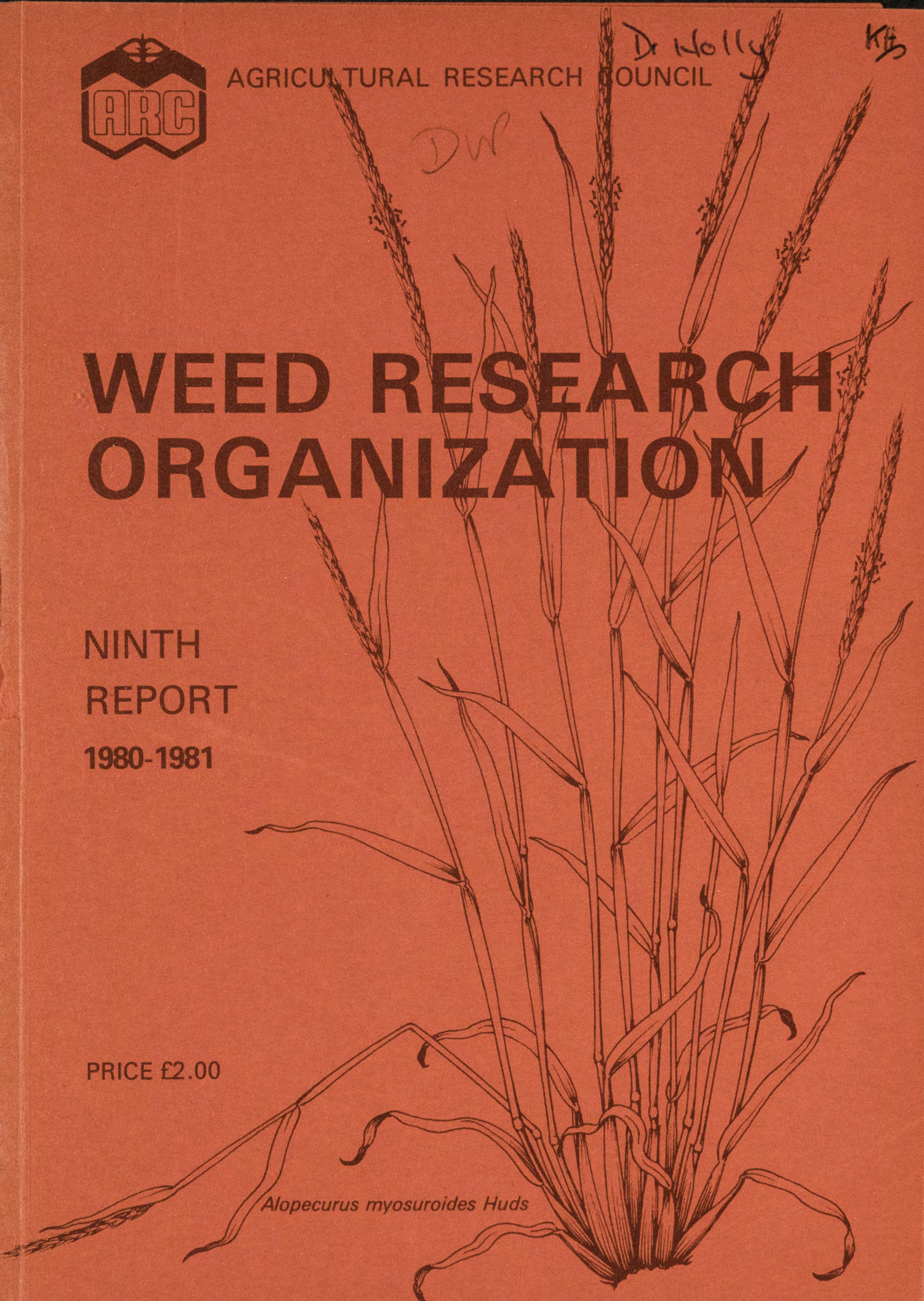
AGRICULTURAL RESEARCH COUNCIL

WEED RESEARCH ORGANIZATION

NINTH REPORT

1980-1981



Alopecurus myosuroides Huds

PRICE £2.00

WEED RESEARCH ORGANIZATION NINTH REPORT 1980 – 81

SOME FACTS ABOUT THE WEED RESEARCH ORGANIZATION (WRO)

WRO is one of eight 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 1980-81 ODA and CAB together provided about 12% of the institute's funds.

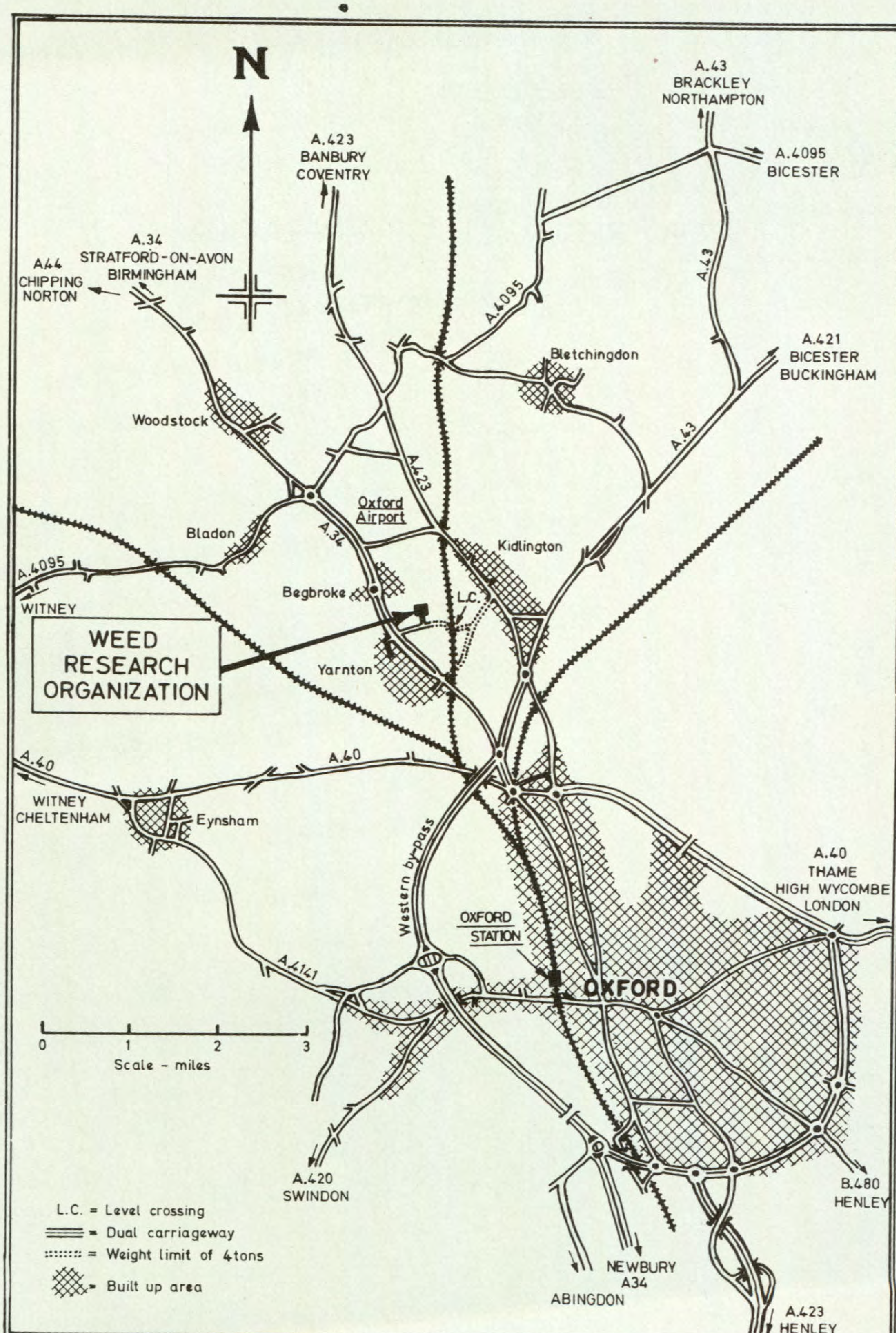
The information provided in this report is necessarily condensed and selective. Readers wishing for more detail, or for an appointment to visit Begbroke, are invited to contact the Information Department.

ABBREVIATED TITLE

The abbreviated title of this report as given in the *World List of Scientific Periodicals New Periodical Titles* (1960-68) is:
Rep. Weed Res. Org. 1980-81 (1982)

WEED RESEARCH ORGANIZATION

NINTH REPORT



N
A.43
BRACKLEY
NORTHAMPTON
A.4095
BICESTER
A.423
BANBURY
COVENTRY
A.34
STRATFORD-ON-AVON
BIRMINGHAM
A44
CHIPPING
NORTON
A.4095
A.43
A.421
BICESTER
BUCKINGHAM
Bletchingdon
Woodstock
A.423
A.43
Oxford
Airport
Bladon
A.34
Kidlington
A.4095
WITNEY
Begbroke
L.C.
WEED
RESEARCH
ORGANIZATION
Yarnton
A.40
A.40
WITNEY
CHELTENHAM
Eynsham
Western by-pass
A.40
THAME
HIGH WYCOMBE
LONDON
OXFORD
STATION
OXFORD
A.4141
0 1 2 3
Scale - miles
A.420
SWINDON
B.480
HENLEY
L.C. = Level crossing
= Dual carriageway
= Weight limit of 4tons
= Built up area
NEWBURY
A34
ABINGDON
A.423
HENLEY

AGRICULTURAL RESEARCH COUNCIL

WEED RESEARCH ORGANIZATION

NINTH REPORT
1980-1981

Published June 1982

BEGBROKE HILL, YARNTON, OXFORD OX5 1PF

Contents

PROJECTS, PUBLICATIONS AND STAFF INFORMATION

DIRECTOR'S INTRODUCTION

ESSENTIAL ROLE OF WRO ENDORSED

There must be few, if any, farmers, growers, gardeners or other managers of land who would claim that weeds are no longer a problem; or that the abundant control measures now available leave little scope for improvement. The resilience of weed populations to the onslaught of herbicides and to changing cultural practices are only too well understood by those who gain their livelihood from the land, as are the high costs and the technical and logistic problems inherent in modern weed control technology. The need for further progress is both well recognised and urgent.

Yet there are some, less closely connected with practical problems of the land, who hold a different view. They maintain that herbicides have been so successful that weeds must surely have been effectively beaten and there is thus little need for further advancement and hence for research. Such thoughts, however well intentioned, are misguided. Moreover, if taken seriously by those on the lookout for economies, they are potentially damaging to the future of British agriculture and to the maintenance of British expertise in weed science such as is found at WRO.

Fortunately there is no doubt on the part of the leaders of the agricultural community about the total dependence on herbicides of economically viable agriculture in this country, nor about the constraints which weeds continue to impose on productivity, about the high cost of their control, the increasing public concern for the environmental impact of herbicides and the vital need for continuing research. An opportunity for this to be confirmed was provided by the institute's celebration of its 21st anniversary in June 1981 when a special luncheon, attended by some 140 guests, featured as part of the two-day event—*Weed Workshop '81.* At this luncheon, provided voluntarily by the WRO Staff Club, with much acclaim by the guests, we were honoured to have amongst the speakers Sir Richard Butler, President, National Farmers' Union, Dr Keith Dexter, Director General of the MAFF Agricultural Development and Advisory Service and Deputy Secretary (Agricultural Science), Dr Ralph Riley, Secretary, Agricultural Research Council and Professor A H Bunting, Reading University and Chairman of the WRO

Opposite: A spray of drops of uniform size and emission speed produced by a solid state device developed at WRO for research into improved methods of applying herbicides. A pulsed microjet produces drops of the required size and speed; subsequent in-flight collision is prevented and dispersion aided by inducing an electrical charge on each drop so that they repel each other.

Sir Richard Butler, President, National Farmers' Union, addressing the guests at the WRO 21st Anniversary Luncheon—June 10, 1981.

Director's Advisory Group. Sir Richard, speaking on behalf of farmers and growers in Britain, emphasized the need to make economies in the use of herbicides and drew attention to changing husbandry practices which are likely to lead to new and more difficult weed problems in the future. It was heartening to hear him report the NFU's view that the work of WRO is essential and that the Union will do everything it can to widen the liaison between the institute, innovators amongst farmers and growers, and herbicide manufacturers. Dr Dexter shared his view that the industry would continue to need the services of WRO until the institute's Golden Jubilee and beyond. He saw a growing need for integrating the different disciplines of crop protection and considered whether WRO might not in the not too far distant future have a wider role to play. Speaking on behalf of the Agricultural Research Council, to which WRO belongs, Dr Riley confirmed that the Council saw the institute as an important component of the national capability for agricultural research and considered the investment it makes in our work at Begbroke Hill—about 2% of the total—well spent.

These remarks and other favourable comments made during Weed Workshop '81 provided much encouragement to the staff and a welcome boost to morale during a period when economies in public expenditure are creating difficulties for WRO in common with the other institutes which collectively make up the Agricultural Research Service.

WRO—ITS DEVELOPMENT AND ACHIEVEMENTS OVER 21 YEARS

Weed Workshop '81 attracted nearly 850 visitors to Begbroke Hill and, in keeping with our desire to celebrate the 21st anniversary of the establishment of WRO whilst all but one of the original founder members were still in post, a special effort was made to demonstrate both past and present aspects of the institute's programme. This involved 22 exhibits and no less than 130 display panels. The opportunity was taken to record in an illustrated commemorative booklet the development and achievements of the institute from 1 April 1960 when Begbroke Hill Farm came into the possession of ARC up to the present. It also seemed timely to document the little known links between WRO and the British Crop Protection Council and the crucial part which each organization played in the establishment and development of the other. The account is published for the first time in this report (p. 78).

TROPICAL WEEDS LIAISON UNIT AXED

During its 21 years WRO has developed into a multi-disciplinary institute unique amongst research organizations devoted to weed science and in the extent of the expertise and resources available to it. These include: (i) an information service based on a library containing an unparalleled collection of the world's published literature relating to weed science; (ii) extensive glasshouse and laboratory facilities equipped with a wide range of techniques for analytical chemistry, microbiology, biochemistry and botanical studies, for transmission and scanning electron microscopy and for research involving controlled environments and rain simulation; (iii) a capability for field experiments on a scale not available elsewhere operating through 15 fully mobile field teams on the 120 ha Begbroke Hill research farm and on farms throughout the country. All this has provided a powerful back-up for the Tropical Weeds Group at Begbroke Hill sponsored by the Overseas Development Administration of the Foreign and Commonwealth Office (ODA). The Group has for many years provided assistance to governments, technical aid organizations and to individuals concerned with helping developing countries to improve their agriculture. Its leader Mr Chris Parker is a world authority on weed control and herbicide use in the tropics and has travelled extensively. Several other members of WRO staff have also worked overseas from the early

1950s onwards when the parent body of WRO, the ARC Unit of Experimental Agronomy, was assigned the responsibility of assisting the agricultural and forestry departments of the many British Colonies at that time with advice, information and research on weed control. WRO thus has accumulated some 30 years of experience of tropical weed work and has become one of the focal points for international weed science. Numerous visitors from or concerned with third world countries have come to Begbroke to widen their experience and benefit from personal contacts with the staff.

It is with the greatest regret that I have to record the closure of the WRO Tropical Weeds Unit on 31 March 1982 and with it the ending of the formal role of WRO to help our colleagues in developing countries through advice and liaison. This regrettable occurrence followed the decision by ODA to terminate its funding for the work of the Unit, a decision which we have been assured was made only with the greatest reluctance and one which was forced on ODA by government cuts in public expenditure. We have energetically sought alternative sources of funding but at the time of writing (April 1982) to no avail. Unless we succeed, the expertise and enthusiasm in tropical weeds and their control built up over a period of more than three decades will be lost to Britain and to world agriculture at a time when improved weed control practices are increasingly seen as one of the principal means by which people in developing countries can grow more food and enjoy a higher standard of living. It is ironic that when at last the importance of weeds is receiving recognition by FAO and other international agencies, when weed science is awakening in the tropical world, and advice and help are increasingly wanted, the support necessary for WRO to make its experience and resources available is taken away.

Fortunately, ODA has seen fit to continue its support for a specific research project by WRO on the parasitic weed *Striga* (see p. 34). Our one home-based post for overseas assignments remains unaffected by the cuts. The door has not yet therefore completely closed and my colleagues and I will do all in our power to ensure it does not. As Professor Hugh Bunting commented during his speech at the 21st anniversary lunch "to terminate an outstanding scientific activity is all too easy in these hard times, but once terminated it tends to be lost forever . . . weeds are simply too important in the battle against poverty and hunger in the world in the 20 years ahead."

WEED ABSTRACTS—THE END OF AN ERA

One other long standing role of WRO is also to come to an end. The Commonwealth Agricultural Bureaux (CAB) finally decided to withdraw, from the end of 1982, their support to WRO for the preparation of the journal *Weed Abstracts* on grounds of greater economy and the need to centralize the production of their journal series. Unlike the ODA decision, this one, however unwelcome, was not unexpected in view of the highly competitive business environment in which CAB now operates. *Weed Abstracts* will in future be produced wholely by CAB, thus bringing to an end an era which started in the early 1950s when the ARC Unit of Experimental Agronomy decided to abstract the diverse but then meagre published literature on weeds and weed control to assist the Unit's research staff and anyone else who might be interested. The demand for the Unit's mimeographed sheets of abstracts grew and *Weed Abstracts* was thus born. Although, later, it was published by the British Weed Control Council and, after 1962, by CAB, its preparation continued to be the responsibility of WRO. The dedication to this task shown by the staff of the Weed Abstracts Group over many years has been exemplary and their efforts have been much appreciated by well over 1200 recipients of the journal as well as by WRO colleagues. Some senior members of the group will retire in 1982; the remainder will be re-deployed within the institute.

GREATER FLEXIBILITY IN THE USE OF HERBICIDES ACHIEVED

In the last report attention was drawn to the problems caused by the apparent infringement of voluntary regulatory schemes operating in the UK when herbicides were used at doses lower than those recommended by the manufacturer. This difficulty has now been largely overcome by it being made clear that reduced doses applied by conventional methods do not infringe the rules of PSPS or BASIS. There is now much wider acceptance, within both the industry and the regulatory schemes, of the need for the maximum flexibility in herbicide use by farmers and growers with the proviso that a) the treatments are cleared for safety under PSPS and b) users accept liability if they do not conform with the manufacturers' recommendations.

TWO NEW PROJECTS COMMISSIONED

The increasing costs of crop production, together with a slower upward movement of commodity prices and increasing public pressures to reduce the volume of chemicals used in agriculture, have done much to stimulate a more critical attitude on the part of farmers and growers in the UK to the use of herbicides which cost them some £120 m annually. There has developed a great deal of interest in how costs of weeds control can be reduced by improved rationale and by the more effective use of existing techniques. Indeed, following the MAFF Cereals Commission Review in 1981, additional funds were made available to ARC by the Ministry to support two additional commissioned projects at WRO. One is to investigate the costs and benefits of weed control in cereal production with a view to the development of more cost effective control strategies. The other aims to rectify the lack of information on factors influencing crop damage by spray and vapour drift of herbicides.

LIAISON WITH INDUSTRY IMPROVED

It has been heartening that so much of the information generated by the WRO programme has been so clearly relevant to practical problems and thus in much demand by farmers, growers, advisers and consultants—and increasingly by the herbicide manufacturers themselves. Whilst very close links have always existed between WRO and individual manufacturers, it has proved difficult to ensure that all relevant branches of a large company are informed adequately of the institute's research relating to its products. In an attempt to promote improved communication of WRO results to the agrochemical industry as a whole, discussions were held in 1981 with the British Agrochemicals Association (BAA). These resulted in an agreement to initiate a procedure by which the Association is informed beforehand when the institute is to present an exhibit at a public event likely to be attended by farmers, growers, distributors, advisers or consultants. The aim is to ensure that manufacturers are aware of the information to be released on recent WRO research relating to their products, so that they can deal more effectively with any questions that subsequently arise.

In promoting greater efficiency in crop protection and the translation of research into practice the specialist consultant is seen as having an increasingly important role. Mutual benefit is expected from the close ties which have already been forged between WRO and the recently formed Association of Independent Crop Consultants, the first Chairman of which is a former member of the institute.

POLICY FOR THE FUTURE

WRO is approaching the end of its first chapter which has seen it develop from a handful of staff from the ARC Unit of Experimental Agronomy, an old farmhouse, a farm, some Land Rovers and spraying equipment into a broadly based, well equipped research institute with a complement of some 170 staff. During the next few years several of the original members will be reaching retirement age. When the time comes for them to go their loss will be keenly felt because all have contributed much and have unrivalled experience in their fields. On the other hand their departure will generate new opportunities to adjust the staffing and the programme of the institute. To ensure that ample time is available to consider all possibilities and that a strategy for the future development of WRO is agreed with ARC Headquarters, a Forward Look exercise was begun in February 1982 with the help of the Director's Advisory Group. The outcome will provide the basis for my report to the next Visiting Group in 1985 in which proposals will be made for the second chapter of WRO extending, all being well, up to the end of the century.

IN CONCLUSION

I am grateful for this opportunity to thank all who make WRO what it is and who help us to do our job more effectively. The staff, I hope, already know how much I appreciate their dedication, enthusiasm, loyalty and friendship. It is appropriate here to pay tribute to Mr John Holroyd who retired in 1980, the first founder member to leave. He played an active role in many parts of the institute's programme becoming one of the nation's authorities on the performance of herbicides. He will perhaps be best remembered for his discovery of the post-emergence activity of tri-allate against wild oats and for his innovation of the successful wild oat roguing glove, now in use throughout the world.

It was with real pleasure that the staff learned of the award to our institute Secretary, Mr B A Wright, of the MBE in the 1982 New Year's Honours List. Brian Wright was one of the first occupants of the old farmhouse at Begbroke Hill after the property was acquired by ARC in 1960. Since then he has presided over the increasingly complex administration and financial control of the institute with outstanding success, making many friends and always emphasizing that his sole purpose has been to enable WRO research to run more smoothly. He must be one of the few administrators who really do regard administration as a means to an end and no more.

It gives me much pleasure to thank the numerous people and organizations who collaborate with and help WRO in many different ways. I am grateful too to those who, by making use of what we have to offer, demonstrate their interest in the institute and its work. Finally, and in particular, I wish to express my gratitude to colleagues at ARC Headquarters for their continuing support for WRO and for the sympathetic attention they give to helping to resolve the many difficulties inseparable from the day to day running of a research institute during these challenging times.

J. D. FRYER
Director

PROGRESS REPORT

REVIEW OF RESEARCH

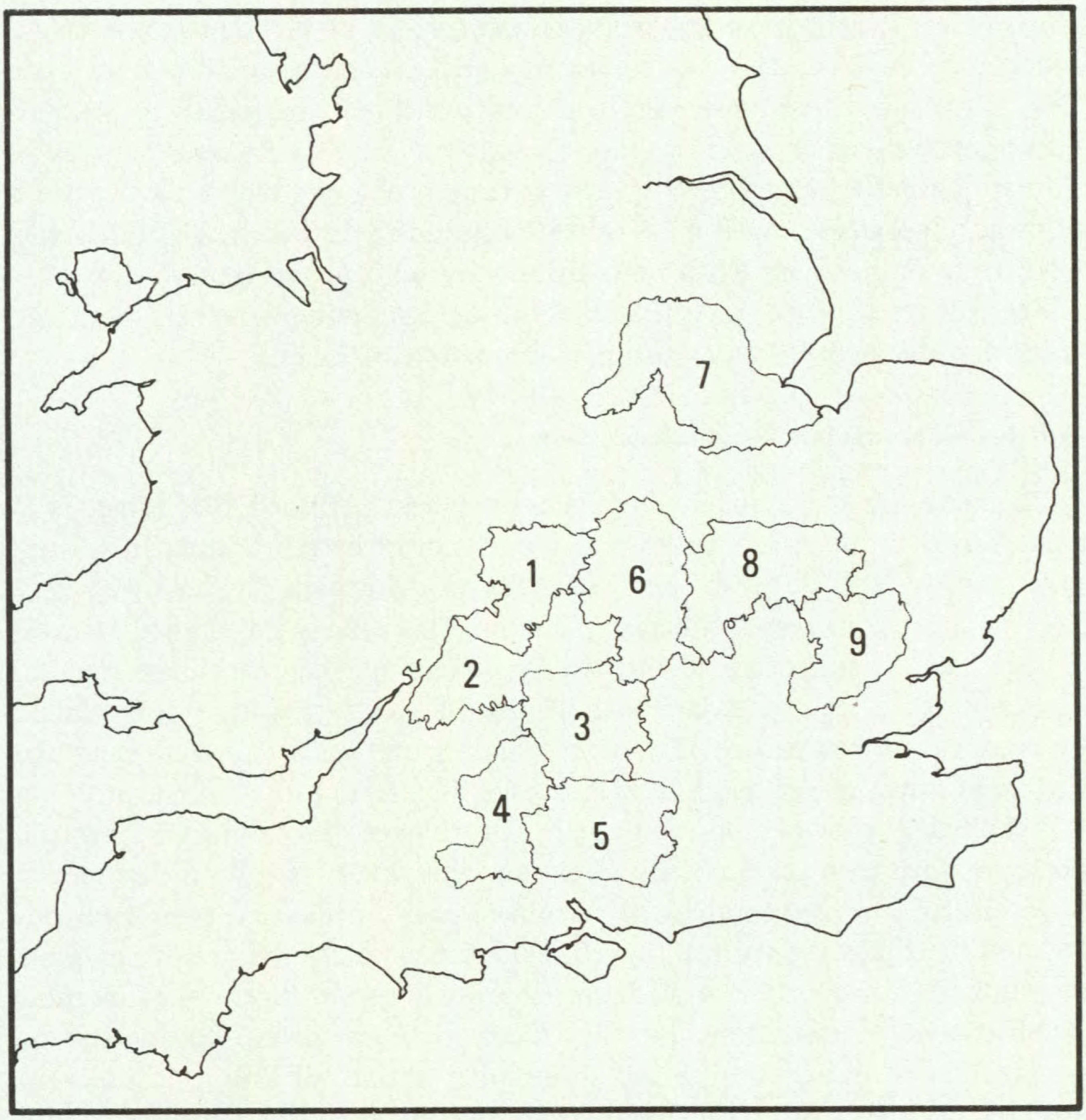
CONTROL OF GRASS WEEDS IN CEREALS

The research programme continues to be dominated by the need to develop effective long-term control of the grass weeds of modern cereal production systems. A recent survey by the Weed Biology Group has confirmed the continuing widespread occurrence of wild-oats and common couch as cereal weeds despite the effective control options now available. Black-grass, somewhat less widely distributed, is now recognised as the most economically damaging of the grass weeds where it occurs. The current status of our research on its biology and control is fully described in the article by members of the Annual Crops Group on page 45. Both groups have continued research on barren or sterile broome (*Bromus sterilis*) to augment the information published in the *WRO 8th Report*. In addition, the significant contributions that the Herbicide, Environmental Studies and Developmental Botany Groups have also made to the solution of the grass weed problem are reflected in the selected topics reported here.

Grass weeds of cereals surveyed

In the summer of 1981, the Weed Biology Group made a survey of the grass weeds occurring in cereals in nine areas of central southern England. Some 2,626 fields were assessed, 2,192 in winter cereals and 434 in spring barley. The main objective was to monitor the occurrence and importance of barren brome. Other grass weeds were also included in the survey, which was conducted by scoring each field by eye when the grasses were in flower and their heads could easily be seen among or above the crop. Only annual meadow grass could not be seen and had to be omitted.

Nineteen species of grass weeds were recorded, but barren brome was not amongst the most frequent. It was found only in winter cereal crops where it occurred in 9 per cent of the fields assessed. Its distribution in fields was often striking for, in a majority of the fields where it occured, it was confined to a narrow belt along the headlands. This narrow belt was often remarkably straight-edged, indicating that this distribution pattern was associated with some cultural practice, possibly the preparation of a fire break before stubble burning. Although only present in the crop in a minority of the surveyed fields, barren brome was also present in the hedges surrounding a further 7



The nine areas of central southern England surveyed in 1981 for the occurrence of grass weeds of cereals: (1) S. Warks & N E Glos; (2) S. Glos & N. Oxon; (3) S. Oxon & W. Berks; (4) E. Wilts; (5) N. Hants; (6) N. Bucks & S. W. Northants; (7) S. E. Notts & S. Lincs; (8) Beds. & S. Cambs; (9) W. Essex.

per cent of the fields. It occurred more or less equally in the nine areas surveyed, which confirms data provided earlier by individual farmers at three agricultural shows and at Weed Workshop '81.

A great deal of useful information was also obtained on the distribution and frequency of other grass weeds. In winter wheat, wild-oat was the most frequent weed, occurring in 32 per cent of fields. Rough meadow-grass (*Poa trivialis*) was second, occurring in 29 per cent of the fields, followed by common couch in 26 per cent, black-grass in 23 per cent and barren brome in

12 per cent. In winter barley, wild-oat occurred in 31 per cent of the fields, couch grass in 20 per cent, black-grass in 9 per cent and barren brome in 4 per cent. Surprisingly, the grass weed which occurred most frequently as a severe infestation was rough meadow grass, though only in western areas.

In spring barley, eight grass species were recorded of which only two were of great importance: couch grass which occurred in 53 per cent of fields and wild oat in 52 per cent. Black-grass came third with 11 per cent.

The survey will be repeated in 1982 to determine whether there are seasonal differences in the occurrence of individual species.

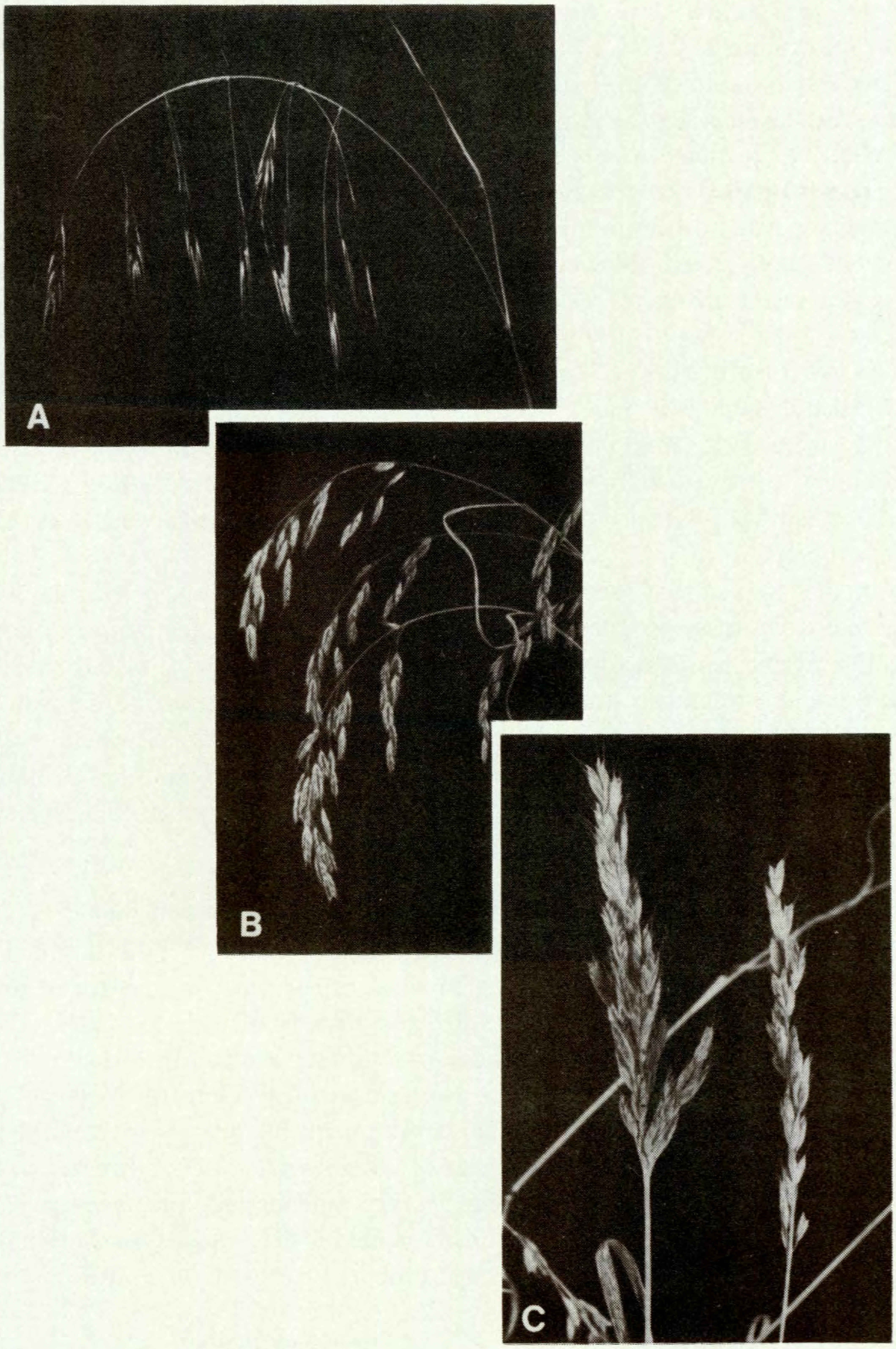
Why barren brome has become a problem

Experiments by the Annual Crops Group have confirmed that tillage is a major factor in the recent increase in occurrence of barren brome. In winter-sown barley, both direct drilling and reduced cultivation have allowed very large population increases, whereas ploughing has usually given good control. When barren brome seeds are buried by ploughing, they germinate rapidly. Those buried at depths greater than 12 cm fail to emerge; the rest are killed by seedbed cultivation. On the other hand, some seeds collected from the surface of direct drilled plots in winter have been found to be dormant.

Preliminary observations indicated that barren brome seeds become dormant when they are exposed to light and that seeds lying on the surface of direct drilled soil may continue to germinate over a prolonged period extending into the following spring. Indeed, evidence from elsewhere now suggests that, in a small proportion of seed, dormancy may persist for up to 14 months.

Subsequent investigations by the Weed Biology Group compared the germination of barren brome and three other species of brome in different qualities of light. In most weed seeds, germination is dependent upon exposure to light converting a proportion of the photoreceptor phytochrome into its active form, Pfr. This ensures that germination only takes place at or near the soil surface. It was demonstrated that the response of barren brome seeds to light is rather unusual; in this species it appears that the presence of Pfr actually inhibits germination. The WRO evidence also shows that, while the three other species of brome appear to be insensitive to quality of light, germination of barren brome is delayed by red light but stimulated by far red light.

The Weed Biology Group also compared the germination of four species of brome at different temperatures. Both barren brome and soft brome (*Bromus mollis*) germinate rapidly over a wide range of temperatures. In contrast, the germination of freshly shed seed of upright brome (*B. erectus*) is inhibited by



Three common brome grasses, which are currently being investigated by the WRO Weed Biology Group. (A) Barren Brome; (B) Meadow Brome; (C) Soft-brome.

temperatures below 7°C and that of meadow brome (*B. commutatus*) by temperatures above 23°C.

Another factor affecting brome populations is the method of disposing of straw. Experiments by the Annual Crops and Weed Biology Groups in which the effect of burning straw *in situ* was compared with that of baling the straw and removing it from the field, have shown that burning can reduce the number of plants in the following crop to about half the number found after straw has been baled. However, the seedlings which survive on the burnt plots are still capable of producing considerable quantities of seed if herbicides are not subsequently applied.

The low susceptibility of barren brome to the herbicides used for wild oat and black-grass control has probably been an important factor in its recent ingress from field margins; to date no herbicide has given consistently satisfactory control. Of those recently evaluated in the glasshouse and the field, asulam has given promising results in barley and is now being tested on a wider scale.

Most of the severe barren brome infestations occur on headlands and originate from seeds produced in the field margins. Although the use of non-selective herbicides in hedge bottoms is a practice generally to be avoided – because it creates more problems than it solves – the selective control of barren brome and other undesirable species in the uncultivated strips surrounding the crop might do much to prevent future infestations. Currently, the Annual Crops Group is investigating the effect of a number of herbicides and growth regulators on the flora of field margins.

Evaluation of new herbicides renews interest in safeners for cereal crops

Chemical industry continues to produce a steady stream of new herbicides and the Herbicide Group has evaluated some 25 of these in glasshouse and pot experiments in the last two years. It has been encouraging to observe that the safener, 1, 8-naphthalic anhydride, can protect cereals, including wheat and barley, which would otherwise be damaged by some of these active compounds. This will facilitate the development of better treatments to control some of the more difficult weeds of cereals such as sterile brome, wild-oat and black-grass, as well as volunteer wheat and barley. Safeners can also protect perennial rye-grass against some herbicides but, to-date, safeners have not given protection to any broad-leaved crop.

Improved formulations for couch and wild-oat herbicides cleared

The Herbicide Group's development work with adjuvants for use with glyphosate to improve its activity against common couch is now almost complete. As a result, three surfactants have been granted clearance under the Pesticide Safety Precautions Scheme and will be marketed in 1982. Studies with ^{14}C-glyphosate make it clear that the main effect of the adjuvants is to increase the rate of movement of glyphosate through the leaf surfaces; there is little effect on the retention of spray by the foliage.

Progress has also been made, in collaboration with Cyanamid and Diamond Shamrock, in developing additives for use with the wild-oat herbicide difenzoquat. Mixtures of surfactants such as the water-soluble Agral and the oil-soluble Ethylan A2 often have advantages over a single wetter; oil is included to help keep the water-insoluble component is suspension but is probably not essential. The additives have relatively little effect on spray retention but markedly improve the wetting and spreading properties of sprays and hence herbicide entry into leaves. Most effect occurs when the additives are used with difenzoquat under adverse application conditions, for example, in low spray volumes or in wet weather. Although most attention has been given to difenzoquat, these mixtures also enhance the activity of other herbicides, notably the salts of phenoxy acids where again the greatest enhancement occurs when the herbicides are applied in low volumes. This development may prove particularly relevant to controlled drop application or the low volume conventional applications made with low-ground-pressure vehicles.

Differences in the tolerance of difenzoquat by wheat cultivars elucidated

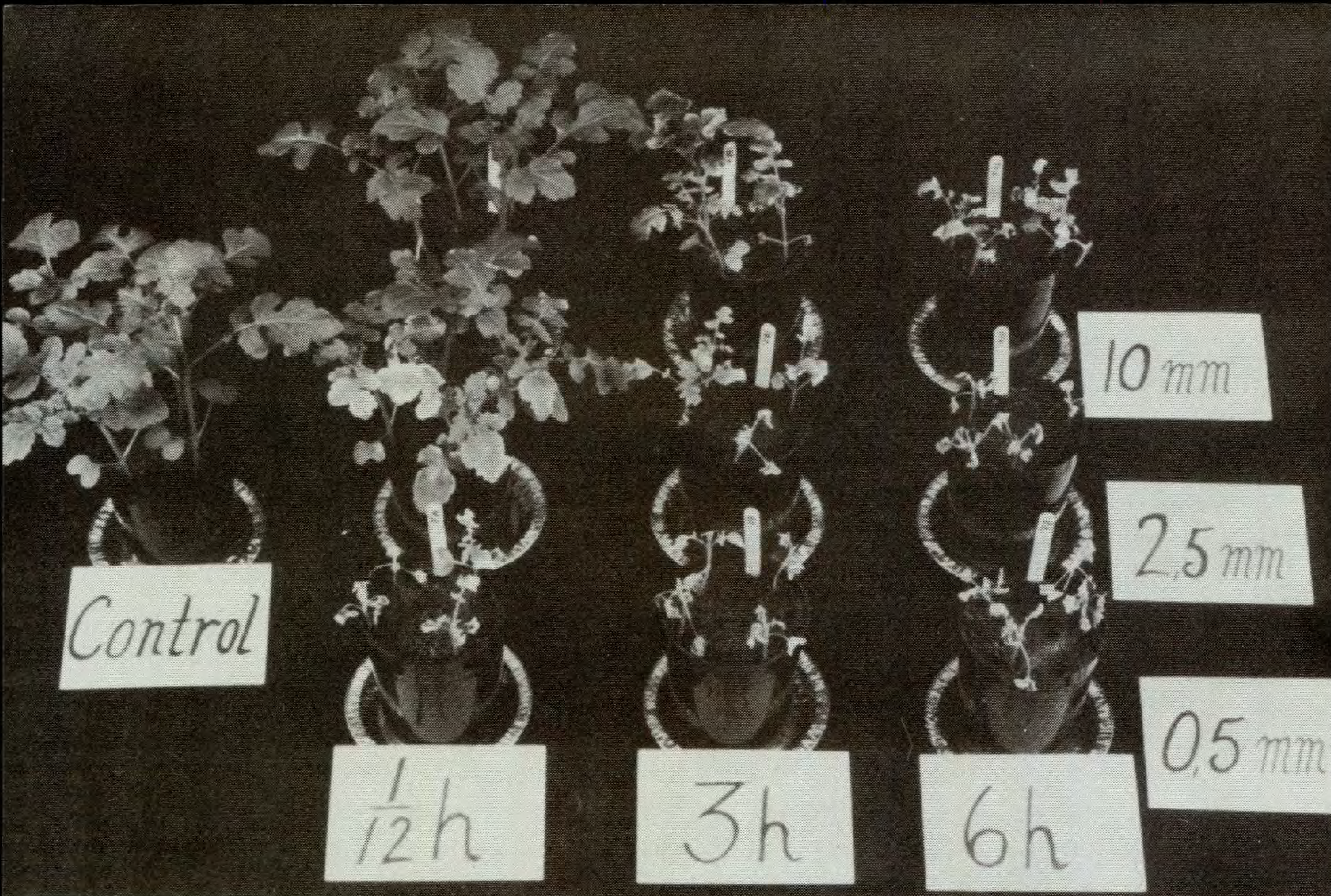
Earlier studies by the Environmental Studies Group with several spring cultivars had indicated that the relative susceptibility of each cultivar to difenzoquat correlated well with the ability of the herbicide to inhibit DNA synthesis *in vitro* in isolated shoot meristems. Although environmental factors did affect the degree of injury by modifying retention, penetration and movement of the herbicide, all cultivars were similarly affected so that the difference in relative susceptibility of each cultivar remained unaffected.

Recent studies with winter wheat cultivars have revealed a more complex situation in that the relative suceptibility of each cultivar does not always correlate with the inhibition of DNA synthesis previously established *in vitro*. This is the result of real inter-cultivar differences in retention, penetration and movement of difenzoquat which modify the effect of the inhibition of DNA synthesis.

This project, grant-aided by Cyanamid, was wound up in September 1981.

Effect of simulated rain on wild-oat herbicide performance

The Environmental Studies Group has employed its new rainfall simulator to carry out a number of investigations of the effect of rainfall on wild-oat



Effect of simulated rainfall upon the performance of a low dose of bentazone against white mustard. 'Rain' at 0.5, 2.5 and 10 mm was applied 5 minutes, 3 and 6 hours after treatment with bentazone at 0.04 kg/ha. Moderate (2.5 mm or more) rainfall falling only 5 minutes after treatment considerably reduced the effect but light rain (0.5 mm) did not. Compare with the untreated control on the left.

herbicide activity. When 0.5 mm of "rain" was applied at intensities of up to 10 mm/h 5 minutes after application of the recommended dose of difenzoquat, diclofop-methyl or flamprop-methyl, there was no significant reduction of toxicity to wild oats. However, when "rain" of between 1.5 and 16.5 mm was applied at up to 10 mm/h after the same period, the performance of difenzoquat and flamprop-methyl, and to a lesser extent that of diclofop-methyl was reduced.

The effects of "rain" applied to bentazone-treated meadow fescue (*Festuca pratensis*) and white mustard (*Sinapis alba*) followed the same general trend. However, the performance of bentazone was less affected because some of the herbicide washed from the leaves entered the plants through the soil.

Night spraying for couch control in cereals?

The development of an environment/herbicide performance profile for the maximum control of common couch with glyphosate, reported in the *WRO*

8th Report, has been pursued further by the Environmental Studies Group, in collaboration with an ADAS Meteorological Office specialist. The meteorological data for July to November for the past eight years from four sites in cereal growing areas were analysed to find out when and how often low wind speeds and absence of recent heavy rain (both favouring spraying) and warm humid air (favouring herbicide entry into the leaves) occurred together. This happened far more often at night than during the day. Recent experiments, in which other environmental variables were kept constant, have confirmed that the application of glyphosate in the dark results in weed control comparable with day time spraying.

DEVELOPMENTAL BOTANY OF THE WILD-OAT

The pillar on which the programme of the Developmental Botany Group rests is the belief that an understanding of the mechanisms in plants responsible for their success as weeds will reveal novel approaches to their control. The main thrust is an investigation of the hormone-regulated "switching" systems present in specific tissues of the wild-oat (*Avena fatua*), which the Group considers as the weed biologist's equivalent of *Escherichia coli*. Special emphasis is given to the key processes of seed shedding, dormancy and germination which are crucial to the survival of wild-oat populations, also to the gravity response of the nodes of flowering stems.

Auxin movement control point located

It is now evident from the most recent studies that the leaf sheath base of the flowering stalk of the wild-oat has a mechanism for rapid (within 15-20 minutes) changes in the direction and flux of cell to cell movement of auxin from one end to the other. This tissue could therefore function as a highly sensitive control point for the movement of endogenous hormones, or applied growth regulators, between the flag leaf and the grain. The movement of photosynthates may also be controlled at this position.

Seed abscission process elucidated

The shedding of the wild-oat fruit at maturity can be related to the auxin level in the embryo, the timing of dehydration of the seed, and the level of abscisic acid to which the abscission zone is exposed. A combined physiological and ultrastructural study has elucidated the sequence of events that leads to eventual cell to cell separation through progressive degradation of the middle lamella. A comparison of the shedding mechanisms of monocotyledon weed seeds and the ethylene-regulated abscission processes in dicotyledons indicates the possibility of selective methods for controlling shedding where the two types of plants grow together. Furthermore, because potentially separating cells have been eliminated from most cereal crops, first by the selection of non-shedding strains by early man and, subsequently, by maintained elimination in breeding programmes, the induction of shedding of immature wild-oat and other grass weed seeds without harm to the cereal crop provides a new and potentially useful agronomic technique.

Germination dependent on activation of aleurone cells

For successful germination a wild-oat embryo must have rapid access to the supply of stored food reserves in the seed. Access can be gained only by an activation of the aleurone cells to synthesise specific enzymes – enzymes which hydrolyse the carbohydrates and proteins of the reserves. Activation is triggered by the production and release of gibberellins by the germinating embryo. An embryo that is dormant, however, must preserve this food store – often for years – until the time when dormancy is broken. By studying the biochemical performance of isolated protoplasts of aleurone cells, the Group has shown that those from seeds with true embryo dormancy are relatively insensitive to gibberellic acid but become increasingly responsive to the hormone as dormancy is broken. The number of molecules of gibberellin required to activate protoplasts from the aleurones of either dormant or non-dormant seeds is now open to quantitative estimation.

At germination the scutellum of an embryo must also function to absorb the hydrolysis products of aleurone action on the endosperm. Physiological, ultrastructural and biochemical studies have followed the growth processes involved in scutellum function and the differences in behaviour of the scutella of dormant and non-dormant embryos. From this work it is clear that the scutellum acts as a regulator tissue, controlling the availability of endosperm products to the embryo.

Tolerance of desiccation characterises seed dormancy

Another "switching system" which has been investigated is the change in desiccation tolerance of embryos at germination. Tolerance exists for a limited duration only. Biochemical and ultrastructural studies have shown that chromatin disruption and loss of DNA integrity are associated with a switch to the desiccation sensitive stage. Unlike the ones that germinate, embryos of dormant wild-oats retain their desiccation tolerance with an effective capacity for DNA repair through a number of hydration and rehydration cycles, i.e., the switch to desiccation sensitivity is not operative during dormancy.

This coordinated approach to specific switching mechanisms in different tissues of the wild-oat provides the opportunity for novel manipulative procedures which could offer innovative approaches for weed control.

CONTROL OF BROAD-LEAVED WEEDS IN CEREALS

Autumn control of broad-leaved weeds evaluated

The Annual Crops Group have, for the past three years, been studying the yield response of winter cereals to the autumn control of broad-leaved weeds. A large area of winter cereals is now sprayed in the autumn, although the evidence that yields benefit from autumn rather than spring spraying of broad-leaved weeds is less clearly defined than it is for grass weeds. In WRO trials, autumn control of large infestations of cleavers (*Galium aparine*) and common field-speedwell (*Veronica persica*) has enhanced wheat yields but, in general, autumn spraying has produced no yield advantage over spring applications made before crop jointing. When spring spraying was delayed until the crop had two nodes, yields were often depressed.

The Group is currently attempting to establish threshold levels at which it would be economic to control autumn germinating broad-leaved weeds. The main difficulty is the sheer number of species, all with differing ability to compete and survive the winter. In 1980/81 cleavers, mayweeds and wild radish (*Raphanus raphanistrum*) were the most competitive on a plant for plant basis, but larger numbers of the lower growing field pansy (*Viola arvensis*), parsley piert (*Aphanus arvensis*), chickweed (*Stellaria media*) and field-speedwell were equally damaging to yield. In the eight experiments completed to date, an average of 80 weeds/m^2 in the autumn reduced yield by 0.37 t/ha.

Methods of application of broad-leaved weed herbicides in cereals compared

The effect of method of application on both deposition and herbicide activity was examined in a Herbicide Group field experiment in which a mixture of mecoprop, ioxynil and bromoxynil esters was applied to knotgrass (*Polygonum aviculare*) growing in a spring-sown cereal. A rotary atomiser was used to spray uniform size drops of 150 or 250 μm diameter at rates of 30 or 60 l/ha, while a conventional hydraulic nozzle (Spraying Systems Teejet 6501) was used to spray at 60 or 120 l/ha. The amount of spray deposited on the weeds was measured in the presence or absence of the fully tillered cereal.

The variability of the deposit was high with both devices. At the lower volume rates there was a tendency for more herbicide to be deposited on the weed but this was not reflected in a higher level of weed control. As expected, the crop intercepted some spray so that less herbicide was deposited on the weed in the presence of a crop than in its absence and, as a result, the final level of weed control was reduced.

In similar work with soil-acting compounds, using a variety of weed species as indicators of phytotoxicity, the effect of application method on the activity of chlortoluron, propyzamide, nitrofen and terbutryne has been studied. A rotary atomiser, a conventional hydraulic nozzle and a dribble bar which produced streaks of herbicide at 2 cm intervals were used. With the possible exception of nitrofen, none of the compounds showed any variation in activity that could be attributed to method of application. We therefore concluded that, within broad limits, the activity of soil-acting herbicides is unlikely to be affected by method of application.

WEED CONTROL IN OTHER ARABLE CROPS

Though the weeds of cereals continue to dominate the programme WRO remains alert to the inevitable weed problems that new trends in crop production bring about in other arable crops. Progress on two new projects is reported here.

Weeds and weed control in oilseed rape

The increasing importance of oilseed rape to British agriculture – over 100,000 ha were grown in 1981 – and the dearth of research into weeds and weed control in this crop led the Annual Crops Group to start a research project on rape in the autumn of 1979. Two aspects of the relationship between the crop, its weeds and the herbicides used to control them, were selected for study. First, the detailed effects of weeds on the growth and yield of oilseed rape were not known, and second, the crops' tolerance of some herbicides, particularly those used for grass weed control, was in doubt.

During the past two seasons the group has studied both these aspects. To date, observations suggest that a well established rape crop can tolerate quite a high level of weed competition but a less competitive crop, particularly when planted late, is much more sensitive. Even so, although plant vigour in the early spring was quite often reduced, weeds have depressed yields only in a few trials. The herbicide tolerance studies have shown that late applications and/or high doses of dalapon will reduce yields but that the recommended 3.4 kg/ha, applied at the 2-3 leaf stage, appeared to be safe. TCA was damaging at the recommended 8 kg/ha in some trials, but, in others, even 32 kg/ha appeared to be safe so further work on the safety of this herbicide is in progress.

Merits of "little and often" spraying systems for sugar beet and onions investigated

In collaboration with staff of the MAFF Arthur Rickwood Experimental Husbandry Farm, the WRO Fenland Team have been investigating the technique of repeated low dose spraying for weed control in sugar beet and onions. This is also often described as the "high pressure" or "low volume" technique. Essentially, however, it makes optimum use of herbicides by applying them at a low dose to the emerging cotyledon stage of each new weed flush. In recent experiments, four quarter doses of metamitron or phenmedipham (each with or without a spray additive), or of a commercial mixture of ioxynil and linuron, applied at the cotyledon stage of each weed flush, gave more reliable and usually better weed control than two half doses or a single full dose. Providing the weeds were treated at this early stage and were not allowed to grow larger, problems with resistant annual weeds did not arise.

Concentration and volume rate were not found to be critical when treatments were applied at the emerging cotyledon stage of the weeds. When applied as the first true leaves were emerging, four quarter doses of metamitron or metamitron plus spray additive, gave better control when applied in 60 l/ha than in 240 l/ha, but phenmedipham, phenmedipham + spray additive, and the ioxynil/linuron mixture were equally effective at both low and high volume rates. However, the label recommendation for the commercial formulation of phenmedipham is that it should be applied at not less than 0.38 kg a.i. in 80 l/ha. There are obvious savings in weight and time when herbicides are applied in low volume, and this product is prone to crystallise out at lower concentrations.

The effect of pressure was investigated at 2.1 or 4.2 bar using Spraying Systems 8001 TeeJets. Good weed control was obtained with all the herbicides at both pressures if applied at the emerging cotyledon stage. Changing the pressure made no difference to the poor performance of either metamitron or phenmedipham when applied at the 4-leaf stage or of the ioxynil/linuron mixture at the 6-leaf stage. Only at the 2-leaf stage did changing the pressure affect the performance. At this stage phenmedipham gave better control of field speedwell and small nettle at the higher pressure.

Increasing the pressure did, on occasion, have an adverse effect on sugar beet if the crop was under stress. The yields of sugar beet after repeated low doses of phenmedipham or metamitron were usually as good as or better than the yields after standard sequences of herbicides. However, in two experiments, application of two quarter doses or a single full dose of phenmedipham to sugar beet under stress gave lower yields at high pressure than at low pressure. There was no difference in the level of weed control achieved.

Measurement of the retention of the ioxynil/linuron mixture on onions showed that more herbicide was deposited on the crop from fine jets producing small slow drops than from slightly coarser jets producing correspondingly larger and faster drops. This aspect is being investigated further because it offers a possibility of increasing the selectivity of this herbicidal mixture.

WEED CONTROL IN GRASSLAND

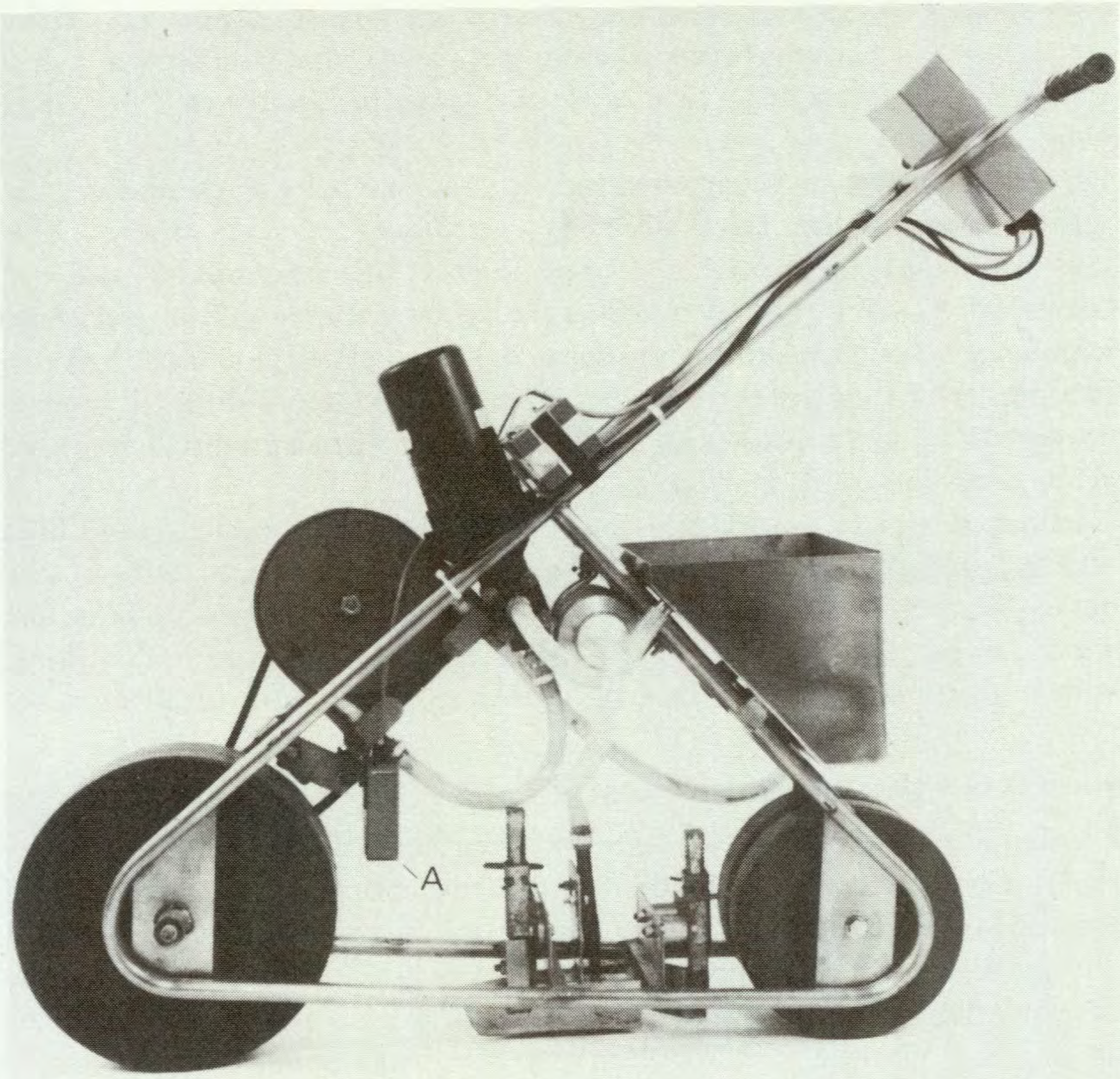
The research effort of the small Grass and Fodder Crops Group continued to be shared between the competing requirements of weed control in grass leys, herbage seed crops and permanent pasture. Recent research on the control of weeds during grass establishment is the subject of the full length article on p. 55. Here, we report briefly on the Group's recent achievements in killing tall weeds in grassland, increasing the clover content of permanent swards, and controlling volunteer ryegrass and sterile brome in perennial ryegrass. There has also been a significant input into the grassland programme by both the Weed Biology and Microbiology Groups. Two aspects of this collaborative work are reported here.

The "selective" control of tall weeds in grassland

The possibility of using roller or wick-type applicators to smear small amounts of non-selective herbicides on tall growing weeds of grassland was investigated in 1980/81. A preliminary survey carried out in 1980 indicated that tall growing weeds were the major problem of 45 per cent of the 830 grass fields examined. Thistles were the most prevalent weed, being present in 60 per cent of fields, followed by docks in 18 per cent and nettles in 16 per cent of the fields.

A second survey showed that, in grazed fields, a safe difference in height between docks and grass existed throughout most of the period from June-September, thus giving ample opportunity to use this technique. However, in fields cut for silage, a safe height difference occurred far less often.

Trials with roller and wick-type applicators on docks and thistles in 1981 showed little difference in efficacy between the two types. Grass damage due to transfer of herbicide from treated herbage increased with the amount of chemical applied. The survival of shorter plants and seedling invasion were



The WRO prototype patch seeder employs a reflectance ratiometer (A) to detect gaps in a sward and trigger the operation of a seeding mechanism. It is still at a very early stage of development.

common problems and we are now investigating more promising combinations of "selective" treatment followed by conventional spraying at appropriate intervals.

Introducing and manipulating clovers in permanent swards

Less than 20 per cent of British grassland contains adequate amounts of white clover. The Grass and Fodder Crops Group has therefore sought low cost methods of introducing clover into live grass swards to increase soil fertility, pasture quality and animal output. In this context the slot-seeding technique, pioneered by WRO, has proved useful for establishing both red and white clover into ryegrass dominated swards. For example, in a two-year experiment, the total herbage harvested from slot-seeded Hungaropoly red clover was equivalent to the DM yield of all-grass plots receiving a total of 160 kg N/ha.

As an alternative to sowing seed in rows, the feasibility of creating regular gaps in swards, either mechanically or chemically, and then sowing clover seed into these gaps or patches is being studied. The detection of patches of brown soil in green vegetation is possible, using a simple, robust and cheap reflectance ratio meter which measures the ratio of red and near infra-red radiances; ratios are lower for soil than for green sward. The meter is being coupled to a fluid applicator capable of dispensing pre-germinated seed in a gel medium containing nutrients and fungicides.

In mixed swards, several-fold increases in the clover content have been obtained by using carbetamide, propyzamide and paraquat to achieve temporary suppression of grass growth. The short-term loss in grass production, which can be minimized by spraying in the autumn rather than in the spring, is more than made good by the extra growth of clover in the following year.

Effect of herbicides on nitrogen fixation

The indirect effects—on clover nodulation and mycorrhizal infection of clover roots—of grass-suppressing herbicides used to improve the clover content of grassland have been the subject of a collaborative study between the Microbiology and the Grass and Fodder Crops Groups. After three years, no adverse effects have been detected. Chemical analysis indicates that, in the absence of nitrogen fertilizer, carbetamide and especially propyzamide increase the yield of nitrogen in the harvested herbage. For example, annual use of propyzamide resulted in a total increase of about 80 kg N/ha over the 3-year experimental period. This was due, in part at least, to an increase in the percentage N content of the grass and, also, to an increase in the dry matter yield of the clover, the percentage N content of which remained unchanged.

By contrast, when fertilizer at 70 kg N/ha was applied, a single application of carbetamide reduced the nitrogen yield in the harvested herbage, both in the year it was applied and in the two subsequent years of the 3-year trial. When, however, propyzamide was applied to the same fertilized sward, after an initial reduction in the nitrogen yield of the herbage in the year of application, there was an increase in nitrogen yield in the two subsequent years, the total gain over the fertilized plots to which no herbicide had been applied being 30 kg N/ha.

These gains in nitrogen found with propyzamide treatments are associated with the increased clover content of the sward but have to be set against losses in grass quality, especially when repeated doses of herbicide are applied.

Nevertheless, the data suggest that treatment with propyzamide every second or, more probably, third year will significantly improve both clover content of swards and the nitrogen yield of the herbage. A full assessment will only be possible, however, after the next three years of the experiment.

Gap colonization in swards studied

Although there is an increasing array of selective herbicides that can be used to control or suppress undesirable species in swards, there is little information on the nature of weed ingress. The Weed Biology Group has therefore undertaken an investigation, in three different types of grassland at WRO, of the colonisation by weeds of small artificially created gaps in the sward. In a short-term perennial ryegrass ley, these gaps have been colonised mainly by annual meadow grass, seeds of which were present in large numbers in the soil. However, in old indigenous pasture, colonisation was almost entirely vegetative despite the presence of a moderate number of seeds in the soil. In a sward resown with ryegrass in 1968, colonisation occurred as a result both of seed germination and vegetative spread. The size of the gaps, the time of year that they were created, and the presence or absence of dead vegetation have all been demonstrated to affect both the rate and nature of weed colonisation.

Controlling weeds in grass seed crops

Within the Grass and Fodder Crops Group, observed reductions in yield of second-year ryegrass seed crops had earlier been attributed to competition from volunteer ryegrass seedlings after the first harvest and over production of vegetative tillers. However, though WRO trials showed that atrazine, chlorpropham and diuron could successfully be used to eliminate these problems, this did not lead to any substantial improvement in seed yield.

The use of asulam to control sterile brome (*Bromus sterilis*), which has been reported as spreading into herbage seed crops from field boundaries, is currently being investigated. So far, applications in November and April have both proved successful, but further work will concentrate on spring treatments when the brome infestations are more easily recognised.

WEED CONTROL IN FRUIT AND OTHER PERENNIAL HORTICULTURAL CROPS

Despite the greater number of herbicides and their extensive use, changing methods of crop production inevitably produce new problems. While the

Dense infestations of creeping thistle were found to reduce yields of winter wheat by 50 per cent. Glyphosate applied pre-harvest has shown promise for its control.

Perennial Crops Group continued its work on deep-rooted perennial broad-leaved weeds, new investigations were started into the control of willowherb (*Epilobium* spp) and other perennials that establish from seed. Considerable emphasis was also given to reducing the amount of field testing required to establish the crop safety of new treatments. The techniques that have led to the introduction of several treatments for strawberries were further evaluated on blackcurrants and plums.

Control of perennial broad-leaved weeds

Attempts to control creeping thistle (*Cirsium arvense*) with glyphosate in pre-planting fallows were disappointing. In both cultivated and undisturbed soils a large proportion of the roots and rhizomes failed to produce shoots and consequently could not be killed.

The introduction of the pre-harvest use of glyphosate in cereals provided a promising new opportunity for pre-planting control of perennial weeds. Experiments were started to assess the long-term effectiveness of this treatment on field bindweed (*Convolvulus arvensis*) and farmers' applications to other weeds including creeping thistle are being monitored. Dense infestations of the latter were found to reduce the yield of winter wheat by 50 per cent, so this technique is also of value to cereal growers. Field horsetail (*Equisetum arvense*) cannot be controlled with glyphosate but propyzamide, which can be used selectively in most fruit crops, has shown promise.

New herbicides for strawberries

The discovery of a number of promising herbicides for use in strawberries was described in the *WRO 8th Report*. Further trials with pendimethalin at outside sites in 1980 confirmed its safety on established crops. A pendimethalin/simazine mixture, applied in late autumn, was also safe but crop damage resulted from application of the mixture in August. Pendimethalin is now recommended for use on dormant and semi-dormant crops.

Further work with 3, 6-dichloropicolinic acid has confirmed its effectiveness against creeping thistle in strawberries though there is usually some leaf damage to the crop. However, treatment in September was much less damaging than 2,4-D and did not result in fruit malformation the following year but, in a young crop, late summer treatment resulted in considerable runner stunting and distortion. It is now recommended in established strawberries—with the proviso that leaf damage may occur—and is being widely used commercially. Investigations continue into the factors affecting foliar damage and the relationship between damage levels and subsequent crop yields.

Leaching of herbicides in soil

The Perennial Crops Group has been studying herbicide movement in soil columns as part of a project to develop more reliable methods of testing the tolerance of herbicides by perennial crops. The objective was to find the soil and rainfall conditions which would maximise downward movement and hence the risk of injury, and use this information to devise more effective tests with fruit plants grown in soil in containers. As far as possible conditions were realistic; herbicide was sprayed onto the soil surface, "rain" was applied from the WRO rain simulator, and the soil was adequately drained. The herbicides most used were simazine and metamitron; their water solubilities are 5 and 1860 ppm respectively. Leaching was assessed either by bioassay on split soil columns or by chemical analysis of residues in different soil layers.

In a sandy loam soil, leaching was generally greater when the herbicide was applied to wet soil rather than to dry soil. Low intensity rain (1.4 mm/hr for 18 hours) led to more leaching than high intensity rain (12.5 mm/hr for 2 hours). Penetration was greater in soil containing large aggregates (0-6 mm) than small (0-2 mm). A delay of 96 hours between herbicide application and "rain" generally resulted in more leaching of simazine but less leaching of metamitron than when rain followed immediately after spraying. When the residues were measured in soil columns after the most effective leaching treatment, 90 per cent of the simazine was found in the top four cm and 90 per cent of the metamitron in the top eight cm. With methazole, oxyfluorfen and pendimethalin, which are all less soluble than simazine, there was little leaching below 1 cm in any rainfall/soil treatment.

This is an important step in our quest to predict the tolerance of herbicides by crops in the field from studies on containerised plants.

WEED CONTROL IN FORESTRY

With the continued financial support of the Forestry Commission the Herbicide Group has evaluated several new compounds for use in forestry. However, most attention is now being given to ways of making established herbicides work more effectively. Pot experiments suggest that triazine herbicides and propyzamide can be used in summer as well as in winter. Summer applications have little effect on many crop species but provide good control of important weed grasses, particularly when these are growing in peat soil and uptake of herbicide by the foliage is assisted by the use of an adjuvant such as Actipron. Summer treatment with atrazine is particularly effective against purple moor-grass (*Molinia caerulea*) while propyzamide applied at this time is active against tufted hair-grass (*Deschampsia cespitosa*) and creeping soft-grass (*Holcus mollis*).

Glyphosate activity against grasses is often greatest in autumn and can be enhanced by the addition of ammonium sulphate and a suitable surfactant. However, there are important differences in susceptibility between grass species, and the adjuvants which are now widely used with glyphosate to improve its activity against couch grass are not necessarily suitable for the grass weeds of forestry.

In relation to the control of woody weeds, the sort of oil surfactant blend noted elsewhere (p. 13) as enhancing the activity of difenzoquat against wild oats can markedly improve the activity of glyphosate and hexazinone. The improvement is particularly evident with rhododendron, perhaps the most important broad-leaved weed of forests in Britain.

VEGETATION MANAGEMENT IN AQUATIC AND AMENITY AREAS

The research of the Aquatic Weed and Uncropped Land Group is concerned with the management of natural vegetation in water and in amenity areas. In achieving these objectives, both the means employed and the end result have to be acceptable to the public and involve no damage to the environment. The use of both chemical and biological agents to control aquatic weeds is described here; also the collaborative work of the Microbiology Group on the de-oxygenation of fresh water after herbicide treatment. On p. 71 a full-length article describes the progress made in an Aquatic Weed Group investigation, financed by the Countryside Commission, into the feasibility of using chemicals for the management of vegetation in country parks and picnic areas. Though the Countryside Commission project comes to an end in 1982, there has been such widespread interest in this work that we are trying to secure alternative funds to allow the programme to be continued.

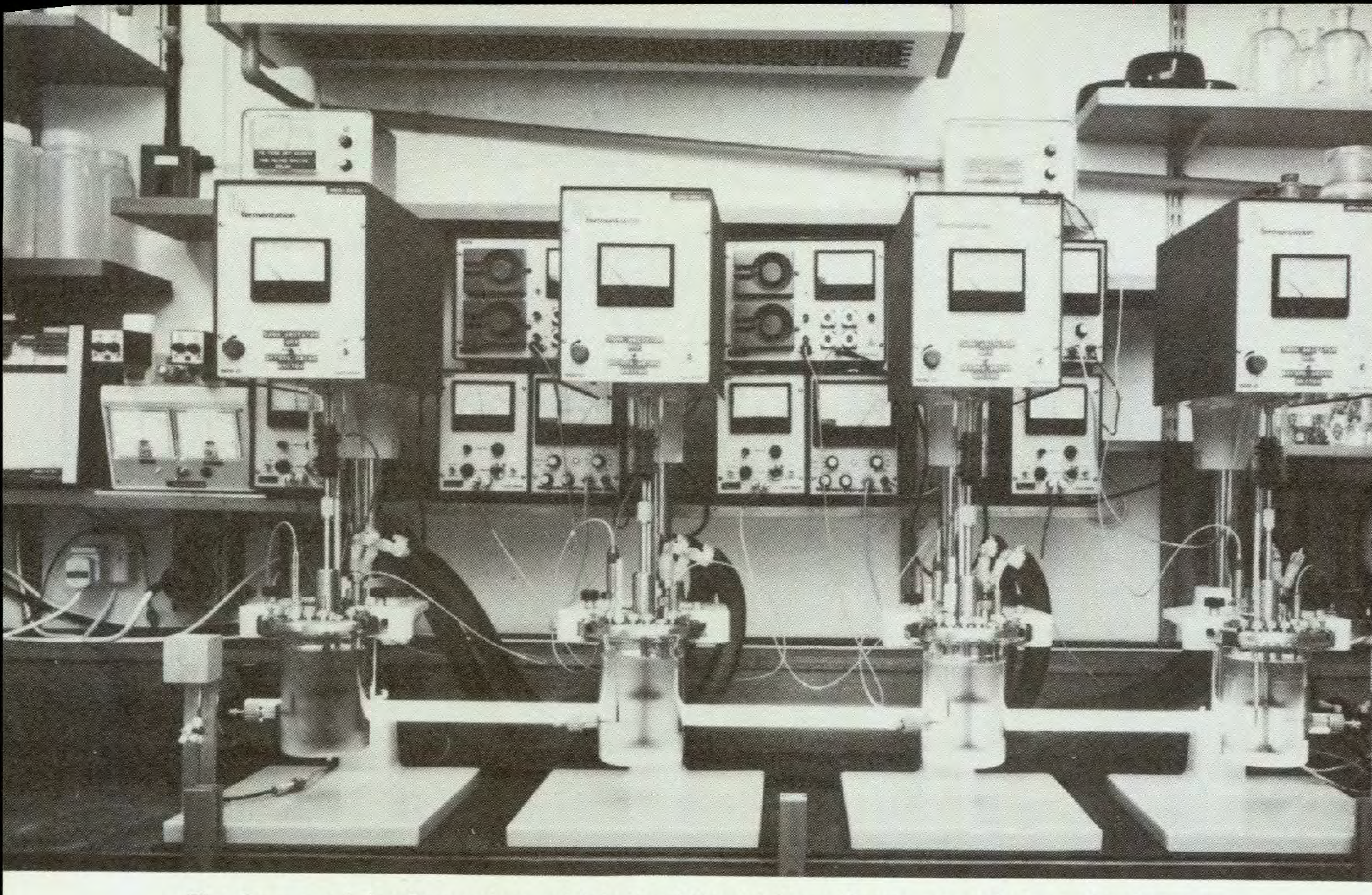
Localised control of submerged weeds

The success of preliminary attempts to localise the effects of diquat on submerged weeds in lakes and rivers—by employing viscous sodium alginate as a carrier for the herbicide—was noted in the *WRO 8th Report*. Further field experiments have enabled the Aquatic Weed Group to select the best formulation and test its efficacy in many different types and conditions of fresh water. The interest of Water Authorities has grown and many have conducted collaborative trials under the guidance of WRO staff. In 1981, Water Authorities completed trials at 28 different sites and the data from these, together with that from WRO experiments, have amply demonstrated the value of the technique. A new formulation of diquat developed from the work will be available on the market in limited quantities in 1982 and full commercialisation will follow.

The main advantages of this technique are that, both in the still waters of lakes and canals and in the swiftly flowing waters of rivers and drainage channels, it provides a means of removing selected patches of weed—thus preserving whatever proportion of the plant community is considered desirable—and enables the user to limit his expenditure on weed control to what he can afford. The group is grateful to ICI Ltd and Alginate Industries Ltd for their interest and support in this project.

Microbial contribution to the deoxygenation of freshwater

The Microbiology Group continued investigations into the deoxygenation of freshwater following the treatment of weeds with terbutryne. The purchase of four modular fermentors, which have been used to simulate freshwater ecosystems, has allowed a more critical analysis of the deoxygenation process and many of the contributory factors. Earlier work (see WRO 8th Report) had



The four modular fermentors which the Microbiology Group are using to simulate pond ecosystems and analyse the whole process of deoxygenation following treatment of pondweeds with terbutryne.

indicated that microbial decomposition of the dead weeds was not a major contributor to oxygen loss. More detailed analysis, with a wider variety of vascular and unicellular target plants, has confirmed that microbial decomposition makes little contribution to the initial phase of deoxygenation. As occurs in natural ecosystems, the major cause is the cessation of photosynthesis by the plants affected by the herbicide, while they continue to respire and consume oxygen. The planktonic, epiphytic and mud microfloras have only a small effect on dissolved oxygen levels. Their major contribution appears to be that of maintaining low oxygen levels after the initial deoxygenation. A "bloom" of bacteria always occurs when the dissolved oxygen level falls below 5 ppm and persists until the level rises again. This seems to be a result of the low oxygen level rather than a cause of it.

The use of fermentors to simulate a non-flowing aquatic ecosystem has been shown to be a valid and useful way of evaluating major effects of herbicides. Because the technique allows a ready identification and evaluation of the major factors involved, the data obtained enables the prediction of similar effects in the field.

The use of herbivorous fish to control water weeds

The collaborative investigations with the MAFF Salmon and Freshwater Fisheries Laboratories into the use of grass carp for the control of water weeds have continued. In the past two years there has been an increase in the number of fry imported from Eastern Europe and as a result a number of Water Authorities have started their own trials with the fish. Supply of fish has also been improved by the acquisition of brood stock by MAAF and a number of successful spawnings. However, with the recent closure of the MAAF Freshwater Fisheries Laboratory in London, this brood stock has now been transferred to a Water Authority.

The WRO contribution to the project has been to investigate the effect of grass carp on weed populations. The Aquatic Weed Group has mapped vegetation changes over a number of years, both in its own experiments and in those conducted by collaborating Water Authorities. While, in a few instances, complete control of weeds has been achieved, generally there has not been a significant reduction of the early spring and summer weed growth. Although, in the cool British climate, grass carp can achieve a gradual reduction in plant density over the summer, it now seems clear that there will often be a need to supplement their grazing with cutting or localised application of herbicides. This may not be a disadvantage because total weed control is seldom required. In future research, priority will be given to integrating the fish with other methods of control to achieve a satisfactory level of weed management at lower cost.

HERBICIDE INVESTIGATIONS

In 1980, the old Herbicide Performance and Chemistry Groups were amalgamated to form a new Herbicide Group. Apart from improving coordination, this change did not affect the continuity of the research programme which has remained focussed on the evaluation of the activity, selectivity and persistence of new herbicides, on improving herbicide performance by changes in application method and formulation, on the interactions between one herbicide and another, and between herbicides and the soil. The Environment Studies Group has not only continued to appraise the effects of individual climatic factors upon herbicide performance but has also, with industrial support, investigated the biochemical basis of observed differences in the tolerance of herbicides by cereal varieties. Relevant aspects of the work of thse two groups, and that of the Microbiology Group, have already appeared in the crop orientated sections of this report at pages 12-14, 17 & 22; the aspects reported here are of more general application. A full-length article by a member of the Herbicide Group on p. 63 is devoted to an investigation into the antagonism which occurs between the wild oat herbicide diclofop-methyl and broad-leaved weed herbicides.

New research sprayer developed

In order to optimise spray droplet characteristics it is necessary to study the individual and combined effects of drop size and speed. The rotary atomiser produces drops of relatively uniform size, but relies on gravity to carry them to the target. Drop speed cannot therefore be varied unless an air stream is introduced. The conventional hydraulic nozzle permits some variation in drop speed, but, because it produces a range of drop sizes, at any given time the drops produced will be travelling at a range of drop speeds. Therefore, none of these devices can be used to study independently the effects of drop size and speed.

The possibility of generating uniform sized drops using a pulsed microjet was discovered elsewhere in 1978*, but in-flight collision of the drops causes them to coalesce and break up again to give a distribution of drop sizes which increases with the distance from the jet. In the jet developed at WRO by the Herbicide Group, collision of the separate drops is prevented by inducing an electric charge on the drops at the source so that they repel each other (see Frontispiece). The WRO jet differs from other generators of charged drops in that the charge is incidental to its main purpose which is to produce drops of controlled size and speed. Its other advantages are that it is relatively insensitive to the nature of the formulation used and that it is possible to apply herbicides at a wide range of flow rates with it. Results so far have shown that retention of drops by cereals is much more dependent upon drop momentum than is retention by broad-leaved plants, indicating that it may be possible to improve selectivity by manipulating this factor.

Straw burning can affect herbicide adsorption and activity

Soil temperatures under a good straw burn may go as high as 250°C which may modify the behaviour of organic and inorganic colloidal surfaces and hence affect both the adsorption and activity of herbicides. Chemists of the Herbicide Group have measured the adsorption of chlortoluron by three soils following heating at temperatures from 109-250°C for 1-5 minutes. Adsorption changed little on a mineral soil with a low content of organic matter, but increased up to 40 times on a peat soil. Similar work on the effects of

* Yates, W E and Akesson, N B (1978) Monodisperse atomization systems for pesticide sprays. In *Proceedings 1st International Conference on liquid atomization and spray systems*. 181-185

temperature of incineration on straw ash showed that the adsorptive capacity of the residue increased with the temperature that had been reached. Since straw burning is not a precise operation the effects, if any, in the field are difficult to predict. However, field studies have shown that where straw burning followed by minimum tillage has left the surface with an increased adsorption capacity compared with an equivalent ploughed soil, then chlortolurton effectiveness is usually diminished. Limited work with other compounds however, suggests that these observations are not of universal application.

Factors affecting herbicide persistence studied

The Herbicide Group has participated in a collaborative study organised by the Herbicide/Soil Working Group of the European Weed Research Society, one of the objects of which was to determine the influence of weather conditions or soil properties on the rates of degradation of simazine in the soil. Results have yet to be fully evaluated but the preliminary conclusions are: that the half-life of simazine is positively correlated with soil clay content and the inclusion of other soil properties gave no improvement in the correlation; that the effect of temperature is similar in all soils irrespective of their country of origin; finally, and perhaps most surprising, that the effect of soil moisture varies considerably, in some cases apparently having no effect at all.

Breakdown products unaffected by presence or absence of plants

In the *WRO 8th Report* work was described which showed that soil pH and nutrient level did not affect the breakdown products of atrazine and diuron. Analagous work with isoproturon by the Herbicide Group has shown that metabolic pathways are the same, whether or not plants are growing in the soil. This means that rhizosphere organisms effect the same reactions as those organisms living in weed-free soil.

Consequently there is no apparent need for registration authorities to ask for metabolic pathway studies in the presence of different crop plants.

Long-term studies continued

The long-term field experiments, in which crops of wheat, barley, maize and carrots are grown on plots where tri-allate, MCPA, simazine or linuron have been applied since 1963, have been continued by the Herbicide Group. There are still no significant differences between the yields from treated and untreated plots.

In another experiment, paraquat has been applied to the same plot annually since 1967. Annual analyses of the residues present in the soil immediately before the spring application showed that, of the total paraquat applied since 1967, only 50-55 per cent in 1980 and 35-40 per cent in 1981 could be recovered. Laboratory studies with soil from these plots treated with ^{14}C-labelled paraquat have been carried out at both WRO and at ICI Plant Protection Division, but the cause of the apparent disappearance of paraquat has yet to be identified.

Effect of soil moisture on herbicide performance

In experiments conducted by the Environmental Studies Group in which soil moisture was determined by regular weighing of potted plants and water was added with a syringe dispenser, it was found that the performance of both foliage and soil-acting herbicides was significantly affected by soil water content. The activities of both ioxynil ester applied to chickweed and diclofop-methyl applied to wild oat were significantly reduced at low soil moisture content and enhanced at soil water contents above field capacity. Under low soil moisture regimes, high humidity partially restored the reduced activity of the sodium salt of ioxynil against chickweed.

The post-emergence activity of isoproturon applied to black-grass and of metoxuron applied to sterile brome was also enhanced at high levels of soil moisture. Applying water through a tube to the centre of the pot, rather than by watering the surface, reduced the activity of isoproturon, indicating that the water status of the surface layers of the soil probably has a major effect upon the field performance of these herbicides.

Effect of temperature on herbicide performance

The Environmental Studies Group has also conducted experiments to determine the effect of temperature before, during and after herbicide application upon subsequent performance. The imposition of higher day and night temperatures, i.e. 26/16°C by comparison with 16/10° and 10/6°C, after the application of diclofop-methyl to wild oat and ioxynil ester to chickweed, increased the level of control. By contrast, following the application of metoxuron to sterile brome, cool conditions resulted in increased activity.

Testing for herbicide effects on the soil microflora

The lack of clear guidance on how to detect and evaluate the effects of chemicals on the soil microflora has been a major problem to regulatory authorities and herbicide manufactureres alike. The research of the Microbiology Group has done much to clarify the situation and, embodied in Technical Report No. 59*, has had a considerable impact. The tests for herbicide effects upon the soil microflora published in that report have now been incorporated in the requirements of several regulatory authorities. Along with Technical Report No. 45 (see *WRO 8th Report*) it is also being used as a basis for the development of guidelines by OECD and FAO.

The report recommends the employment of a few simple tests and, thus, it has been welcomed by industry. However, as the report also points out, further research on pesticide side-effects is necessary. Such research continues to be the main occupation of the group.

BIOMETRICS

The ARC Letcombe Laboratory/WRO Joint Biometrics Group has two members of its staff based full time at WRO, while three others are frequent visitors. Group members advise and assist WRO staff in the design and analysis of experiments, and investigate computing and other problems arising from this work.

Provision of new accommodation and the acquisition of additional terminal devices have facilitated use of the Rothamsted computer by WRO staff. A 'macro' (user program) has been written to enable occasional users to carry out standard statistical analyses in GENSTAT more readily. The SYMAP contour-plotting program has been used in processing the results of a whole-farm survey of the incidence of black-grass and wild oats. Address lists for Weed Workshop '81 were compiled using RESBOL programs written at Letcombe.

An Apple II microcomputer has also been installed in the terminal room and considerable effort put into developing its use in conjunction with hand-held data loggers and for the preliminary processing and plotting of experimental results.

OVERSEAS ACTIVITIES

The Tropical Weeds Group, financed by the Overseas Development Administration (ODA), continued with a wide range of activities including detailed research on the parasitic witchweeds (*Striga* spp.), the evaluation of herbicides for controlling weeds in tropical crops, and the provision of information and advice to overseas correspondents, visitors and students.

* Greaves, M P, Poole, N J, Domsch, K H, Jagnow, C & Verstraete, W Recommended tests for assessing the side-effects of pesticides on the soil micro-flora. *Technical Report ARC Weed Research Organization*, 1980, *59*, 15 pp, £2.00

CONTROL OF TROPICAL WEEDS

The witchweed project, financed by ODA on behalf of the International Crops Research Institute for the Semi-arid Tropics (ICRISAT), has produced valuable information to aid that Institute's programme of selecting and breeding witchweed-resistant sorghum and millet varieties. In particular, certain types of resistance have been shown to depend on environmental conditions, especially soil moisture and nitrogen. New techniques have been developed for studying mechanisms of resistance, and new sources of resistance have been identified in semi-wild populations of millet.

The herbicide evaluation programme has included several new candidates for the control of purple nutsdege (*Cyperus rotundus*) of which Fisons' NC 20484 appears to be the most promising. Exciting new grass-killing herbicides, including ICI's fluazifop-butyl, have been tested on a range of tropical perennial grasses and shown to be particularly effective on paspalum grasses and Bermuda grass (*Cynodon dactylon*). Further work with herbicide safeners (antidotes) has revealed interesting possibilities for the use of 1, 8-naphthalic anhydride (NA) for protecting maize against chlorsulfuron and both maize and rice against diclofop-methyl. Thus it may be possible to achieve better control of itch-grass (*Rottboellia exaltata*) and both wild and red rice.

LIAISON WITH TROPICAL DEVELOPING COUNTRIES

Liaison has been maintained with many ODA personnel and local workers in the field. In correspondence, advice and information on a wide range of weed problems, weed research methods and equipment have been given in answer to more than 130 technical enquiries each year. Five annotated bibliographies have been published on tropical weed topics and two papers produced in a new series of tropical weed control reviews. In addition, members of the group discussed weed problems with more than one hundred visitors each year from developing countries.

The group leader made five visits overseas in 1980/81 including one to Botswana and another to Bolivia to study weed problems and advise on further ODA-financed weed research effort. Invited review papers on various topics were presented at conferences in Brazil, Liberia, Upper Volta and India, the last two concerning witchweed.

The home-based officer undertook two consultancy visits for ODA to the Solomon Islands to advise on methods of controlling creeping and climbing vines (*Merremia* spp.) which are causing serious problems in newly planted forests. Subsequently, the research he recommended has shown that 2,4-D and related herbicides are potentially useful for controlling *Merremia*.

He also undertook a 3-month secondment to the Regional Centre for Tropical Biology (BIOTROP), Indonesia, where he organised a 6-week weed science training course for 23 students from South-East Asia. The problem posed by the tropical perennial speargrass (*Imperata cylindrica*) was also appraised and a detailed proposal for a 3-year research project on this weed was submitted to, and accepted by ODA. The home-based officer has been appointed to lead this project, starting early in 1982.

In May 1981 ODA announced that, because of financial pressures, they would cease funding overseas liaison activities at WRO from March 1982, although provision would be made for the research on witchweed to continue for another three years. The home-based officer post is also not affected. Alternative funds are still being sought for continuation of the herbicide evaluation work on tropical crops and weeds and the associated advisory service which has been an important part of the role of WRO since its inception.

LIAISON AND INFORMATION

LIAISON

The long established role of WRO in promoting liaison between all concerned with the advancement of effective weed control in the UK has become even more vital in the present stringent economic climate. Within the institute, the Director and Department Heads meet regularly to review, in succession, every major aspect of the research programme to ensure that the limited funds available for research are spent to the greatest effect and that existing arrangements for the coordination of reseach between WRO and other official, commercial and university centres are both adequate and effective.

Liaison with ADAS

The activities of the Agricultural Development and Advisory Service Liaison Unit at WRO have been recognised as vital to the proper functioning of the institute ever since it was established. Today, there are two liaison officers, one specialising in agricultural herbicides and the other in horticultural herbicides. Not only do they keep WRO informed of new problems requiring research but they also keep their ADAS colleagues informed of new developments. They assist in the planning and coordination of the ADAS herbicide trials which provide opportunities for the further development of treatments and techniques originating at WRO. Much time is spent in answering inquiries from ADAS colleagues, farmers and growers, giving talks to the latter on weed control, liaising with herbicide manufacturers, and compiling and frequently revising the numerous ADAS advisory booklets on weeds and herbicides. A full list of these booklets is available from any ADAS office.

The liaison officers' activities in 1980-81 followed a typical pattern. The outstanding feature of the period was the number of inquiries received by the agricultural liaison officer on the control of barren brome in cereals. ADAS first alerted WRO to this weed in 1976 and, as a result, the then Herbicide Performance Group screened a number of candidate herbicides. The most promising treatments were included in a series of ADAS trials on the control of barren brome in the late 70's. The results of this series of trials, together with information on the biology of the weed obtained by WRO, formed the basis of a comprehensive ADAS advisory leaflet on barren brome published in June 1981. This was used in conjunction with a very successful joint ADAS/WRO exhibit on the biology, distribution and control of barren brome which was shown at Weed Workshop '81, the Royal Show and the East of England Show.

Contacts with the chemical industry

The annual Chemical Industry Days organised in conjunction with the British Agrochemicals Association were again repeated in 1980 and 1981 providing the occasion for mutually advantageous contacts between the younger staff of chemical firms and WRO. Over 70 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 addition to these formal events there was constant informal liaison between individual members of WRO and staff of the agrochemical companies.

Liaison with agricultural merchants and consultants

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 two Merchants' Days held each February in conjunction with the United Kingdom Agricultural Supply Trades' Association. A total of 260 merchants' staff attended the days in 1980 and 1981 and it has been gratifying to observe the steadily rising level of technical knowledge on the part of those attending. A new enterprise started in 1981 was a Consultants' Day organised on similar lines to the Merchants' Days but in co-operation with the recently formed Association of Independent Crop Consultants.

The Director and Secretary, Mr B A Wright—later to receive an MBE in the 1982 New Year's Honours List—talking to Mr J North, member of the Director's Scientific Advisory Group during Weed Workshop '81.

Weed Workshop '81 and WRO's 21st Anniversary

Weed Workshop '81, the 6th in this biennial series of displays of current research at WRO, was held on 9, 10 and 11th June 1981. In addition to the Workshop lectures, the event featured field demonstrations and marquee and laboratory displays of the latest advances in cereal and horticultural weed control, grassland and aquatic weed management, and the latest findings in the more basic research on weed biology, physiology and factors affecting herbicide performance.

Of the 850 visitors, 40 per cent were scientists from the pesticide industry, 25 per cent were government research and advisory personnel, another 25 per cent were farmers and growers, and 12 per cent were scientists from the universities. The highlight of the event was the celebratory luncheon for 140 invited guests held to mark the 21st anniversary of the establishment of

WRO. The luncheon guests included many of the people who had been directly involved in the development of WRO over the first 21 years of its existence. Both guests and staff were gratified to hear from the four speakers (see Director's Introduction) of the high regard in which the achievements of WRO have come to be held.

Participation in other public relations events

Displays of WRO research on various topics were prepared by the Information Department for exhibition in 1980 at the British Growers' Look Ahead Conference, Fruit Focus, Winter Wheat '80, the Chelsea and Royal Shows, the International Conference on the Mechanization of Field Experiments at Wageningen, the BCPC Application Symposium, the AAB Amenity Planting Symposium and the BCPC Weed Conference. In 1981 displays were prepared for Cereals '81, the Royal and East of England Shows, the ARC Golden Jubilee, and the BCPC Insecticide and Fungicide Conference.

In addition to visitors to the Merchants', Chemical Industry and Consultants' Days and Weed Workshop, a total of 2,400 other visitors came to WRO in 1980-81 whose reception and programmes were arranged by the Information Department.

Conferences and journals

In 1980-81, despite the constraint of more limited funds for travelling, senior members of WRO were again called upon to participate in organising and planning the programmes of several conferences and symposia. These included the British Crop Protection Conference—Weeds in 1980 and, in 1981, the joint AAB/British Ecological Society's colloquium on seed ecology, the AAB conference on aquatic weeds and their control, and two European Weed Research Society symposia, one on aquatic weeds in Amsterdam and another on the behaviour of herbicides in the soil in Paris. Details of the overseas conferences and symposia in which WRO personnel participated are given on p. 000.

In addition, several members of staff served either as chairmen or as members of the editorial boards of a number of scientific journals including *Weed Research*, *Pesticide Science*, *Agrochimica*, and *Aquatic Botany*.

An integrated approach to grass establishment

In 1980, at the request of the British Grassland Society, Mr J G Elliott invited a number of crop protection specialists interested in grassland to pool their expertise in order to develop a more integrated and systematic approach to grass establishment. The initial concept quickly broadened to embrace other aspects such as nutrition and control of plant populations. An informal group of some 60 different specialists from both commercial and non-commercial organisations was selected by correspondence, all of whom contributed to the flow of information on the subject. WRO acted as a central collecting and coordinating agency for this information. A first draft of an appreciation of the current situation was produced during the summer of 1980 and plans were set in hand for a specialists' meeting which eventually took place in Cirencester in December 1980. Here, some 30 hours of structured discussion were recorded and, on the basis of this, a proposal for a more integrated approach to grass establishment was produced and sent to collaborators for comment. The final document, which contained a great deal of new information, was submitted to the Executive Committee of the British Grassland Society in 1981.

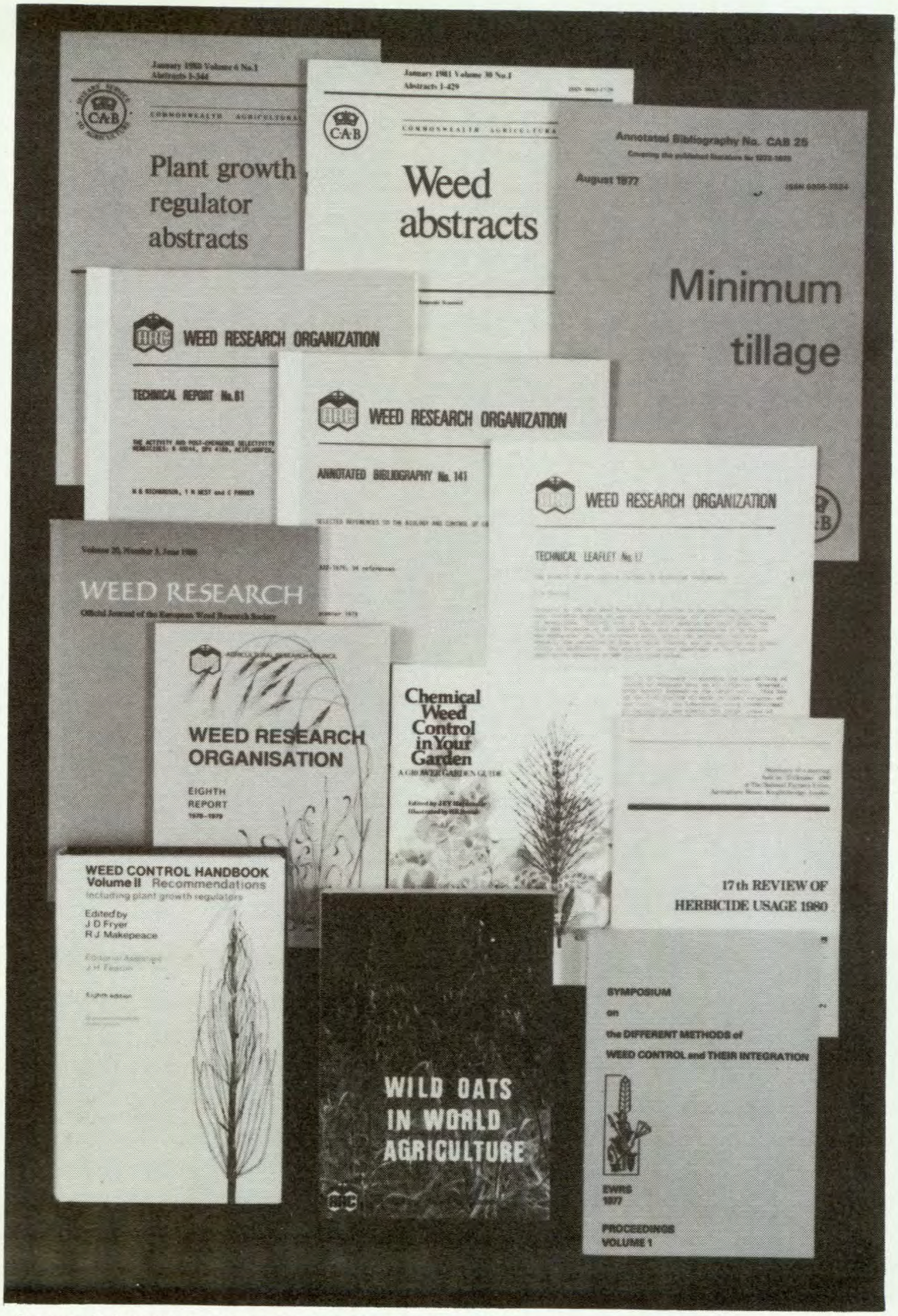
INFORMATION AND PUBLICATIONS

Staff of the Information and Public Relations Group continued to provide both the research staff and external enquirers with the library, current awareness, and information retrieval services which have gained widespread recognition for WRO as the UK centre for information on weed science. Nearly 1800 inquiries were dealt with in 1980-81, many by on-line searching of the CAB and other data bases. Because cash limitation prevented us from replacing our retiring information officer in 1980, there was a sharp reduction in the number of annotated bibliographies prepared (see p. 97). However, with funds from FAO, we did employ a temporary information officer in 1981 to compile and review a bibliography of some 900 references entitled *The Effect of Weeds on the Production of Five Tropical Crops*. This major work is to be published by FAO in 1982.

In response to the bi-annual circulation of the *List of Recent WRO Publications* to some 860 weed scientists and institutions, requests were received for 530 bibliographies, 750 technical reports and, despite the necessity of having to impose a reprint charge in 1981, for more than 7,300 reprints. In addition, the *WRO 8th Report (1978-79)* was published and well received by the media in 1980 and, subsequently, nearly 1800 copies were distributed to administrators, weed scientists, official and commercial research establishments, advisers, farmers, growers, and visitors to WRO.

Publications

Staff of the Weed Abstracts Group of the Information Department continued to compile the abstracting journals *Weed Abstracts* and *Plant Growth*



Some of the many publications with which WRO has been associated in recent years.

Regulator Abstracts under contract to the Commonwealth Agricultural Bureaux which printed and published them. In 1980-81, *Weeds Abstracts* published a further 8,947 abstracts from the world literature and, with an average annual circulation of 1250 volumes, the journal was obviously holding its own against competition from on-line services.

In the same period, the "re-packaged" journal *Plant Growth Regulator Abstracts* published 4,694 abstracts of interest to its specialist readership while its circulation was maintained at an average of more than 430 volumes/annum.

Amongst other journals with which WRO continued to be associated, the Director remained chairman of the 16-strong international Editorial Board of *Weed Research.* Three other senior members of staff also served on this board. Published by Blackwell Scientific Publications on behalf of the European Weed Research Society, the journal published 103 papers on all aspects of weed science in 1980-81.

Despite the withdrawal of ODA support for the Tropical Weeds Group in 1982, it is hoped that the existing close liaison between WRO and the "weeds" editor of *Tropical Pest Management*, published by the Centre for Overseas Pest Management, will continue to be maintained in the future.

In 1981, the British Crop Protection Council decided to publish a revised edition of Volume 1 of the *Weed Control Handbook*, dealing with the principles of weed science. Harold Roberts, senior weed scientist at NVRS and an old colleague of many WRO staff, was appointed editor and several members of WRO staff have served as managers of small committees responsible for producing particular chapters. The aim is to publish in time for the 1982 British Crop Protection Conference—Weeds.

Complete works by WRO authors included *Garden Weeds and Their Control* by R J Chancellor and H R Broad, published by Inkata Press in 1980, and *Interactions between Herbicides and the Soil*, a series of reviews edited by R J Hance, and published by Academic Press, also in 1980. WRO authors' contributions to new or established reference works in 1980-81 included chapters on the past, present and future of weed control, and on new weed problems in *Opportunities for Increasing Crop Yields*, edited by R G Hurd, P V Biscoe and C Dennis; a chapter on weed control practices in *Pests, Pathogens and Vegetation*, edited by J M Thresh; chapters on the fact and fable of weed management and the manipulation of weed behaviour for control in *Crop Protection Chemicals: Directions of Future Development*, edited by L Fowden and I J Graham-Bryce; a chapter on herbicide effects on the environment in *Methods in Microbial Ecology*, edited by R G Burns and J H Slater; a chapter on herbicide transport in the vapour phase in *Interactions between Herbicides and the Soil*, edited by R J Hance; a chapter on the literature of weed science in *Information Sources in Agriculture and Food Science*, edited by G P Lilley; a chapter on the physiological and biochemical aspects of seed development in *Advances in Research and Technology of Seeds*, edited by J R Thomson, and on senescence in seeds in *Senescence of Plants*, by K Thimann; and a chapter on the fine structure of downy mildews in *The Downy Mildews*, edited by D M Spencer. Numerous illustrations in *Diagnosis of Herbicide Damage to Crops*, by D J Eagle and D J Caverley, were provided by WRO.

EDUCATION AND TRAINING

Within the period 1980-81 WRO provided research facilities for nine higher degree students. These came from a number of universities though students of the University of Reading, of which we are an associated Institute, predominated. Details of all post graduate students are given at p. 000. In addition, facilities have been provided for a variety of visiting research workers. Such students and research workers come from many countries and provide welcome diversification and contact with other centres.

The Reading University MSc in the Technology of Crop Protection now offers a more specialised option in weed science and WRO has helped by providing staff lecturers as well as arranging for a few of these students to do their 3-month research projects at WRO. The Institute has also continued to provide a three-day introduction to weed science for the overseas students on the Imperial College Silwood Park Pest Management Course. Several staff have contributed lectures to the new MSc course in Bioaeronautics at Cranfield Institute of Technology. Members of WRO have also assisted by lecturing other courses at Reading University, Leeds University, Chelsea College and Oxford Polytechnic.

Many members of staff from all parts of WRO have devoted considerable amounts of time, often their own, to giving talks at many levels both to groups visiting WRO and at outside meetings. Audiences range from advisory service officers and staff of agrochemical and merchanting firms, to consultants, farmers, growers, students at all levels and many others.

Through the day release system, junior members of staff make considerable use of courses provided by the Oxford College of Further Education. As a result of the contacts created thereby over many years a member of WRO staff sits on the Science and Mathematics Advisory Committee which advises the College on many aspects of the provision of courses and problems which may arise in connection with them.

ADMINISTRATION

TECHNICAL SERVICES IMPROVED

The Administration Department continued to provide support to the institute's scientific programme with both technical and office services. Reference was made in the *WRO 8th Report* to the inability of the limited technical service staff to keep pace with the demands from a growing scientific staff. The appointment of a professional Station Engineer in February 1981 allowed for an important reorganisation of the engineering services, where the maintenance requirements of the plant and equipment, and the technical engineering requirements of the research programme had become inextricably tangled. The Station Engineer, who reports to the Secretary, is now responsible for the maintenance of all buildings, plant, and vehicles. Those engineering and electronics staff whose prime role is the support of research through the design, construction, modification and maintenance of scientific equipment have been transferred to the Weed Science Department, where a team of six now provides this important service to the institute. Another welcome improvement has been the strengthening of the Photographic Section by the provision of additional part-time help.

NEW BUILDINGS

The economic situation has meant a further delay in the provision of a permanent extension to the laboratory. Although internal discussions have continued, we are a very long way from bringing in an architect. The consequence of this is that, not only are the overcrowding problems still with us, but the periods for which planning approval had been given for the temporary buildings are slipping away. We have, however, been able to provide some temporary relief through the purchase of about 3500 ft^2 of second-hand prefabricated offices. Staff who were occupying serviced accommodation in the laboratory block as offices have now been moved into this temporary suite, allowing the serviced space to be more profitably used as laboratories. Though not ideal, the arrangement is working well, even though an outside temperature of 20°C below on 13/14 January 1982 made the new offices rather less than comfortable!

ACQUISITION OF MORE LAND

Reference was made in the *WRO 8th Report* to negotiations for the purchase of some additional land bordering the institute. These negotiations were completed in 1981 and 8 hectares on the north and 4.59 on the south side have now been taken in.

OBITUARIES

We regret to have to record that during 1980-81 three serving or former staff members have died. Mrs Jo Martin, who died on 13 May 1980 after a long and painful illness, had been a member of our Cleaning Staff since 1964 and Cleaning Supervisor since 1977. Mr Harry Peacock had joined the staff in 1965 and then formally retired from ARC service after illness in 1973. However, he continued to work here on a casual basis until his death on 16 November 1980, giving excellent service through his great craft and experience as a pest controller. Then on 27 October 1981 Mr Jack Fearon, formerly an HSO in the Information Department, died. He had joined WRO in 1974 after long service in industry and then retired from ARC service in 1979.

Black-grass—some results of recent WRO research

S R MOSS and G W CUSSANS

DISTRIBUTION

Black-grass (*Alopecurus myosuroides* Huds.) is now a major weed of winter cereals. A survey in 1977 (Elliott *et al.*, 1979) showed that black-grass was present on 50 per cent of the cereal farms surveyed in England and that 33 per cent of the winter and 13 per cent of the spring cereal area was infested. If these data are applied to the entire UK cereal area they suggest that black-grass infested over 650,000 ha of cereal crops in England. Severe infestations are almost entirely restricted to winter cereals, although where black-grass does occur in spring crops, it can be difficult to kill with herbicides. Although the survey did not record any major movement of the weed into new areas since a previous survey in 1972 (Phillipson, 1974), we have received many comments from farmers, advisers and crop protection specialists that black-grass is an increasing problem in the south-west and in Yorkshire and Lancashire, areas where it was formerly of minor importance.

WHY IS BLACK-GRASS A PROBLEM?

Black-grass has been encouraged by earlier autumn drilling, the sowing of more winter cereal crops and by the widespread adoption of reduced cultivation systems. Because black-grass seeds germinate mainly in the autumn (Fig. 1), early drilling of winter cereals—in September or early October—results in

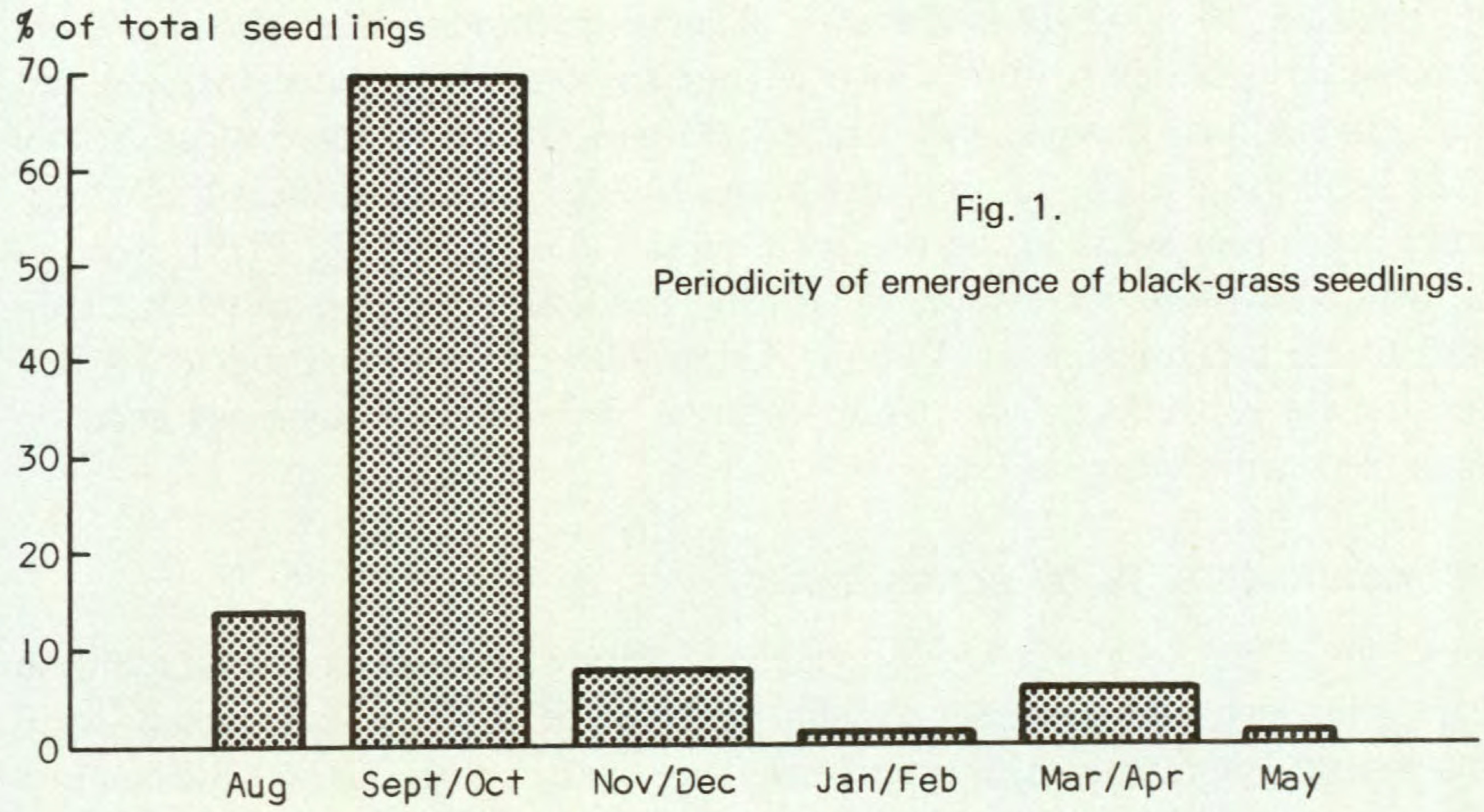


Fig. 1.

Periodicity of emergence of black-grass seedlings.

Table 1. The effect of drilling date on black-grass infestations in winter barley

Drilling date (1980)	Black-grass plants/m^2 (Dec 1980)	Black-grass heads/m^2 (July 1981)
Sept. 15	283	485
Oct. 2	264	446
Oct. 24	205	129

Table 2. The effect of cultivation system on black-grass infestations in winter wheat crops (No herbicides applied)

Cultivation system	Site and year (plants/m^2)				
	A 75/76	B 75/76	C 75/76	D 80/81	E 81/82
Ploughed	4	28	8	84	36
Tined	78	139	88	—	—
Direct drilled	177	159	91	531	282

a higher proportion of weed seedlings emerging in the crop, instead of before drilling when they could be more easily destroyed (Table 1).

Reduced cultivation systems have been found to favour black-grass (Moss, 1979a, 1981a; Pollard *et al.*, 1982) (Table 2). This is partly because these systems tend to be associated with winter cereal growing and early drilling, but is mainly a result of the effect that these reduced tillage systems have on the distribution of seeds in the soil. Whereas ploughing buries most freshly shed seeds to a depth from which emergence is unlikely, direct drilling and tine cultivations, because they cause little soil inversion, leave most freshly shed seeds close to the soil surface (Moss, 1979a, b). As most black-grass seedlings arise from seeds in the top 3 cm of soil (Cussans *et al.*, 1979), reduced cultivation systems leave seeds in an ideal position for successful germination and seedling establishment. We also have evidence that some soil-acting herbicides are less effective on land prepared by reduced cultivations than on ploughed land (Moss, 1979a).

ECONOMIC EFFECTS OF BLACK-GRASS

Black-grass can seriously reduce yields of winter cereals—probably more so than wild-oats. Yield losses normally occur when there are more than 20-50 black-grass plants/m^2 or when there are more than 50-100 black-grass heads/m^2. In our experiments, yield loss has been about 1 t/ha for every 100 plants/m^2 or 1 t/ha for every 250 heads/m^2. As populations of black-grass in excess of 500 plants and 1500 heads/m^2 have been recorded, the potential yield losses from this weed can be appreciated (Moss, 1981a; Wilson, 1979, 1980). However, it is difficult to define precise thresholds because the competitive ability of black-grass depends on the vigour and density of the crop.

As well as reducing crop yields, black-grass can reduce combine performance and increase harvesting costs (Elliott, 1980). There is also evidence from elsewhere that ergot infestation in black-grass is often associated with ergot in wheat—the same strain affects both weed and crop (Mantle & Shaw, 1977).

AGRO-ECOLOGY OF BLACK-GRASS

Because black-grass is an annual grass weed propagated solely by its seeds, long term control is dependent on minimising seed return. At WRO we have studied the black-grass seed cycle (Fig. 2) to improve our understanding of the factors affecting field populations and, using this knowledge, we are trying to develop integrated control strategies for black-grass.

Our studies have shown that vast amounts of seed can be produced and figures of over 100,000 seeds/m^2 have been recorded in cereal crops (Moss, 1982). However, the viability of black-grass seeds can be very variable; we

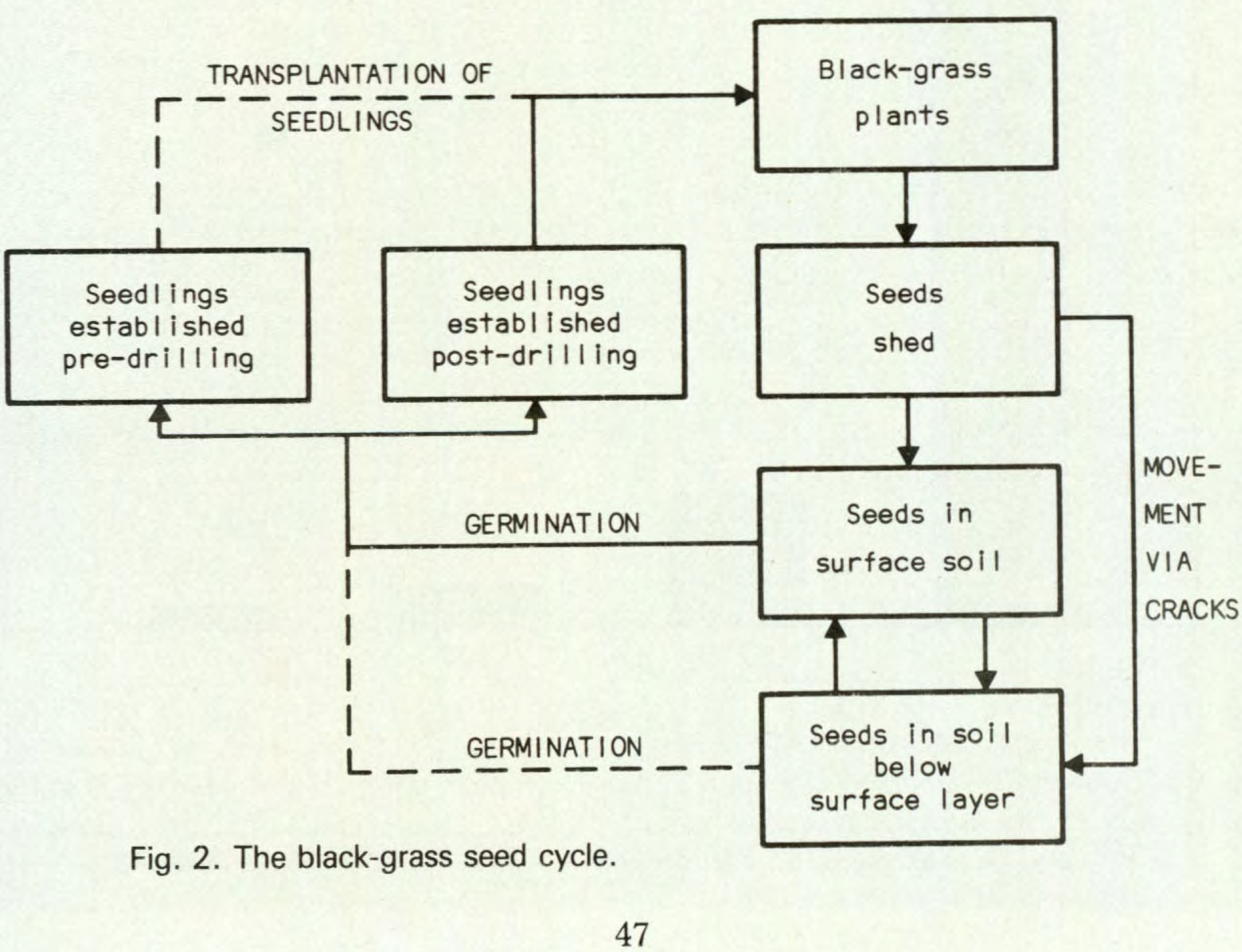


Fig. 2. The black-grass seed cycle.

have recorded a range of 43-76 per cent over ten sites (Moss, 1982). Shedding occurs from late June to late August and so, in winter wheat crops, most seeds are shed prior to harvest. However, in winter barley, harvested in July, severe contamination of grain may result because many seeds remain unshed (Moss, 1981b).

After shedding, seeds on the soil surface are subject to attack by fungi and predators and to death by premature germination. An experiment at WRO showed that only 32 per cent of viable seeds shed in a winter wheat crop in July were still present on the undisturbed soil ten weeks later (Moss, 1980a). This substantial natural mortality of seeds can be increased by straw burning (Moss, 1980b; 1981a). We have also studied the effect on ungerminated seeds of the application of herbicides for weed control in stubbles (Moss, 1978a). Paraquat and aminotriazole (but not glyphosate) appear to kill some seeds but this cannot be considered as anything more than a fortuitous side effect.

Seeds on the soil surface are incorporated into the soil by post harvest cultivations. Different cultivation systems incorporate freshly shed seeds to different depths (Moss, 1979b), but may also bring up old, still viable, seeds to the soil surface (Moss, 1980c). The survival of black-grass seeds in the soil

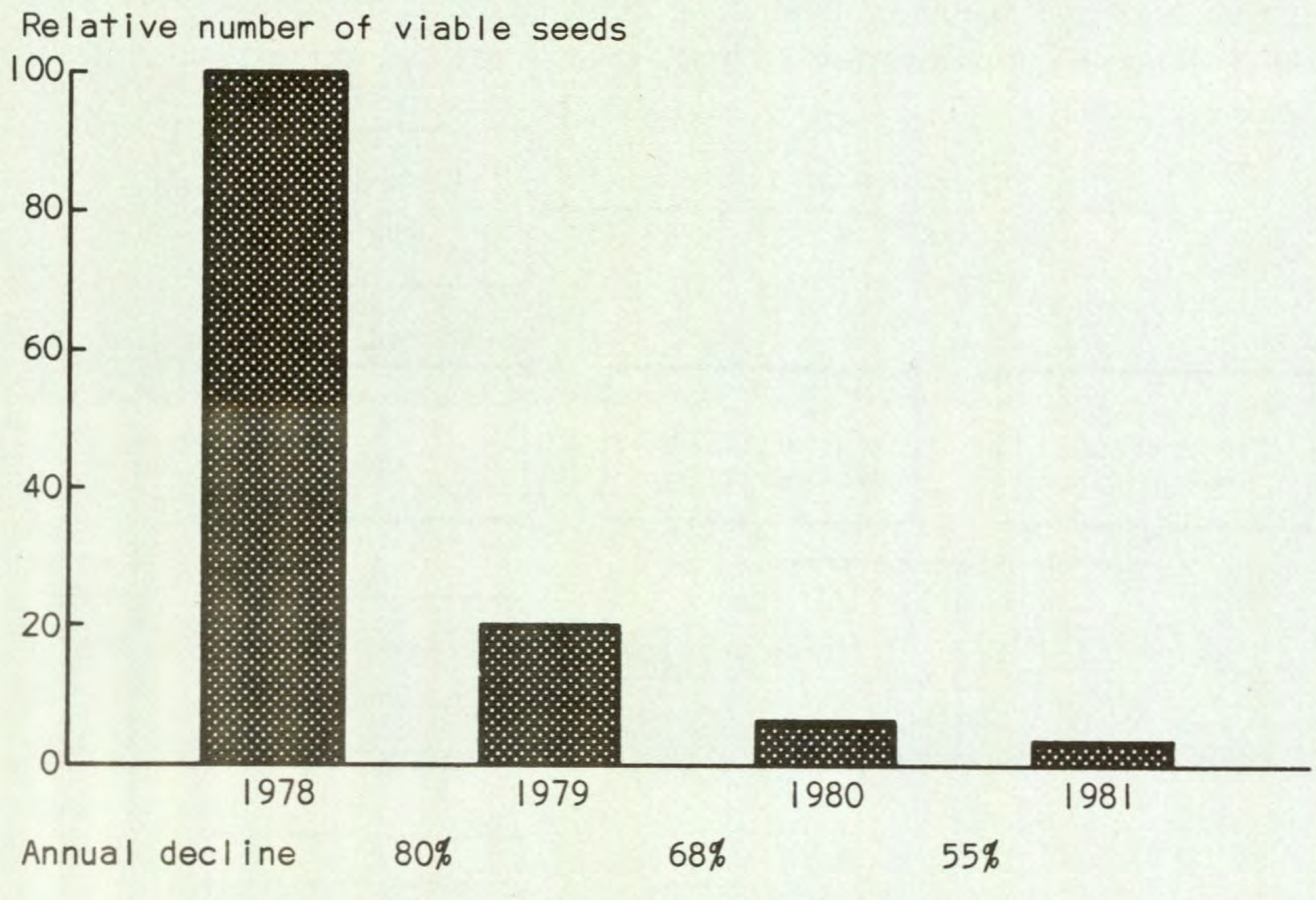


Fig. 3. The annual percentage reduction of natural populations of black-grass seeds in the soil (means of five winter cereal sites on which initial seed populations varied between 2,800 and 56,000 seeds/m^2 and on which no seed shedding was allowed).

has received much study and we know that some black-grass seeds can survive in the soil for many years (Fig. 3).

After shedding some seeds are capable of almost immediate germination but most have a short, but variable, period of innate dormancy (Froud-Williams, 1981a). Black-grass seeds will germinate over a wide range of temperatures (7-20°C) (Froud-Williams, 1981b) but the optimum temperature depends partly on the time of shedding (Froud-Williams, 1981a). In ideal conditions in the field at least 80 per cent of black-grass germination occurs in the autumn, from September to November. Much of this germination occurs before the drilling of winter cereals and the proportion germinating before drilling can be increased by straw burning (Moss, 1981b).

Because those present before drilling can be destroyed, e.g., by applying paraquat, it is usually only those black-grass plants that emerge after drilling that are important as potential competitors with the crop. However, it is sometimes impossible to destroy all black-grass plants present before drilling the crop—especially if tine cultivations are relied upon. Then, some black-grass seedlings may be transplanted to re-emerge in the crop and add to the infestation resulting from later germinating seeds.

The value of studying the black-grass seed cycle has been demonstrated by the results of an investigation of a black-grass infestation in a wheat crop established by minimum cultivations. Figure 4 shows that the 3,900 seeds/m^2 present in the soil in July 1978 had decreased to 1200 seeds/m^2 by July 1979. However, in July 1979 some 51,000 viable seeds/m^2 were returned to the soil,

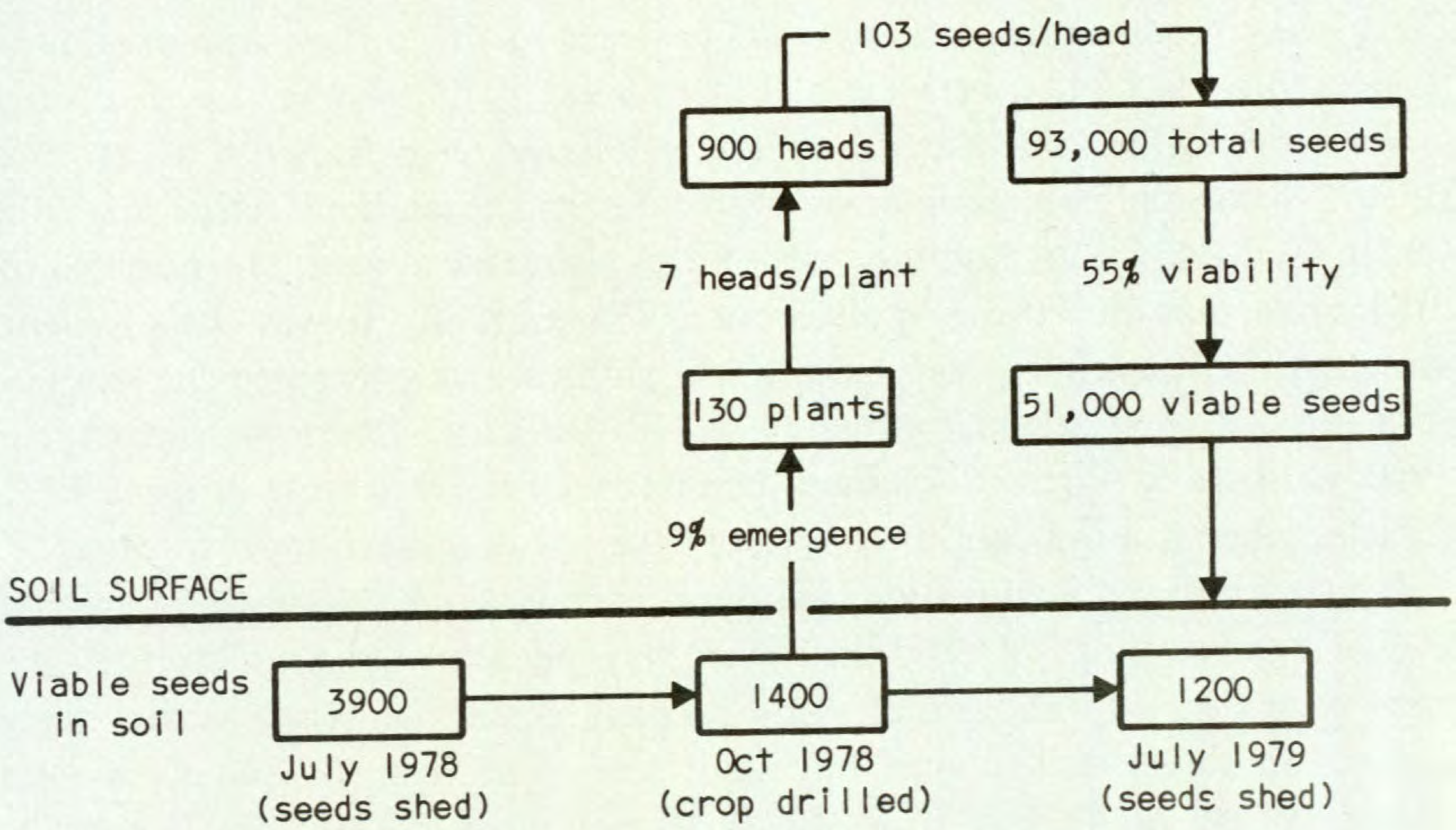


Fig. 4. A study of the black-grass seed cycle in a winter wheat crop.

augmenting the 1200 viable seeds/m^2 surviving from the previous year. To have prevented any increase in the number of viable seeds already present in the soil in July 1978, the seed return in July 1979 should not have been allowed to exceed 2,700 seeds/m^2 i.e. 3,900 less 1,200. To have achieved such a reduction in the number of seeds returned to the soil would have required 95 per cent control i.e.

$$\frac{51{,}000-2{,}700}{51{,}000} \times \frac{100}{1}.$$

This demonstrates the very high level of weed control needed to prevent a build-up of black-grass in a minimum tillage system. Although these results relate to a single experiment, the figures for the various parts of the cycle can be supported by observations and assessments made on other WRO experiments.

HERBICIDES

The 1977 survey showed that black-grass herbicides were applied to 39 per cent of the UK cereal area infested with this weed (Elliott *et al.*, 1979). We estimate that over £18 million is spent annually on herbicides to control black-grass in the UK.

Herbicides are obviously an important method of reducing black-grass populations in order to prevent both crop losses from weed competition and to reduce seed return. However, complete weed control is not usually achieved. Black-grass heads were present on 70 per cent of the survey area previously treated with black-grass herbicides (Elliott *et al.*, 1979).

Many herbicide experiments in winter cereals have shown a clear yield benefit from applying black-grass herbicides in the autumn rather than the spring (Wilson, 1979). Autumn applications also tend to give better control of black-grass than do spring applications (Wilson, 1980). It was the problems associated with applying herbicides in the autumn that prompted the study of spraying with low ground pressure (LGP) vehicles. These studies (Ayres, 1980; Cussans & Ayres, 1978) have demonstrated the feasibility of using LGP vehicles when ground conditions prevent the use of conventional tractors.

Because reduced cultivation systems encourage black-grass, a higher level of weed control is needed than when the land is ploughed. Unfortunately, there is evidence to show that some herbicides may be less effective when applied on direct drilled and tine cultivated land than on ploughed land (Moss, 1979a). Nyffeler & Blair (1978) demonstrated that ash can reduce the activity of several soil-acting herbicides but, on the evidence of the results obtained by Moss (1979a), it appears that straw residues may be more significant than ash in reducing herbicide performance. Other experiments have also demonstrated that chlorotoluron performs better when straw and ash residues are incorporated into the soil instead of being left on the soil surface (Moss, 1978b). The precise reasons for the reduction in herbicide performance are unclear and further studies, on a wider range of herbicides, are still in progress.

Although the presence of straw and ash residues are unlikely to result in complete herbicide failure, any reduction in herbicide efficacy may seriously affect the long-term control of the weed in reduced cultivation systems because of the importance of minimizing seed return. With long-term direct drilling or minimal cultivations, there may also be a gradual increase in the organic matter and ash content of the surface soil. If this occurs, then the corresponding gradual reduction in soil-acting herbicide activity may lead to an increase in black-grass infestations.

Because of the variable performance of soil-acting black-grass herbicides, we were greatly encouraged by the discovery of clofop iso-butyl, a post-emergence herbicide with very high and consistent activity against black-grass. In WRO experiments we have never recorded less than 95 per cent kill of black-grass from applications made between the beginning of October and the end of February. Indeed, most results were better than this with over 99 per cent kill on many occasions. Although this compound has not been introduced commercially, there can be no doubt that a herbicide of similar efficacy could completely change the scale of the black-grass problem, even in vulnerable farming systems.

INTEGRATED CONTROL OF BLACK-GRASS

The use of a combination of weed control measures, each of which alone is only partially successful, should improve the overall suppression of the weed. At WRO, having studied the factors affecting black-grass populations in the field, we have proposed an integrated control strategy for the weed (Moss, 1980a). The best and worst possible combinations of factors for black-grass control in cereal crops are summarized overleaf.

Although our studies have shown that reduced cultivations encourage black-grass, if complete prevention of seed return could be achieved regularly on a field scale, black-grass plant populations should decline more rapidly in reduced cultivation than in ploughing systems (Moss, 1980c).

Control factor	Best strategy	Worst strategy
Cultivation	Plough	Direct drill or reduced cultivation
Herbicide	Good herbicide at correct timing	No herbicide
Straw disposal	Spread and burn	Bale
Drilling date	Late	Early
Stubble hygiene	Complete weed kill before drilling	Incomplete weed kill
Rotation	Include spring cereal or non-cereal crops	Continuous winter cereals
Crop competition	High seed rate; High rate of N fertiliser; Vigorous cereal variety; Drainage programme	Low seed rate; Low rate of N fertiliser; Weak growing cereal variety No drainage programme

CONCLUSIONS

Our studies have shown that modern cereal growing systems are greatly encouraging black-grass. Despite this, we can see no justification, in current economic circumstances, for a total return to mouldboard ploughing in place of the simplified tillage systems which have been so successful for managing many heavy soils and have permitted the massive increase in area of winter cereals. However, a rotational return to mouldboard ploughing, possibly as little as one year in five or six could drastically reduce the scale of the present black-grass problem.

The herbicides commercially available today can be very effective at controlling black-grass but their reliability can vary from year to year. This is partly because most of the herbicides available at present are soil-acting and are partly dependent on environmental conditions for good weed control. Because black-grass populations can increase very rapidly, reliability of weed control is important. Greater reliability may be achieved through using herbicide sequences rather than single applications. Alternatively, new materials may become available with greater activity.

If herbicide reliability can be improved, then herbicides alone may successfully contain black-grass populations. This would, inevitably, involve a heavy and continuing expenditure on chemicals. However, if herbicide reliability continues to vary from year to year, then programmes which integrate both cultural and chemical measures may be essential to achieve a standard of weed control high enough to permit the continued intensive growing of winter cereals.

Click here to continue