate that two herbicides could cause damage (albeit only at high doses) and that two others were safe. The same information had been indicated in a single pot test, lasting only a few months, six years previously.

Pot tests have also been used to screen and select the new herbicides that are now recommended for strawberries. This work is described in the report on page 59. As yet, the main use for the pot test results has been to concentrate field testing on the most promising herbicides. It is hoped that in future it will be possible to predict field performance from crop plants growing in large containers of soil which can be subjected to simulated rain. This will still further reduce the amount of field testing needed to develop new recommendations.

Black polythene increases growth

When black polythene film laid on the soil surface is used to control annual weeds there is a greater increase in crop growth than can be accounted for simply by the removal of weed competition. This has been shown in experiments at Begbroke on the effect of weeds on the growth of newly planted crops.

Blackcurrants mulched with black polythene have consistently outgrown and outyielded those kept weedfree with standard herbicides and/or careful hand weeding. Black polythene has also increased the extension growth of apples by 30–50% in 32 out of 34 trials in commercial orchards in the Southeast, East Anglia and the West Midlands.

The small scale of current commercial trials of black polythene in apples is largely because the laying has to be done by hand. It has been used more extensively in blackcurrants in which laying machines can work efficiently. Although all the WRO work has been with one-year-old blackcurrants, growers have been quick to appreciate the value of the technique for crops grown from cuttings. Cuttings are cheaper than bushes but they are more sensitive to soil applied herbicides; polythene overcomes this problem.

The future for black polythene will be determined largely by the availability of machines to lay it mechanically and the alternative offered by

Black polythene sheet, laid by machine, is gaining favour with growers as a safe alternative to soil-applied herbicides for blackcurrants.

herbicides in terms of effectiveness, safety and reliability. The cost of film will also be a key factor and in this connection experiments are now in progress to determine the optimum width for the mulched strip. Another aspect under investigation is the possibility of using polythene in the crop row and herbicides between the rows. Such an approach might permit the use of herbicides that cannot be used safely over the entire crop area. Although beyond the scope of the current WRO programme, it is apparent that the techniques being developed for tree crops could be used to control unwanted vegitation around the base of individual trees planted in amenity areas.

FORESTRY WEED CONTROL

Development of new herbicide treatments

The Herbicide Performance Group, with financial assistance from the Forestry Commission, continued to evaluate both new and old herbicides for use in forest nurseries and plantations. Some of the most interesting results in the last two years relate to summer applications of atrazine and terbuthylazine in young plantings. These treatments may provide better control of grasses such as purple moor-grass (*Molinia caerulea*) which commence growth in late spring. Earlier species such as creeping soft-grass (*Holcus mollis*) are probably more susceptible earlier in the year. The activity of triazine herbicides applied to foliage can often be increased by oil or surfactant additives.

In studies relating to pre- or post-emergence weed control in forestry seedbeds, the herbicides butam, butralin, prodiamine, isopropalin, fluorodifen, napropamide, terbuthylazine and bifenox all showed promise.

AQUATIC AND AMENITY VEGETATION MANAGEMENT

The projects of the Aquatic Weed and Uncropped Land Group differ from those of other research groups at WRO, in that they are not concerned with the reduction of weed competition in crops but with the management of natural vegetation in water and rural amenity areas. In most cases the objective is to reduce plant density without destroying all the vegetation; current work is primarily concerned with the use of chemicals to achieve this objective.

Localized control of submerged weeds

An adequate range of herbicides has been available for some years for the total control of emergent, floating and submerged aquatic plants. The removal of emergent vegetation may be achieved simply by spraying herbicides on the leaves. Employing glyphosate, this method can also be used to remove unwanted patches of water lilies. However, localized control of submerged plants by this means is not possible, because the recommended concentration of herbicide has to be maintained throughout the body of water and then all susceptible plants succumb. Thus, the main object of our recent research with herbicides has been to find ways of achieving localized control of submerged plants. We have used two herbicides, dichlobenil and diquat, both of which are already cleared for use in water under the Pesticides Safety Precautions Scheme.

Dichlobenil is recommended for use at a concentration of 1 ppm to kill a wide range of submerged vascular plants. This recommendation is based on the assumption that the herbicide in solution is taken up by the plant through its foliage. However, when the chemical is used in terrestrial situations it is applied to the soil and taken up by the roots and other underground parts. This suggested that, if rooted aquatic plants behaved in a similar way, the application of granules containing the chemical to the mud might provide an effective way of achieving localised control. This was confirmed in 1978 and '79. Whole blocks of vegetation within weed beds in lakes were cut out simply by spreading the granules evenly on the surface of the water and allowing them to sink into the mud. Water and plant analyses showed that absorption of the dichlobenil was confined to the rooted plants in the treated plots and that the very small quantity that dissolved into the water was totally ineffective against plants outside the plots.

The second method of localizing control involved a novel carrier for diquat. Diquat has to be absorbed by actively photosynthesising plant tissue to be effective and is normally used against aquatic weeds at a concentration of 1 ppm. Water movement and diffusion make it impossible to maintain the required phytotoxic concentration in one part of a lake long enough to achieve localised weed control. By adding diquat to a viscous solution of sodium alginate it has often been possible to overcome this problem in lakes, and also to cut narrow channels through weedbeds in swiftly flowing rivers. The principles underlying the behaviour of the mixture have not been fully elucidated but work is continuing in collaboration with the commercial companies concerned. The technique has created a great deal of interest in the water industry and fishing and sailing fraternities, because it is more acceptable environmentally.

Microbial contribution to deoxygenation of water

Considerable residues of aquatic plants are often left in water following weed control measures. In static water this may be accompanied by deoxygenation of the water and it has been suggested this partly results from microbial decomposition of the plant material. The Microbiology Group collaborated with the Aquatic Weed Group in an investigation of this phenomenon in a small lake in Oxfordshire, heavily infested with the filamentous alga *Spirogyra* sp., which had been treated with terbutryne. Early results indicate that, as expected from previous work, the herbicide stopped photosynthesis by the alga and other aquatic plants but did not effect their respiration which thus caused deoxygenation. Microbial

Localized area of pond weed killed by diquat/alginate applied originally at position marked by white stake.

decomposition of the plant residues was not appreciable until after deoxygenation was established. Factors such as water temperature and movement by wind action, which affect oxygen solubility and diffusion into the water, appear to play important roles.

Deoxygenation of pond water has also been successfully simulated in the laboratory. Dense 'blooms' of the unicellular alga *Stichoccus* sp. were treated with terbutryne, at normal dose (0.1 ppm). Three to four days later the bacterial population in the water increased greatly, as a result of nutrient release from dying algae, and the oxygen content dropped to zero. It seems that, in this system, microbial consumption of dissolved oxygen is a major contributor to deoxygenation.

Parallel studies in the lake, in artificial ponds, and in the laboratory have not shown any effect of the use of terbutryne on aquatic bacteria, protozoa or planktonic algae which indicates harm to the ecosystem.

Herbicide mixtures and sequences

For practical and economic reasons farmers and growers are now making increasing use of mixtures and sequences of herbicides or other crop protection chemicals. Mixtures of herbicides have therefore featured strongly in the evaluation programme of the Herbicide Performance Group in recent years. Mixtures of barban with metoxuron, difenzoquat with isoproturon, and diclofop-methyl with isoproturon were found to be particularly successful for the control of mixed populations of black-grass and wild-oat, and have subsequently been commercially developed. In more recent work, a mixture of triclopyr and 3,6-dichloropicolinic acid has proved particularly effective against well-established perennial species such as coltsfoot (*Tussilago farfara*), broadleaved dock (*Rumex obtusifolius*), gorse (*Ulex europeaus*) and creeping thistle (*Cirsium arvense*) occurring in perennial ryegrass.

The Herbicide Performance Group has recently been strengthened by the addition of Dr H F Taylor, a biochemist formerly attached to the now disbanded ARC Unit of Systematic Fungicides. He has started a programme of strategic research with the objective of explaining some of the reasons for the antagonism which can occur between broad-leaved herbicides such as 2,4-D and wild-oat herbicides such as diclofop-methyl. So far, herbicide metabolism and translocation appear to be implicated in the reduction of diclofop-methyl activity by 2,4-D.

Herbicide additives

Recent work with additives in the Herbicide Performance Group has concentrated on the autumn control of common couch in stubbles and the selective control of wild-oats in cereal crops.

The enhancement of the activity of low doses of glyphosate by the addition of ammonium sulphate and/or surfactants is now well established. Where a couch grass population does not justify more expensive control measures, routine use of low doses of glyphosate with the addition of suitable adjuvants can be a useful method of containing the weed infestation. The technique has been used in practice by a number of interested farmers, apparently with satisfactory results.

More recently, attention has been given to another aspect of glyphosate usage, namely rainfastness. In experiments in which plants were sprayed with the recommended doses of glyphosate and subjected to simulated rain within 2–6 h of treatment, the addition to the spray solutions of ammonium sulphate with the lipophilic surfactant Ethomeen C12 markedly increased phytotoxicity.

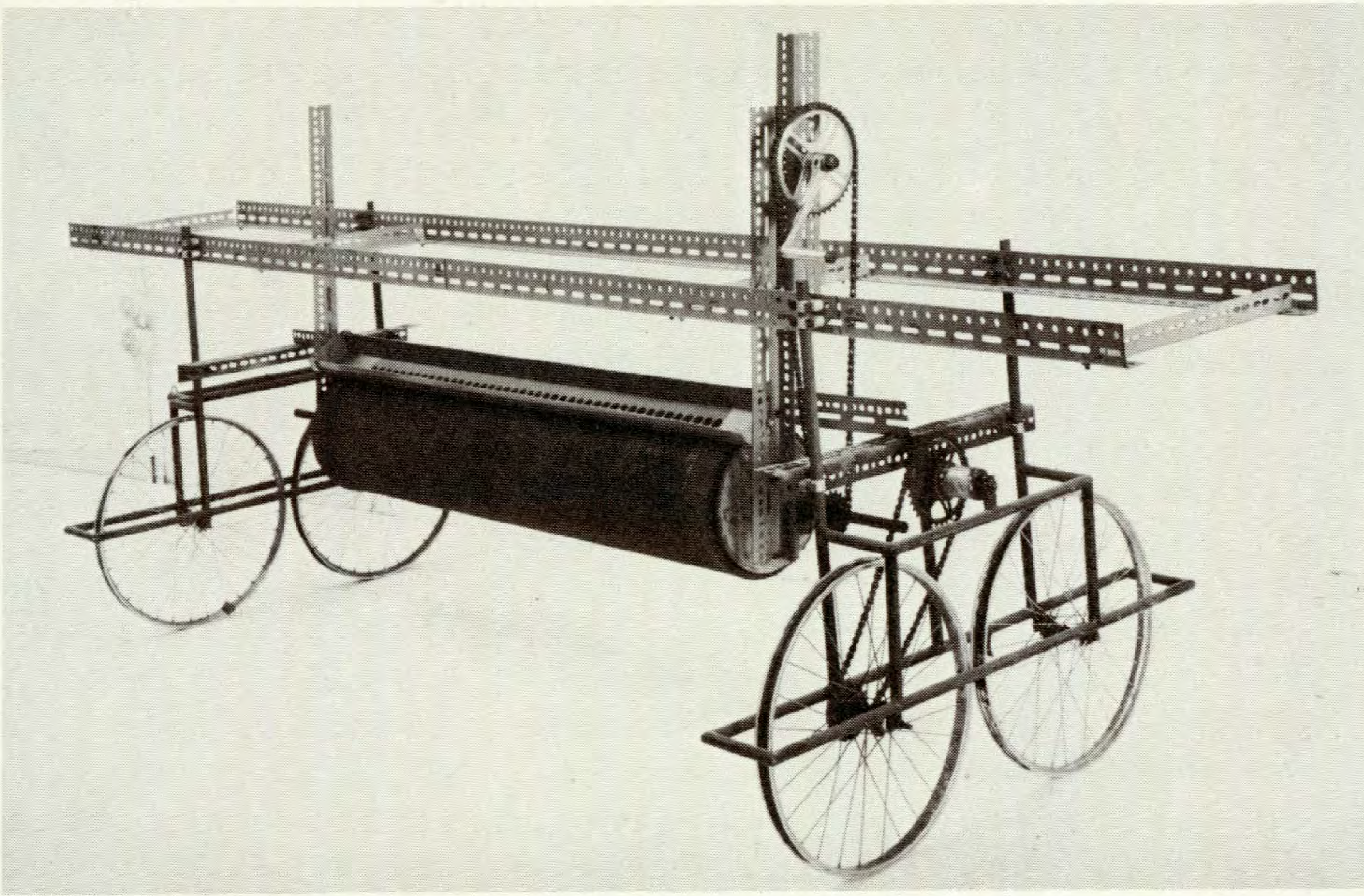
Earlier experiments with the wild-oat herbicide difenzoquat indicated that low volume CDA treatments were less effective than conventional medium volume applications (refer WRO 6th Report, pp 84–85). In the last two years our studies of the effect of adding solubilized oil on the activity of difenzoquat have progressed from the laboratory to the field. In the latter, the addition of a 5% oil and surfactant mixture to difenzoquat applied in 20 l/ha with a rotary atomizer markedly improved wild-oat control to the extent that the low volume sprays of difenzoquat were as effective as equivalent 200 l/ha conventional applications. The additives also slightly increased the phytotoxicity of the herbicide when sprayed conventionally.

Selective application of herbicides

Because of the difficulty of controlling some aggressive weeds within crops with selective herbicides, alternative methods based on smearing non-selective herbicides such as glyphosate on to individual weeds are being investigated both by the Annual Crops and the Grass and Fodder Crops Groups. In particular, attention has been focussed on the possibility of controlling tall weeds in short crops and grassland. It is clear from preliminary work on such weeds as volunteer potatoes, docks and thistles that topical applications of small and concentrated amounts of glyphosate will achieve good control. The suspension of the herbicide in an alginate gel is also effective in reducing splash and run-off. A prototype applicator, consisting essentially of a rotating roller that smears herbicide on to the tall weeds but not the shorter crop, has been tested with some success. Volunteer potatoes have been controlled in carrots and sugar beet, although in the latter crop the level of crop damage was too high and further work is needed. Docks and thistles have also been successfully controlled in grassland. Further work with a commercial roller applicator is in progress.

Straw ash reduces performance of black-grass herbicides

The new Environmental Studies Group came into being on 2 April 1979 and comprises the 'environmental team' of the former Herbicide Group plus two more graduate biologists. The group has continued its former programme of research into the effects of environmental factors on herbicide performance, details of which are given in the article on p. 68.



The WRO experimental roller applicator for smearing herbicide on to tall weeds in short crops has shown the technique has promise in some arable crops and in grassland.

The recent increase in staff has also enabled the group to investigate the inconsistent field performance of the pre- and post-emergence urea-based black-grass herbicides chlortoluron and isoproturon.

In pot experiments designed to simulate the pre-emergence application of these two herbicides to black-grass in burnt stubble, the ash resides of the burnt straw were found to reduce the activity of both herbicides when they were applied soon after burning. At low humidity, post-emergence treatments primarily exerted their effects via the soil, but uptake from the foliage increased under warm humid conditions. A greater quantity of these herbicides was observed to enter the plant from the inner part of the leaf sheath than from the leaf blade.

The effect of changing environmental factors

Studies with both wild-oats and common couch clearly showed that morphological and physiological differences induced by the environment in the pre-spraying period can also have significant effects on herbicide performance. For example, reduced light levels led to increases in both leaf area and herbicide spray retention in wild-oats. This resulted in an improvement in the performance of benzoylprop-ethyl but that of difenzoquat was unaffected. Moisture stress reduced the activity of both these herbicides.

In short-term studies of the effect of the post-spraying environment on the activity of herbicides on common couch, high temperatures favoured rapid translocation of ^{14}C-glyphosate whereas cool conditions increased activity in the rhizome buds (see the article on pp.68). The activity of the wild-oat herbicides benzoylprop-ethyl, diclofop-methyl and difenzoquat was enhanced by high humidity following spraying.

The mode of action of glyphosate

The fate of glyphosate has been followed in ^{14}C-glyphosate treated couch grown in nutrient solution. The root exudates contained undegraded glyphosate but only in quantities unlikely to affect adjacent plants. Biochemical studies on the mode of action of glyphosate, using single node fragments of couch rhizome and wheat roots, indicated that the phytotoxicity of glyphosate is mediated, at least in part, by a decrease in free phenylalanine. This results in a stimulation of phenylalanine ammonia lyase (PAL) activity and an inhibition of protein synthesis.

HERBICIDE/SOILS RESEARCH

Movement of herbicides in the soil

The work previously reported by the Chemistry Group in the WRO 7th Report (pp. 23–24) has been pursued further in collaboration with the ARC Letcombe Laboratory and Rothamsted Experimental Station. The movement of fluometuron and simazine, together with that of $^{36}Cl^-$ (to monitor water movement) and $^{144}Ce^{3+}$ (to trace movement of soil particles), was measured in the field at two sites. At Begbroke Hill fluometuron moved a little, but, after 185 days, the bulk of it remained in the top 6 cm. At Compton Beauchamp there was essentially no movement below 3 cm. Simazine at both sites was almost entirely confined to the top 3 cm. The adsorption characteristics of the two compounds are similar so presumably the higher mobility of fluometuron is a consequence of its greater water solubility.

The movement of water, as indicated by ^{36}Cl distribution, in relation to that of the herbicides, supports the hypothesis that there are mobile and immobile categories of water in the soil and that the mobile component may move too fast for equilibrium to be established with the solutes present in the soil. The movement of soil particles, as measured by $^{144}Ce^{3+}$, was similar in extent to that of simazine. It seems, therefore, that soil structural effects can be more important than adsorption in controlling the movement of solutes.

In a parallel laboratory experiment, using a standard leaching column technique of the sort included in registration guidelines, the movement of both herbicides was considerable and gave a misleading indication of mobility in the field.

Breakdown products of atrazine and diuron are unaffected by soil pH and fertilizers

It is well established that soil pH can affect herbicide persistence and that this could reflect changes in the soil microflora. In the field, transient high salt concentrations may occur close to fertilizer granules which could also change the component organisms of the soil population. Such changes could, in turn, affect the nature of the degradation products of a herbicide but studies of herbicide metabolism in the soil do not normally reflect this possiblity. To test this hypothesis, ^{14}C-labelled atrazine and diuron were incubated in the laboratory with samples of two soils, adjusted to pH4 or 8, and containing either none, 0.2% or 20% of a compound fertilizer. The highest fertilizer rate was an attempt to reproduce the conditions that might exist immediately adjacent to a fertilizer granule in the field.

The nature of the radio-active products from both herbicides was not affected by the soil treatments. Although the proportion of hydroxy-triazine derivatives of atrazine was greater from the soils adjusted to the lower pH, this was to be expected as atrazine can be hydrolysed non-biologically. Otherwise there were no great differences, which shows that the metabolic pathways of these compounds in soil are insensitive to wide variations in salt concentration and pH. Thus, it should not normally be necessary to include a wide range of conditions in studies of degradation products such as those required to meet registration requirements.

Some degradation of paraquat may occur in the soil

Paraquat applied to the soil is so strongly adsorbed that it is usually assumed to be unavailable, not only to susceptible plants but also to the micro-organisms that might decompose it. In an experiment at WRO to test this assumption, paraquat has been applied annually to field plots at

4.48 kg/ha since 1967 and soil samples have been analysed at regular intervals. There is, inevitably, great variability in the residue levels within field plots and small differences are difficult to detect so that, in the early years of the experiment, no breakdown was apparent, as expected. After 11 years, however, it is clear that the residues present are less than the total amount of paraquat that has been applied. The decline is consistent with a yearly rate of loss of about 10% of the total amount present immediately after each annual application. Co-operative work is now in progress with ICI Plant Protection Division to try to identify the processes involved.

HERBICIDE MICROBIOLOGY

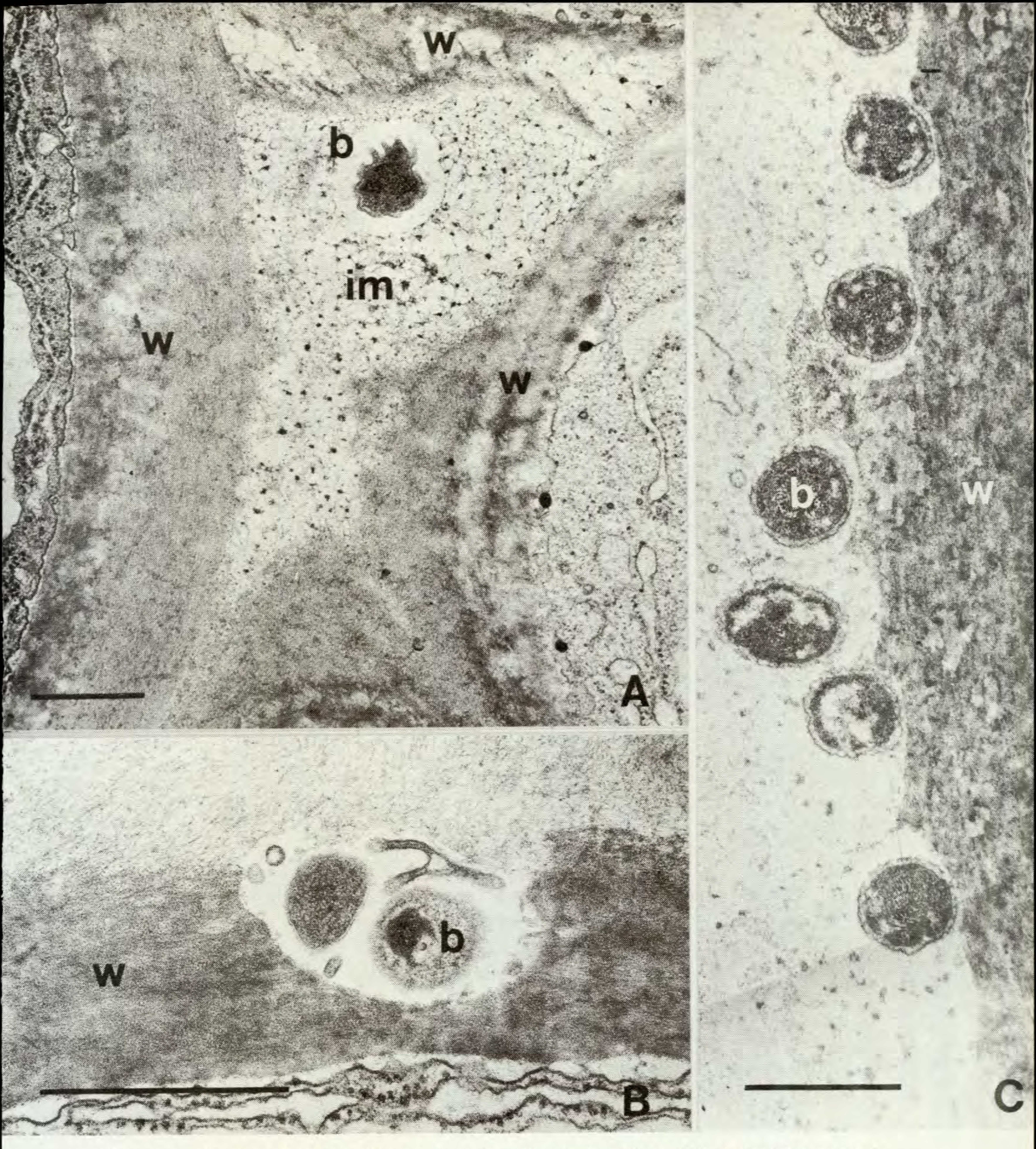
Effects of herbicides on the soil microflora

The Microbiology Group continued to give priority to the evaluation of methods of assessing the effects of herbicides on soil microbes. Many of the methods evaluated were published in *WRO Technical Report No.* 45. Subsequently this was used as a standard reference by the International Group of National Associations of Pesticide Manufacturers in their contribution to an FAO meeting on the harmonization of environmental criteria for the registration of pesticides.

The response of the microflora to a herbicide can vary with the environmental conditions obtaining in the soil. Recent work has shown that herbicides may have more pronounced effects on soil microbial processes when fertilizer is present, possibly because the fertilizer can lower the pH of the soil. Thus, in the presence of fertilizer, asulam completely stopped the microbial oxidation of ammonium-nitrogen whereas in the absence of fertilizer, the herbicide had little effect. Future development of this work will include the effect of nutrient uptake by plants on the interactions between fertilizer, herbicide and microflora.

Herbicide effects on the root microflora

Some effects of the misuse of mecoprop on wheat roots were described in the WRO Reports for 1974/75 and 1976/77. Further investigation has shown that the invasion of the root tissues is confined generally to bacteria. A wide range of bacterial types is present in the root cortex. One group, the fluorescent pseudomonads, is particularly well represented and they have been investigated further. Electron microscopy has revealed a variety of effects on the root tissue which appear to be associated with the invading bacteria. Cell walls are damaged, protoplasm is disrupted, and the junctions between cells are softened so that cells pull apart and may slough



Electron micrographs of sections through roots of wheat (var. Maris Dove) damaged by mecoprop and invaded by bacteria: (A) Bacterium (b) attacking intercellular material (im) in the root cortex. Note also damage to cell walls (w) at top and right of the micrograph. (B) Bacteria (b) 'dissolving' a hole through the wall (w) of a cortex cell. (C) Bacteria (b) 'dissolving' the wall (w) of an epidermal cell. The bar represents 0.5 μm.

off the root. Some of these effects are illustrated on p. 29. Bearing in mind the implications for crop growth, a detailed examination of these effects and the bacteria which may be responsible is being made in collaboration with the Developmental Botany Group.

Legume nodulation and nitrogen fixation

In glasshouse trials, several herbicides have reduced the nodulation of, and so the fixation of nitrogen by, legumes such as pea, french and field beans, clover and fenugreek. This is almost certainly due to the effects of the herbicides on the host plant rather than to any direct effects on the *Rhizobium* spp. It is clear that factors such as nitrogen fertilizer level and stage of legume growth at spraying could modify the effects and these have been examined further. As yet there is little evidence that the reduction in nitrogen fixation that occurs in the field is such that crop yield is affected. However, there is a possibility that, in situations of low nitrogen, the effect could be significant and nullify or reduce the benefits of weed control.

A detailed study of the indirect effects of the use of herbicides to suppress grass growth and so improve clover content in grassland has commenced in collaboration with the Grass and Fodder Crops Group. The nitrogen content of soil and plants and the nodulation and infection of clover by symbiotic mycorrhizal fungi are all being examined. Early results indicate little or no effect of herbicides on the micro-organisms or their activities.

BIOMETRICS

Members of the ARC Letcombe Laboratory/WRO Joint Biometrics Group continued to advise and assist WRO staff in the design and analysis of experiments and in computing, and investigated problems arising out of this work. The computer terminal facilities at WRO have now been considerably improved by the installation of a serial printer which has speeded up the completion of computing jobs.

Principal component analyses have been carried out to assist in examining the changes in the distribution of a large number of weed species in a field which occurred over a 12-year period. Bioassay information on the movement of herbicides down soil columns, which was difficult to treat by standard methods, has been analysed successfully using simple parameters derived from curves describing their overall vertical distribution. Progress has also been made with the development of a computer program to handle the data obtained from a patternator table and thus speed up the time-consuming process of selecting and matching spray jets to give as uniform a distribution as possible.

OVERSEAS ACTIVITIES

ODA TROPICAL WEEDS GROUP

In the last two years the glasshouse and laboratory facilities available to this group at WRO, financed by the Overseas Development Administration, have largely been monopolised by the special witchweed (*Striga*) research project described in the article on pp. 76–83. Evaluation of new herbicides on tropical species has, however, continued and some new grass-killing herbicides have shown great potential for the control of perennials such as seashore paspalum (*Paspalum vaginatum*), a salt-tolerant grass which is a serious weed in tidal swamp rice in Sierra Leone. Some new herbicides with potential for controlling purple nutsedge (*Cyperus rotundus*) in cotton have also been studied. Fluridone was found to be more selective than the other compounds available but has an undesirably long persistence in soil. The use of herbicide antidotes to protect direct sown rice has been further investigated.

The liaison activities of the group have included discussing weed problems with many overseas visitors and responding to requests from research workers in developing countries for information and advice. Eleven annotated bibliographies were prepared on tropical weed control topics.

Advisory visits to developing countries

The leader of the Tropical Weeds Group (as ODA Liaison Officer) made several advisory visits in response to requests from developing countries. These included visits to the United Planters Association of Southern India to advise on weed control and weed research in tea; to an ODA/West African Rice Development Association project in Sierra Leone to advise on control of seashore paspalum and other weeds in tidal swamp rice; and to the Regional Centre for Tropical Biology in Indonesia to assist in a training course and to advise on a research programme on spear grass (*Imperata cylindrica*), a dominant problem for the transmigrants from Java attempting to settle in Sumatra.

He also travelled widely in connection with the witchweed research project, including participation in a Striga/Orobanche Workshop in the Sudan in November 1978; attending the 2nd International Symposium on Parasitic Weeds in USA, July 1979, and spending three weeks in late 1979 as a member of a USAID team touring West Africa and the Sudan to prepare proposals for a major USA-financed witchweed project for West Africa.

In August 1978 and again in March 1979 the Director visited India on behalf of ODA to attend the 17th Co-ordinated All-India Wheat Workshop at Hyderabad, to discuss the establishment of a central interdisciplinary weed research unit under the Indian Council for Agricultural Research, and to advise on a strategy for the control of canary grass (*Phalaris minor*), a serious weed of irrigated wheat in India.

Following his earlier survey of weed problems in the Gambia, the ODA "home-based officer", P J Terry, has been seconded there for at least 12 months to establish simple weed control trials and determine the situations in which improved methods should be introduced.

Before leaving for the Gambia, P J Terry spend six months preparing a weed control manual for East Africa. The project, requested by the Kenya Government and sponsored by ODA, included a visit to Kenya, Tanzania and Zambia to collect material for the book which is scheduled to be published by the East African Literature Bureau by late 1980.

LIAISON AND INFORMATION

LIAISON

Now that the financing of agricultural research is subject to strict cash limits the long-established role of WRO in promoting liaison between all concerned with the advancement of weed science and technology in the UK has become even more important. It is vital that the funds available should be spent to the greatest effect and, to this end, previous arrangements for coordinating WRO research with that taking place in other official, commercial and university centres have been maintained and where necessary, further developed.

Liaison with ADAS

The Agricultural Development and Advisory Service Liaison Unit at WRO comprises an agricultural and a horticultural herbicide specialist and the

Herbicide Liaison Officer of the Agricultural Chemicals Approval Scheme. In addition to responding to technical equiries from their ADAS colleagues, farmers and growers, the Liaison Officers plan and coordinate ADAS herbicide trials; a common feature of these is the further development of techniques originating at WRO including new herbicide treatments for minor crops. They are also responsible for drawing the attention of WRO to new problems requiring research, for the compilation of ADAS technical leaflets on weed control, for keeping their colleagues informed of new developments, for liaising with herbicide manufacturers, and for giving talks on weed control to farmers and growers.

The Herbicide Liaison Officer of the Agricultural Chemicals Approval Scheme is seconded to WRO from the Ministry of Agriculture's Plant Pathology Laboratory at Harpenden. The purpose of the scheme is to enable users to select efficient and appropriate crop protection chemicals and to discourage the use of unsatisfactory products. The Herbicide Liaison Officer is thus in the unique position of being fully informed of all stages of industry's development programmes for new herbicides while having access to all the information emanating from WRO research.

Contacts with the agrochemical industry

The annual Chemical Industry Days organised in conjunction with the British Agrochemicals Association, described in detail in the WRO 7th Report, were again repeated in 1978 and '79 providing the occasion for mutually advantageous contact between younger staff of chemical firms and WRO staff. Over 80 visitors participated on each occasion.

In both years WRO staff contributed to the annual Review of Herbicide Usage sponsored by the British Crop Protection Council.

In 1979 the Head of the Microbiology Group at WRO was asked to organize, in collaboration with Dr N Poole of ICI Plant Protection Division, an international workshop on the effects of pesticides on soil micro-organisms. The workshop, held in November at Jealott's Hill Research Station, was attended by 35 delegates from all over Europe representing government research, universities and industry. The workshop resulted in the production of unanimously agreed recommendations for methods of testing side-effects of pesticides on the soil microflora which, now published as *WRO Technical Report No.* 59, have been circulated widely, particularly to the authorities responsible for the registration of pesticides.

Liaison with agricultural merchants

Farmers obtain a great deal of their advice on chemicals from agricultural merchants' representatives so it is important that the latter should be as technically knowledgeable as possible. WRO contributes to their education through the two Merchants' Days held each February in conjunction with the United Kingdom Agricultural Supply Trades Association. A total of 320 merchants' staff attended the days held in 1978 and 1979 and it has been gratifying to observe the steadily rising level of technical knowledge of those attending.

Weed Workshop '79 and other events

Weed Workshop '79, held on 13th and 14th June 1979, was the 5th in this series of biennial displays of major topics of current research at WRO. The occasion featured weed control in winter cereals, grassland management with herbicides, new developments in fruit weed control, and factors affecting herbicide performance. The objective, as always, was to subject current research achievements to the hard-headed appraisal of practising farmers and growers as well as that of colleagues from industry, the universities, the advisory services and other ARC institutes. The record attendance figure of over 1300 undoubtedly reflected the ever-growing interest in WRO's activities. For the first time also, farmers and growers formed over 30% of the visitors.

The graphic staff of the Information and Public Relations Group also designed several displays of WRO research for exhibition at the Chelsea Flower Show, Potato Marketing Board Spring Demonstration, and British Crop Protection Conference—Weeds in 1978, the British Growers Look Ahead Conferences in 1978 and 1979, and the Royal Agricultural Society's Barley '79 Demonstration.

Apart from the visitors to Weed Workshop '79 and the participants in the Merchants and Chemical Industry Days held in both years, nearly 1300 group visitors came to WRO in 1978–79 whose reception and programmes were organized by the Information and Public Relations Group.

Conferences

WRO staff have always actively participated in the organization of weed science conferences and symposia sponsored by scientific societies. Whether in the UK or overseas, these events provide an excellent opportunity for the presentation and discussion of the results of research while some, like the British Crop Protection Conference—Weeds, afford research workers from WRO and other institutions a unique chance to meet

Two of the 1300 visitors to Weed Workshop '79 discussing the role of herbicides in grassland management with a member of the Grass and Fodder Crops Group.

their opposite numbers from the world's agricultural industry. This was well illustrated by the 1978 BCPC weed conference where, of a total attendance of 1600, some 1000 delegates represented chemical firms, many from overseas. Some 26 WRO research staff attended and contributed 24 out of the total of 143 papers presented.

In 1978/79 senior staff also served on the organising and programme committees of the BPC symposium on controlled drop application; the European Weed Research Society's international symposium on aquatic weeds; the EWRS symposium on the influence of different factors on the development and control of weeds; the British Grassland Society's symposium on changes in sward composition and productivity; and various symposia organised by the Physiochemical and Biophysical Panel of the Society of Chemical Industry.

Details of the overseas conferences and symposia in which WRO personnel participated are given on pp. 106–108.

The National Wild-oat Advisory Programme

Readers of the WRO 7th Report will recall that the National Wild-oat Advisory Programme, started in 1972, was a joint venture by official and commercial organizations to improve farmers' knowledge and control of wild-oats. WRO was heavily involved in the organisation of both the programme and the national survey of wild-oats and other grass weeds that occurred in 1977. Now that the survey is complete and published it stands testimony to how much can be achieved by the voluntary collaboration of many diverse people of common purpose and goodwill. By any standards the survey was a tremendous effort; 2250 fields were visited on 1153 farms throughout the United Kingdom. A vast amount of data was collected and fed into a computer; as a result, massive concertinas of computed results accumulated, enough, it might be thought, for years of study. Yet a team of authors, led from WRO, digested this mass of data to produce first a preliminary report in February 1978 (only 6 months after the completion of the field work), and then a full report which was submitted for publication in August 1978 and appeared in April 1979. This full report*, containing 23 tables of data will stand not just as a description of the weeds that were surveyed, but also as an up-to-date statement on cereal growing in the United Kingdom.

With the completion of the survey the National Programme has been scaled down, and its effects are being appraised.

INFORMATION AND PUBLICATIONS

It is the provision of specialist library, current awareness and information retrieval services, both to its own research staff and other weed scientists, that has won widespread recognition for WRO as a national centre for information on weed science. These services are largely the responsibility of the staff of the Information and Public Relations Group who, in 1978–79, managed to cope with a further increase in demand. This was reflected in more than 1800 inquiries answered and in the preparation of 13 new annotated bibliographies on selected topics. Over 840 requests for these and earlier bibliographies were processed. In addition, as a result of circulating some 850 weed scientists and institutions with half-yearly lists of WRO publications, requests were received for nearly 15600 reprints, 500 technical reports and 2500 copies of the WRO 7th Report. There were also 46 external subscribers to the weekly Current Awareness List.

* ELLIOTT, J G, CHURCH, B M, HARVEY, J J, HOLROYD, J, HULLS, R H and WATERSON, H A (1979) Survey of the presence and methods of control of wild-oats, black-grass and couch grass in cereal crops in the United Kingdom during 1977. *Journal of Agricultural Science, Cambridge,* **92,** 617–634

Publications

WRO has continued to be closely associated with a number of serial and regularly re-edited publications in the field of weed science. Members of the research staff have also found time to make major contributions to both new and established reference works in this and related fields.

Weed Abstracts. This abstracting journal, now in its 29th year, is compiled from the world literature on behalf of the Commonwealth Agricultural Bureaux (CAB), by the staff of the Weed Abstracts Group of the Information Department. A total of 8,627 abstracts was published in 1978/79, an increase of 10% over 1976/77. There was a slight increase in the number of subscriptions.

Plant Growth Regulator Abstracts. This monthly collection of abstracts from other CAB journals, collated and edited at WRO, is still the most successful of the new style 're-packaged' journals assembled for the convenience of a select readership. Subscriptions increased by 7% to 419 by the end of 1979.

Agricultural Engineering Abstracts. Originally envisaged by CAB as another 're-packaged' journal when it started in 1976, a member of the group was asked to collate and edit it because of his previous experience of the world literature in this field. It rapidly became apparent that the existing CAB journal coverage was inadequate and a considerable input of original abstracts had to be provided. It was therefore recommended that an independent abstracting unit should be established. CAB acted accordingly and set up a unit at the National Institute of Agricultural Engineering in late 1978 so bringing to an end WRO's brief but successful association with this new and much-needed journal.

Weed Research. The Director remains chairman of the 16 strong international Editorial Board of this journal; a former member of the Information Department is the Honorary Secretary. Published by Blackwell Scientific Publications as the official journal of the European Weed Research Society, 109 papers on all aspects of weed science appeared in the journal in 1978/79. The circulation increased to 1700 in 1979 as a result of the decision to issue each member of EWRS with the journal as a privilege of membership.

Tropical Pest Management. Close links have been maintained between the editor of the weeds section of this journal (formerly known as *PANS*), and the leader of the ODA Tropical Weeds Group at WRO. Published quarterly by the Centre for Overseas Pest Research with the intention of keeping scientists in tropical countries informed of the latest advances in pest control, it is a valuable medium for the publication of reviews and original articles on weed control, new herbicides and application technology.

Weed Control Handbook. Publication of the 6th edition of *Volume I, Principles* in 1977 was followed by the publication of the 8th edition of the companion *Volume II, Recommendations* in early 1978. It now seems likely that this will prove to be the last appearance of this well-established manual in its two-volume format. Sponsored by the British Crop Protection Council and published by Blackwell Scientific Publications, both volumes were the product of nearly 80 contributors amongst whom senior members of WRO played a prominent role. The onerous voluntary task of editing the whole two-volume work was undertaken on this, as on previous occasions, by the Director and the Herbicide Liaison Officer of the Agricultural Chemicals Approval Scheme, who is based at WRO.

Chemical Weed Control in Your Garden. This popular booklet embodying much of the experience of the Perennial Crops and other groups at WRO has sold some 35,000 copies to date. In response to an approach from the manager of Grower Books it has now been agreed that, in return for an annual revision of the text, the printing and marketing of future editions of this booklet will be handled by this company. WRO will receive a royalty on the proceeds of the sales.

Major contributions by WRO authors appearing in other works published in 1978–79 included a chapter on weed control and vegetation management in *Amenity Grassland Research*, edited by I H Rorison and R Hunt; a chapter on weed control in *The Potato Crop*, edited by P M Harris; a review of the effects of pesticides on nutritional requirements of plants in *The CRC Handbook Series in Food*; a chapter on weeds and weed control for *The Plant Pathologists Pocket Book*; chapters on ethylene in *The Phytohormones and Related Compounds*, edited by D S Letham, and on the senescence of seeds in *Plant Senescence*, edited by K V Thimman; a review of analytical procedures for the assay and indentification of ethylene in *Isolation of Plant Growth Substances*, edited by J R Hillman; and a chapter on the literature of weeds, weed control and herbicides in *The Literature of Agriculture and Food Science*, edited by G P Lilley.

Several WRO staff have served on the editorial boards of scientific journals including *Weed Research*, *Agrochimica*, *Annals of Applied Biology*, *Aquatic Botany*, and *Pesticide Science*.

EDUCATION AND ADMINISTRATION

EDUCATIONAL ACTIVITIES

As an Associated Institute of Reading University it is appropriate that 6 of the 13 post-graduate students who enjoyed the use of WRO facilities for their higher degree research projects in 1978–79 were students of that University. Details of all post-graduate students are given at p. 110. In addition to supervising these and other higher degree students, five members of staff gave a course of seminars on various aspects of weed science to final-year students at Reading. The Director, who is a Visiting Professor and member of the University's Plant Sciences Committee, has also been active in stimulating greater co-operation between the ARC Thames Valley Institutes and the University's research staff.

Individual members of the senior staff have also given courses of lectures on weed biology and hydrology at Chelsea College and Brunel University, seminars on wild-oat population dynamics at Liverpool University, and lectures on application technique at Cranfield Institute of Technology.

The acquisition of more laboratory space, albeit of a temporary kind, enabled WRO to accommodate an increased number of visiting research workers and overseas trainees in 1978–79. Details are given on p. 111.

As in previous years WRO continued to provide a three-day introduction to the principles of weed science for the overseas plant protection students participating in the Silwood Park Pest Management Course, financed by ODA. This annual event was organised by the leader of the Tropical Weeds Group who also served as external examiner for students reading for the MSc in Weed Biology of Brunel University and the MSc in Crop Protection of Reading University.

Many members of the research staff, particularly those of the Annual Crops Group, devoted a considerable amount of their own time to talking to various types of audience, either about the broad spectrum of activities at WRO or about topics of particular interest to the group addressed. Audiences ranged from professional advisers, agrochemical field staff, merchants' representatives, farmers and growers, to students, Rotarians, Women's Institutes and gardeners.

ADMINISTRATION AND TECHNICAL SERVICES

The Administration Department's role is to support the institute's scientific programme, not only through its office services, but also by providing adequate photographic, engineering and maintenance services. While it

The new Field Teams building provides long required space to accommodate the equipment, transport, chemical storage and laboratory facilities required by the 40-strong field team of the Department of Weed Control. Fifty per cent of the field experiments conducted by WRO each year are sited off the station.

has been possible to cope with increased pressures on the office services by implementing improved procedures, the technical services have not been able to keep pace with the demand from a growing scientific staff. This has inevitably resulted in some considerable delays in executing work needed to support the scientific programme.

New buildings

A new building providing much needed storage and service facilities for the field experimental teams, an improved field chemical laboratory and re-sited vehicle and plant maintenance workshops were completed and occupied in 1978. Space released in the range of original farm buildings has enabled more suitable accommodation to be provided for some central services.

In order to provide 'instant accommodation' for the staff transferred to WRO from the Units of Developmental Botany and Systemic Fungicides and also for those of the ODA *Striga* project, prefabricated laboratory and office buildings had to be provided and were occupied early in 1979. Although planning permission for these was sought and given for only three years in the very genuine belief that a permanent laboratory extension would be provided in that period, these plans have fallen victim to the public expenditure cuts and an application for an extended planning life of the temporary buildings will have to be made.

A new range of glasshouses and an improved pot standing area came into use late in 1979, together with an increase in the boiler capacity which will be capable of heating those parts of the institute at present dependent on electricity as well as the future laboratory extension.

Finally, work began late in 1979 on the first purpose-built accommodation for the WRO/Letcombe Joint Biometrics Group who provide the statistical service for WRO staff. For the last 10 years or so the service has operated from a room in the old Stone Barn where conditions have been far from ideal for computer peripherals!

Acquisition of more land

Although Oxford County Council's proposals to designate the whole area of Begbroke Hill Farm for urban development were rejected at an Examination in Public in 1977, the advance of new housing estates towards the perimeter of the farm has continued so that, to the north-east, housing is now only separated from the farm by the Oxford Canal. The trespassing problem is thus likely to worsen since several public foot paths pass through the centre of the farm. In view of this trend it has been deemed prudent to attempt to acquire more land round the perimeter of the farm. This would also relieve the arable part of the farm of the pressure of experiments from which it now suffers. One field has already been purchased and another leased while negotiations proceed to purchase both this and a third field.

Equipment

Major items of equipment purchased and commissioned in 1978–79 included a small plot combine for the Annual Crops Group, a Sigma 10 data processing system and PARC polaragraph for the Chemistry Group, a replacement titrator for the Microbiology Group, and a rain and mist simulator for the Environmental Studies Group.

Professor J D Fryer being represented with the Otto Appel Memorial Medal for his services to weed science by the Secretary of State for Agriculture of the Federal Republic of Germany.

HONOURS AND AWARDS

Director receives CBE

It was with profound pleasure that the institute staff learned that Her Majesty the Queen had conferred the CBE on the Director in the Birthday Honours List in 1979.

The Director had already, in 1978, been awarded the rare privilege of Honorary Membership of the Weed Science Society of America in recognition of his services to weed science.

A further honour followed. Whilst attending the 42nd German Plant Protection Conference in Mainz in October 1979, the Director was presented with the Otto Appel Memorial Medal, the highest award for plant protection in Germany, for his outstanding contribution to research in the field of weed science and for his efforts in furthering world-wide co-operation in this subject.

Barren brome: a threat to winter cereals?

R. J. FROUD-WILLIAMS, F. POLLARD and W. G. RICHARDSON

Recently there has been an increasing number of reports of barren or sterile brome (*Bromus sterilis*) occurring in winter cereals. The panicles were certainly a frequent sight in field headlands during the summer of 1979. Before 1970 this species had not been considered an important arable weed, although it was reported as a problem at Drayton Experimental Husbandry Farm in the mid 1960s. (Anon. 1967; Wybrew, 1969). Since 1970 there has been a gradual increase in reports of the weed from many areas of the country. Whether it will continue to invade arable land is difficult to predict, but its rapid increase and present occurrence is of concern to many farmers.

WRO responded promptly to the apparent threat to cereal production posed by barren brome and investigations have been in progress since 1976. This paper discusses the existing information on the weed status of *Bromus* species generally, corrects some misleading statements that have occurred in the literature, and reviews the recent achievements of WRO research upon barren brome.

THE CHANGING STATUS OF BROMUS SPECIES

The brome grasses originate in the Mediterranean Region but are now cosmopolitan and, although not listed amongst the world's worst weeds (Holm *et al.* 1977), many of the annual species are of agronomic importance. Long (1910), Brenchley (1920) and Morse & Palmer (1925) classify both barren brome and soft brome (*B. mollis*) as weeds of pastures rather than arable fields and rye brome (*B. secalinus*) as an arable weed. Salisbury (1961), however, refers to all three as formerly common contaminants of sanfoin.

Downy brome (*B. tectorum*), which was introduced into N. America from Eurasia during the nineteenth century, has now spread throughout all but the south eastern states (Klemmedson & Smith, 1964). Its lack of palatability together with its competitive exclusion of sown forage grasses makes it a noxious rangeland weed of the mid and north-western states. Rye brome and rip gut (*B. rigidus*) are also species of considerable importance in the United States (Hitchcock, 1950). The former occurs as a competitive weed of small grain cereals while the latter is particularly injurious to livestock, causing irritation to eyes, nostrils and alimentary tract if ingested.

Bromus species now appear to be causing increasing problems in many countries. Cairns* has referred to the appearance of great brome (*B. diandrus*) in S. Africa and Parker* has indicated a significant increase of *B. tectorum* and *B. pectinatus* in Turkey and Tanzania respectively. Castro (1976) reports that *B. catharticus* is a serious weed problem in Argentina. Furthermore, in England the occurrence of soft brome in pastures has increased since the drought of 1976 while barren brome has also become a serious problem in herbage seed crops.

PRESENT STATUS OF BARREN BROME

Love (1862) described it as an 'annual grass of dry, shady roadside situations', but it can also spread into the headlands of winter cereals where it germinates with the crop, often in profusion. The attractive purple panicles are produced in June–July. These shed most, but not all, of the seeds before harvest. The unshed seeds are dispersed by the combine harvester. The recent increase of barren brome has coincided with an increase in the monocropping of winter cereals, notably winter barley, and with the trend towards minimal cultivation. A greater proportion of seed has managed to germinate in the autumn-sown crops of recent years mainly because dry autumns have delayed germination and also because the cereals have been sown earlier. It has become an important weed in these situations because it is resistant to many of the herbicides used for wild oat and blackgrass control. However, it is often restricted to headlands, extending no further than the inner edge of the cultivated firebreak, which indicates that stubble burning gives a good measure of control.

DESCRIPTION OF BARREN BROME

Seedlings of barren brome have a light yellow-green colour and long prominent hairs. The upper leaf surface is ribbed, and both surfaces are hairy, the margins densely so. The leaves exhibit a characteristic clockwise twist of 1½ turns when observed from the leaf tip (Fig. 1) which, in young plants during winter, may develop into a curl. In contrast, wild oats twist anti-clockwise. The ligule is long (2–4 mm) and ragged, while auricles are absent (See Fig. 1). The veins at the base of leaf sheaths are often purple.

The mature plant may have as many as ten fertile tillers each reaching up to about 1 m in height and terminating in a panicle. However, the stems are not usually strong and lodging can occur, frequently resulting in a thick tangled mat. The plant becomes purple in late June but this colour may be

* Personal communication.

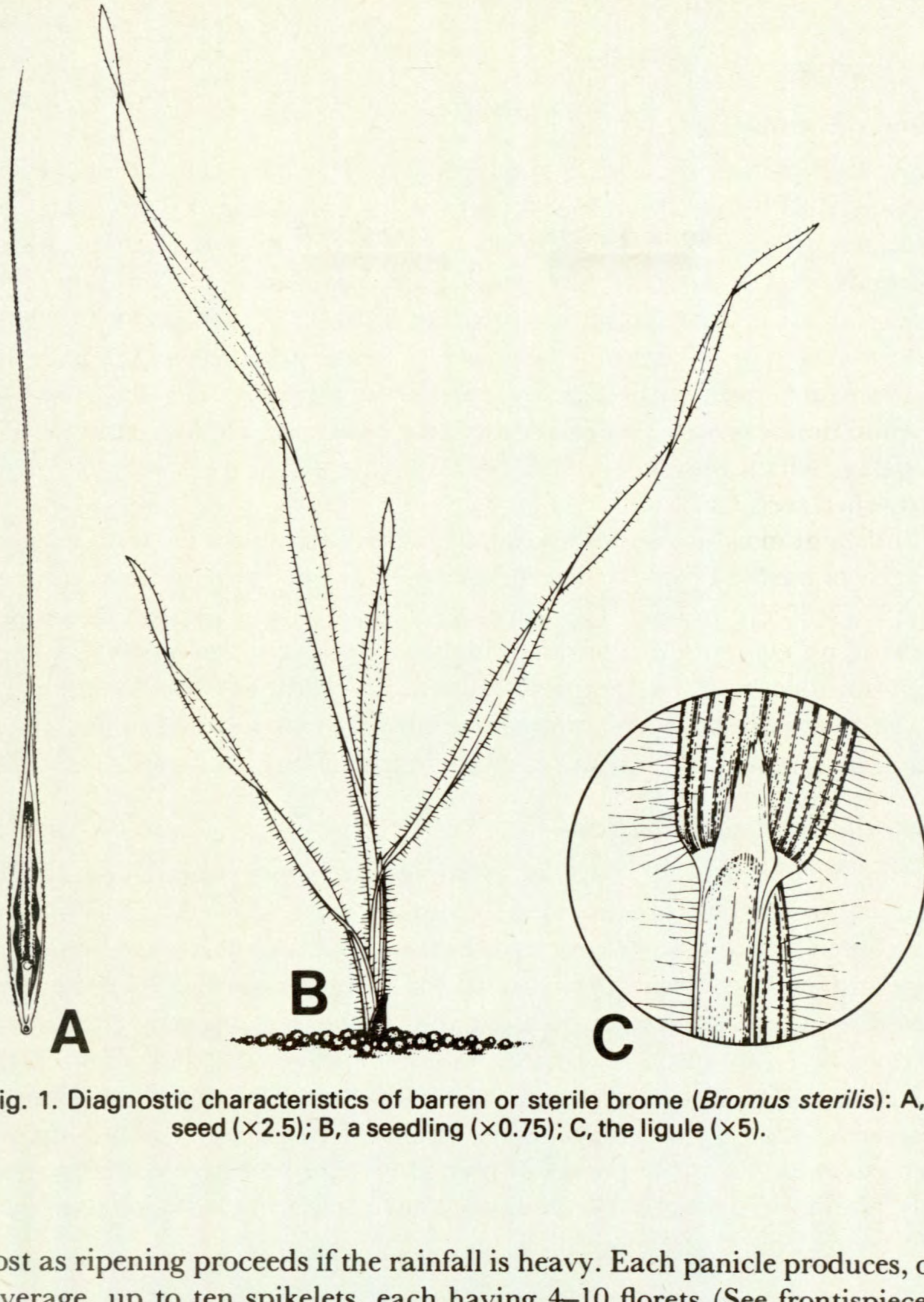


Fig. 1. Diagnostic characteristics of barren or sterile brome (*Bromus sterilis*): A, a seed (×2.5); B, a seedling (×0.75); C, the ligule (×5).

lost as ripening proceeds if the rainfall is heavy. Each panicle produces, on average, up to ten spikelets, each having 4–10 florets (See frontispiece). Ripening is rapid and most seed is shed in July, although the basal seed of each spikelet is more persistent. The seed of barren brome is extremely long (approximately 1 cm) and narrow in relation to its length (< 2 mm). The average seed weight is about 8–10 mg and its persistence after germination is a considerable aid to identification.

Seed germination

Most seed of barren brome is shed from late June to early August. In pot tests at WRO it has been found that seed is not dormant when shed, for germination will occur rapidly in the presence of sufficient moisture. Nevertheless, apparently ripe seeds collected from plants in June and incubated at an alternating temperature of 10/20°C (16h night, 8h day), have required approximately twenty days before germination is apparent. In contrast, seed collected in July required only ten days before germination was apparent under the same conditions. Thus a short period of delay, which may imply rudimentary dormancy, appears to occur in early shed seed.

Sufficient moisture appears to be the main requirement for germination, as seed of barren brome will germinate over a wide range of temperatures (<5°C–>30°C), but at 2°C and below, dormancy is enforced.* However, there is no evidence of dormancy induced by low temperature, for germination occurs upon return to favourable conditions. Germination of freshly shed seeds of barren brome is inhibited by both strong sunlight and red light. In contrast, dark or far-red light promotes germination.

Periodicity of germination

A single concentrated flush of seedling emergence usually occurs in response to the moisture provided by autumn rains. However, if dormancy is enforced by drought—as occurred in autumn 1978—or low temperature, ungerminated seed may persist until the following spring. Nevertheless, seed does not persist longer than one year in soil, forming only a transient seed bank (Thompson & Grime, 1969). Even so, basal seeds in each spikelet tend to show prolonged attachment to the parent plant. Hence, delayed shedding may alleviate the apparent handicap of non-dormant seed, thus allowing the period of germination to be extended. However, only plants persisting in the hedgerow are likely to be a major source of infestation from late shed seed.

Seedling establishment

Seed/soil contact to obtain moisture is crucial for establishment of barren brome because of the relatively large seed size. Nevertheless, radicle protrusion and soil penetration is extremely rapid and establishment may be

* NB If certain environmental conditions prevent germination of non-dormant seed for as long as those conditions last and no longer, then dormancy is *enforced*; but if dormancy persists after the conditions that imposed it have changed then it is *induced*.

successful even with variable moisture. Establishment has been observed even at a moisture tension of 0.1 atmospheres. Soil aggregate size is a critical factor determining whether seed will establish on the soil surface. Few seedlings establish when soil aggregate size is large, because many seeds become suspended upon the clods which have poor moisture continuity. In contrast, establishment is improved upon the flatter soil surfaces resulting from small aggregate sizes. Seedling establishment is also improved by seed burial to a depth of one to two centimetres. Burial below two centimetres reduces the percentage establishment, but emergence can occur from seed buried at depths of up to 13 cm (i.e. the limit of coleoptile extension). Seeds buried below this depth fail to emerge. Burial does not appear to enforce dormancy.

However, this species possesses several characteristics which appear to be of potential value for a weed. The relatively fast growth rate of barren brome (Grime & Hunt, 1975) suggests that it is likely to be extremely competitive in crops. It is also resistant to drought and low temperature. Barren brome was least severely affected in a comparative study of the response of several annual grass species to frost injury during the cold winter of 1978. Furthermore, this species is also particularly resistant to factors such as trampling and cutting, and autumn germinating seedlings disturbed by cultivations may re-establish as transplants.

Seed production

Seedlings of barren brome appear to require vernalisation for floral initiation. This suggests that spring germinating seedlings would fail to set seed in the current year. It is not known as yet whether ungerminated seed can be vernalised.

Seed production in a crop may be in excess of 200 per plant, and very few infertile seeds are produced. Seed maturation is rapid. In an experiment, plants arising from buried seed tended to produce more fertile tillers than plants arising from seed sown on the surface, but the differences were not significant. Furthermore, numbers of florets per spikelet and spikelets per plant were not significantly different.

CULTURAL CONTROL

The problem of barren brome in cereals is similar to that of other grass weeds in that the similarity to the crop complicates both cultural and chemical control.

The production of a large number of viable seeds leads to a rapid annual increase in numbers while the lack of dormancy results in most of the seed germinating and producing plants in the year of shedding. However, this latter feature must also be its weakness. Any break in the life cycle should eradicate the population because of the absence of a persistent seed bank. It follows that the object of control should be first to prevent the introduction of both additional seed and plants and second, to break the life cycle of the existing population.

When harvesting an infested crop, it is inevitable that the grain will be contaminated with seeds of barren brome and hence subsequent sowing of this grain will result in further infestations. When it is not present in field margins the spread of this weed may be contained by careful selection of seed crops and efficient seed cleaning. When it is present at the edges of fields and headlands other methods have to be employed. Spraying hedge bottoms with glyphosate is of dubious value. It may well destroy innocuous perennials and thus present bare patches which barren brome may colonise. A narrow headland strip kept weed free by cultivation or herbicides may be more practical. Indeed, headland hygiene appears to be very important in preventing the spread of the weed throughout the field. Thus it may be necessary to manage headlands separately in order to prevent cultivations from introducing transplants or disseminating seed at harvest. This would entail harvesting headlands last and then sowing them later, possible to a spring crop. It would even be possible to plant a non-cereal crop in which herbicides could be used but this is unlikely to be acceptable to farmers. Some farmers have accepted the risk of crop damage from the high rates of herbicides believed to give control as a means of headland hygiene.

Attempts at breaking the life cycle of existing infestations in continuous winter cereals may only be possible in the period between harvest and sowing the next crop. Pre-harvest applications of glyphosate cannot be made early enough to prevent the shedding of viable seed, while attempts to increase the competitive ability of the crop offer little hope. The inability of seedlings to emerge from depth in excess of 13 cm suggests that burial of seeds by ploughing should be an effective means of control. Runyan & Peeper (1978) report efficient control of *Bromus* spp. with the mouldboard plough. However, complete soil inversion is rarely achieved in practice, particularly upon shallow stony soils which often have bad infestations. Experiments by WRO have shown good control on deep, easily ploughed soil at Begbroke Hill but not on a shallow Cotswold cornbrash soil.

Nonetheless, such a cultural control measure is not acceptable to farmers committed to minimal cultivation systems. This is unfortunate, for the problem of barren brome tends to be fostered by such regimes. It is possible, however, that no cultivations at all would encourage a similar loss of surface-sown seed as was shown to occur with wild oats (*Avena fatua*) by Wilson & Cussans, (1975). Where minimal cultivations are practised, crop rotation or the inclusion of a spring-sown crop may be the only effective means of cultural control currently available.

Delayed drilling of the crop might be considered a useful means of control, because encouraging the weed to germinate prior to sowing would allow the application of non-selective herbicides. However, Runyan & Peeper (1978) report that this was ineffective for other *Bromus* spp. in N. America, because weed germination continued after the crop had been sown. This is likely to be particularly important in a dry autumn.

CHEMICAL CONTROL

The increase in this species as a weed despite apparently poor adaptation as an arable weed must be due in part to its resistance to the herbicides commonly employed to control wild oats, blackgrass and other grass weeds. Evaluation of susceptibility to these and other herbicides has been taking place at WRO since the autumn of 1976.

Fifty herbicides and 13 mixtures have been tested in pot experiments with a view to selectively controlling barren brome in wheat and/or barley. Post-emergence, only isoproturon, metoxuron, a metoxuron/simazine mixture (for use in wheat or barley) and asulam (for use in barley only) have shown any potential for selectivity, but this has often been marginal and not always reproducible. Experiments on formulation of metoxuron have shown that various surfactants, although improving control, also reduce crop tolerance. However, the wettable powder formulation of metoxuron has shown slightly greater activity and selectivity than the newer flowable formulation, suggesting that further research may be worthwhile.

Pre-emergence herbicides have shown some degree of selective control. Of these, tri-allate and EPTC (barley only) have given good control, but only if incorporated into the soil. Other potentially useful treatments include isoproturon, perfluidone, nitrofen (wheat only) and asulam (barley only).

With asulam, the margin of selectivity was improved in an experiment when the weed germinated at a shallower depth than the barley. It may be possible to exploit this in direct-drilled crops where the seed of barren brome would be near or at the soil surface but field experience has been disappointing. Some potentially useful binary mixtures have been found and as no single herbicide treatment gives consistently good control, more work will be done on mixtures in future.

Field tests with some of the herbicides which gave useful selectivity in the greenhouse have not revealed any compounds likely to prove adequate for long term control, i.e., by suppressing seed formation. None has given more than 75% weed control without producing symptoms of damage to the crop. With such a fecund species, better control than this is needed to prevent an annual increase. Some improvement of crop yield may result from reduced competition, but the effects of this have not yet been established. Tri-allate and EPTC (in barley) incorporated into the soil pre-emergence, and metoxuron and metoxuron/simazine applied post-emergence have been the most promising treatments in WRO experiments. Trials conducted by ADAS have also shown promise. Tri-allate incorporated pre-emergence or metoxuron applied early post-emergence gave the best results while isoproturon has also been useful.

In crops other than cereals, control of barren brome would appear to be less of a problem. In perennial ryegrass pastures, ethofumesate is already approved. The weed is also susceptible to simazine (field beans), metamitron (sugarbeet), and propyzamide and carbetamide (oil seed rape). It is also susceptible to dalapon and TCA which are used to control grass weeds in many crops.

CONCLUSIONS

In view of the lack of dormancy and the ability to germinate readily, it is perhaps surprising that barren brome should have become a problem. The trend towards earlier drilled continuous winter cereals established by minimal cultivations, the present inability to control it chemically, and the recent run of dry autumns have all contributed to its success as a weed.

Traditional methods of cultivation should cure this problem, at least in some areas, but if minimal cultivations have been adopted then other control measures need to be employed. Thus, if the weed is not already established, then preventive measures including use of clean crop seed and good headland hygiene are essential to prevent its invasion from the field margins. If it is already established in a field, the position is difficult in the absence of satisfactory herbicides. Delayed autumn drilling may contain the problem, but currently the only solution is rotation with a spring cereal which will break the seed's cycle, or oil seed rape which allows the use of better herbicides. Much more research is needed on the part of industry to find a satisfactory herbicide, and on the part of WRO to gain a better understanding of the weed's recent increase and its encouragement by modern farming systems.

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Dormancy in wild-oat seed and its agricultural significance

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INTRODUCTION

There are two species of wild-oat in Britain, wild-oat (*Avena fatua*) and winter wild-oat (*A. ludoviciana*). The common name wild-oat is often loosely applied to both species but, in this article, wild-oat is used only in reference to *A. fatua*. The two species can be distinguished by their seeds (Fig. 1). In wild-oat all the seeds in each spikelet separate when mature, but in the winter wild-oat they remain joined together. There can be up to three seeds in a spikelet, each of which is contained within two bracts which form a husk around the seed. Each species has been divided into types depending upon husk colour (brown, grey or cream) and hairiness, and on the hairiness of the scar at the base of the seed (Thurston, 1957). It was once thought that the degree of seed dormancy was related to husk colour, but it is now known that there is a complete range of dormancy within each type.

Each seed cover can exert an effect upon the germination of the seed. The seed husk, being the outermost layer of the seed forms the first barrier to gaseous diffusion, particularly when the seed is moist, and this alone can inhibit germination. The husk is also known to contain chemical substances which can prevent germination.

Within the husk is the seed, which consists of an embryo and endosperm around which is a single layer of aleurone cells, and in turn these are enclosed by the seed coat.

A wild-oat seed can be dormant for two main reasons. Firstly, the embryo itself may be dormant, and this has been demonstrated by dissecting embryos out of dormant seeds and culturing them in the laboratory (Andrews & Simpson 1969). Secondly, the seed coat may prevent the germination of an otherwise non-dormant embryo. In this situation, if the seed coat is damaged germination will usually occur. Pricking or fracturing as occurs when the seed is frosted or the soil cultivated, has this effect. How damage to the seed coat triggers germination is not known, but in addition to allowing diffusion of air and moisture into the seed, the physical damage may also induce the formation of growth hormones, or remove any physical restraint on growth and development.

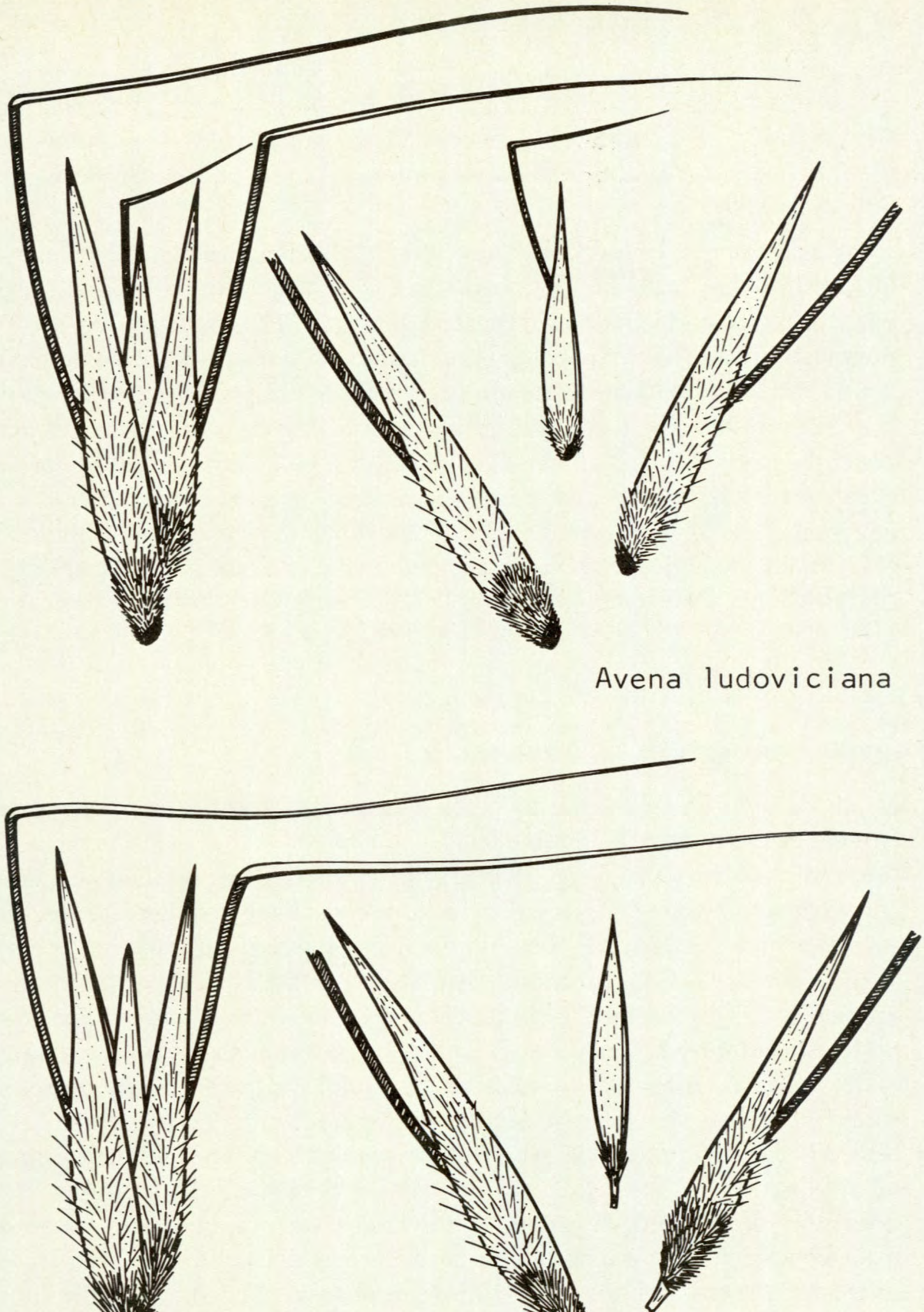

Fig. 1. Single spikelet and component seeds of *Avena fatua* and *Avena ludoviciana.*

Another method by which dormancy can be broken is by administering gibberellin, a plant growth hormone, to the seeds or isolated embryos, though precisely how this breaks dormancy is not known (Andrews & Simpson 1969).

In addition to its probable key role in the regulation of dormancy, gibberellin may also be responsible for ensuring that the germinating embryo is provided with adequate nutrients. The bulk of the seed's nutrients are stored in the endosperm mainly as starch, and these reserves have to be broken down (for example starch is hydrolysed to sugars) before the embryo can use them. When an embryo begins to germinate it apparently sends a chemical message, probably a gibberellin, to the aleurone cells beneath the seed coat and these respond by synthesising and secreting enzymes. It is these enzymes which break-down the starch and other food reserves in the endosperm making them available to the growing embryo. (Naylor 1966, 1969, Chen & Chang 1972, Chen & Park 1973).

HERBICIDE EFFECTS ON SEED DORMANCY

It was thought that seeds produced by plants which had survived herbicide treatment might have a different level of dormancy to that found in seeds of untreated plants (Aamisepp 1959). Wild-oat herbicides applied at a late stage of growth were considered to be those most likely to have an effect on seed dormancy and have been the subject of recent experiments at the Weed Research Organization. Benzoylprop-ethyl, which is normally applied at 1.1 kg/ha at a fairly late stage, (between the tillering and two node stage of the wild-oats, Zadoks 30–32), was applied at a sub-lethal rate of 0.6 kg/ha at either the one-node stage (Zadoks 31) or when the panicles were just beginning to emerge from the top-most sheath (Zadoks 50–53). At the early date of application, which corresponded to the recommended time of application in the field, no increase or decrease was found in the dormancy of the seed. However, at the later date of application, the seed from treated plants was found to be 30% less dormant than seed from untreated plants. At both dates of application, and particularly at the later date, both seed numbers and the viability of the seed were reduced (Peters 1978). It would, therefore, be expected that, although not giving much relief from competition, later than normal applications would reduce the return of dormant seeds to the soil.

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