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AGRICULTURAL RESEARCH COUNCIL

WEED RESEARCH ORGANIZATION

FIFTH
REPORT
1972-1973

PRICE £1

SOME FACTS ABOUT 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 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 of the Foreign and Commonwealth Office (ODA). Its information role is international and is assisted by the Commonwealth Agriculture Bureaux (CAB). For 1972-73 ODA and CAB together provided about 12% of the institute's funds.

ABBREVIATED TITLE

The abbreviated title of this report as given in the *World List of Scientific Periodicals New Periodicals Titles* (*1960-68*) is:

Rep. Weed Res. Org. 1972-73 (1974)

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FIFTH REPORT
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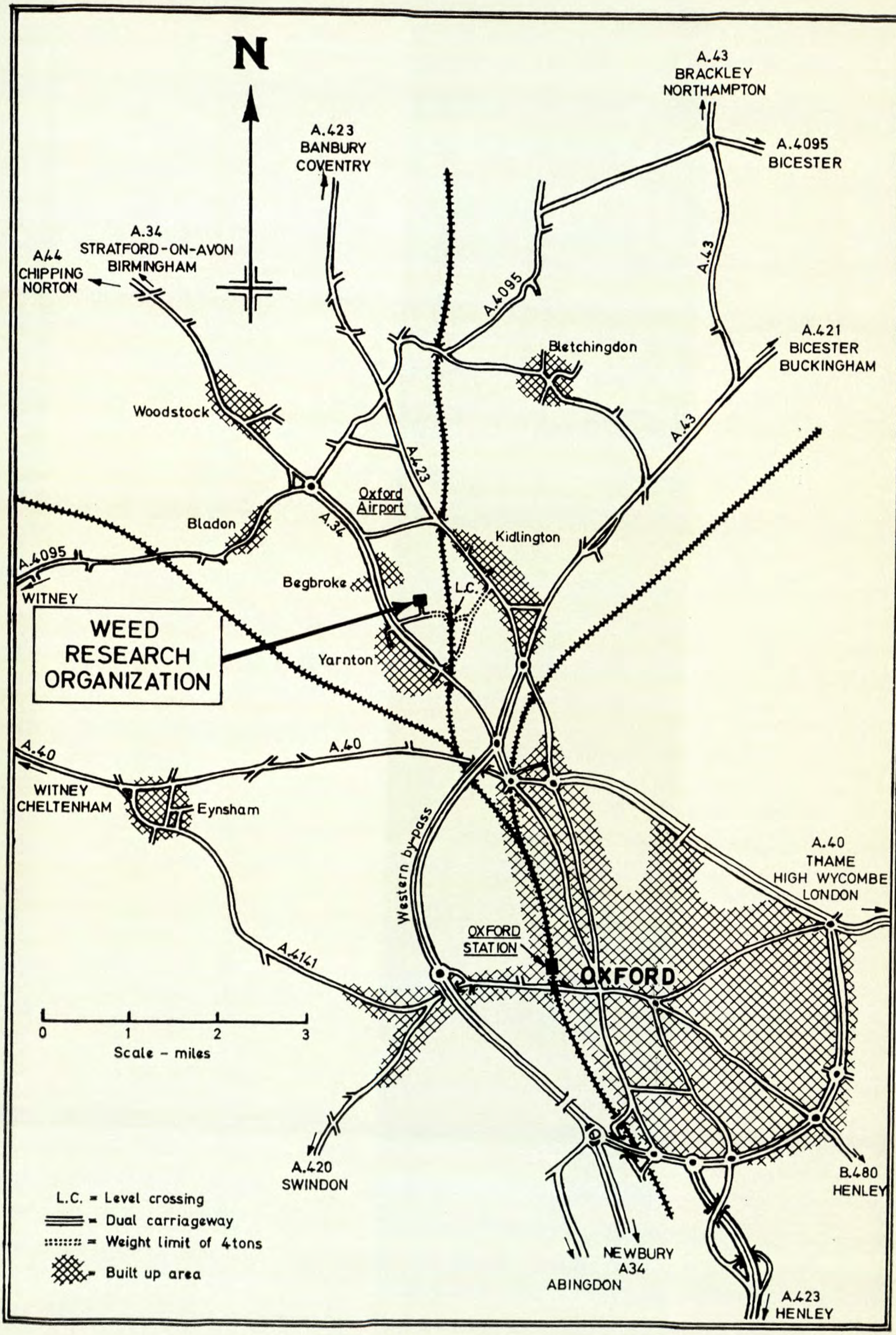
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Western by-pass
A.40
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HIGH WYCOMBE
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A.4141
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Scale - miles
A.420
SWINDON
B.480
HENLEY
L.C. = Level crossing
= Dual carriageway
= Weight limit of 4tons
= Built up area
NEWBURY
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HENLEY

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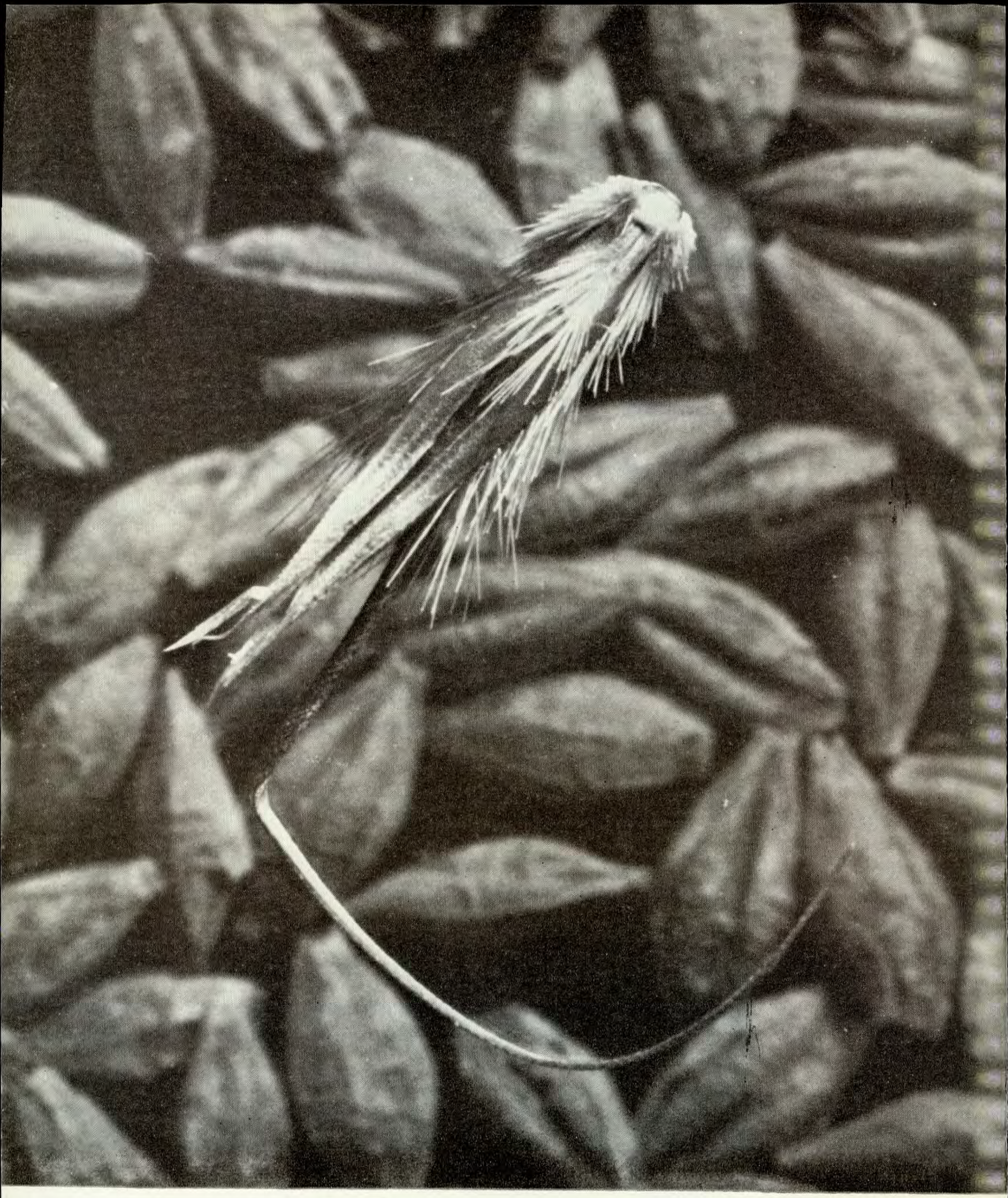


A seed of wild oat (x10). Now officially recognised as the No. 1 problem weed, the wild oat is also the subject of the first nationwide weed control campaign to be jointly sponsored by government, commercial and farming organizations in Britain.

REPORT OF THE DIRECTOR

INTRODUCTION

During the 14 years of its existence the Weed Research Organization (WRO) has grown from an off-shoot of an ARC Unit* into a sizeable Institute with a total staff of around 150 and an annual budget approaching £0.3m in 1972/73. This rapid expansion reflects the fundamental importance of weed control in our agricultural industry and the revolutionary development of new control methods based largely on the use of herbicides. A much larger report than this would be required to describe in detail all the progress and activities of WRO which have taken place during the past two years since the last report was issued.† Our aim is to give the reader a broad review of those parts of the programme which we hope will prove of general interest and to record statistical data about the institute. Included also is a series of four articles which portray a few aspects of the current programme in greater depth. If any reader would like to learn more about the work of WRO, appropriate members of staff will be only too pleased to be approached. General enquiries should be addressed to the Director.

CHANGES IN THE ORGANIZATION OF THE RESEARCH PROGRAMME

Up to the present the research programme has been developed and approved as a result of proposals submitted by the Director of WRO to the ARC for consideration first by Headquarters' staff, then by the Visiting Group (a small team of independent specialists), and finally by the Council itself. This procedure is the standard one for ARC institutes and the exercise has taken place every three years. In addition there have been independent reviews for those parts of the programme financed by other agencies. Thus, the initiative for the strategy for the programme as well as for the detailed nature of the work has been the responsibility of WRO staff.

With the implementation of Lord Rothschild's proposals for the integration of government research and development and the transfer of some 55% of the ARC's budget to the Ministry of Agriculture, Fisheries and Food (MAFF) by 1975/76, responsibility for deciding what research is important and how much money is to be spent on a

* ARC Unit of Experimental Agronomy, University Department of Agriculture, Oxford 1950-70. Honorary Director Professor G. E. Blackman.

†*Rep. Weed Res. Org., 1969-71*, 1972, pp 104.

particular project is increasingly passing to the Chief Scientist's Group of the Ministry which is advised by the Joint Consultative Organization (JCO) of ARC, MAFF and the Department of Agriculture for Scotland.

Anticipating the involvement of WRO staff in the affairs of the JCO and to improve efficiency, plans for re-organization of the research work were submitted to ARC and implemented on 1 October 1973 following approval by the Visiting Group who examined the institute's programme in May 1973 (See Fig. 1.) The main change was

ORGANIZATION OF RESEARCH AT WRO

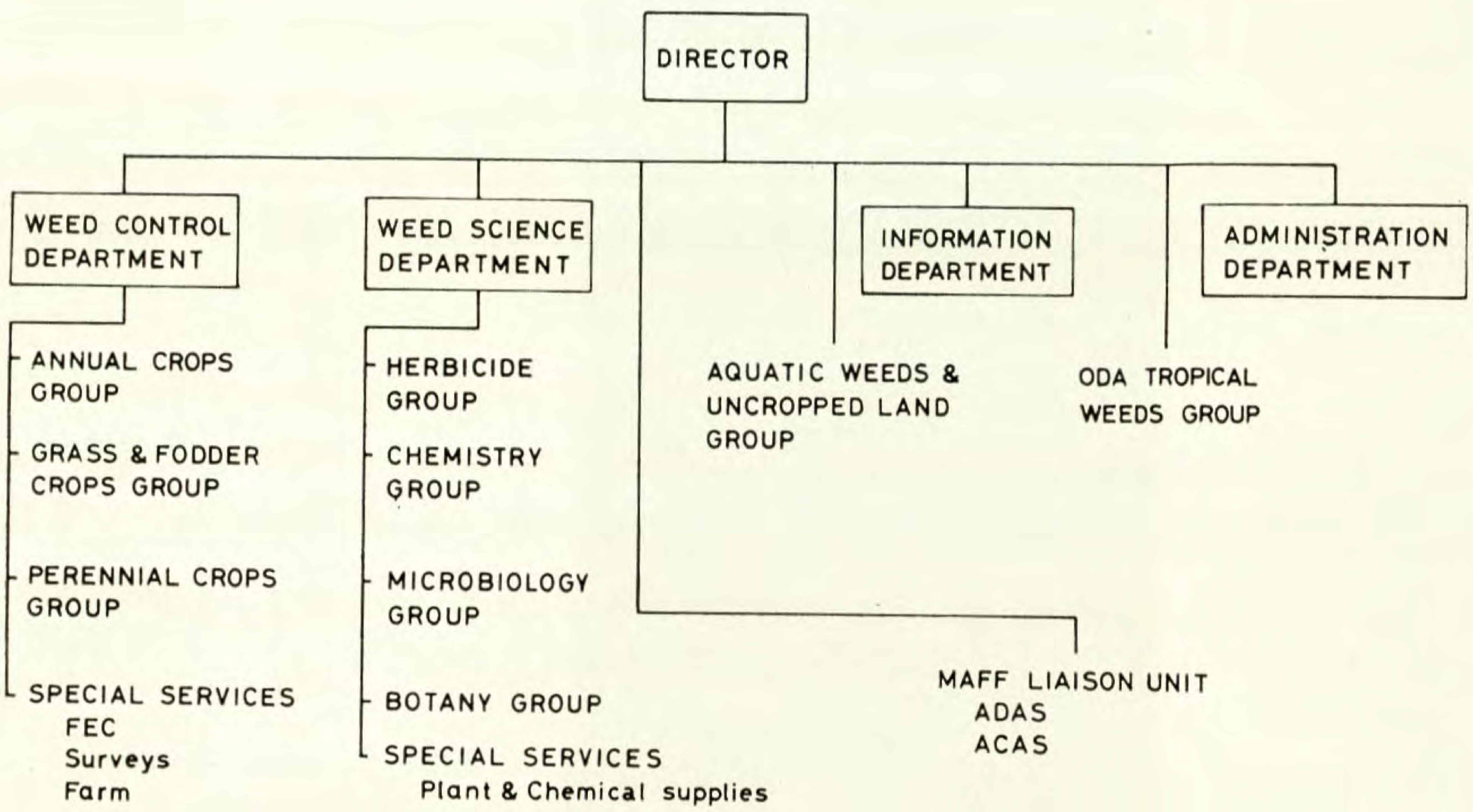


Fig. 1. The re-organization of WRO research and ancillary services effected on 1 October 1973 was designed to clarify group responsibilities in anticipation of the new research commissions being drawn up by MAFF in consultation with the Joint Consultative Organization and the Specialist Committees.

to reconstitute the Weed Control Department to provide three research groups each with a responsibility (*a*) to be informed about the present and future weed research requirements for a given sector of crops grown in Britain, (*b*) to submit proposals for work by WRO and (*c*) to undertake agreed relevant projects. The largest of the groups is concerned with annual crops, the other two respectively with grass and fodder crops and perennial crops. Although at any one time it may only be possible (or necessary) for each group to be working actively on one or two crops, its members are expected at all times to be up-to-date and familiar with the dynamic weed picture which exists in all the crops for which they have responsibility, also with relevant R & D undertaken elsewhere. To assist them in this task a Special Services branch was set up to carry out surveys and obtain information not otherwise easily available.

Most of the relevant committees of the JCO are based on crop commodities and this improved planning capability of WRO has already helped in providing authoritative information to the JCO on future requirements and priorities.

The Weed Control Department now has the major responsibility within WRO for research to develop more efficient weed control systems and procedures on the farm. Much but not all of its work is based on field experiments either at Begbroke or on private farms throughout the country. It has exceptional mobility based on 11 two- or three-man research teams, each with a Land Rover and all the equipment to undertake a wide variety of field investigations. To strengthen the department in its expanded role several members of the former Herbicide Evaluation Section who had been involved primarily on agronomic work were transferred to the new Annual Crops Group.

Another important reason for the reorganization was to allow the members of the former Herbicide Evaluation Section, under its new title of the Herbicide Group, to concentrate their resources on research aimed at improving the performance of herbicides. Such work has a great potential to increase efficiency and reduce costs through a better understanding of the factors influencing the action of herbicides in plants and soil.

Three further changes were also made. The Aquatic Weeds Section was given extra-departmental status and its terms of reference expanded to include the topic of vegetation control on uncropped agricultural land. Agreement was reached with ARC that, in principle, finance could be sought from other bodies concerned with the development of new, ecologically sound methods of vegetation management where traditional practices are no longer feasible and where the terrestial or aquatic habitat involved has uses other than crop production. The Information and the Administration Sections were both given departmental status in recognition of their enlarged role in the institute.

Where 'Sections' are referred to in this report the work described was undertaken before the reorganization.

COLLABORATIVE RESEARCH

Whilst the changes described have done much to encourage collaboration and communication within WRO, the problem of how to develop further collaborative programmes between WRO and other institutes of the Agricultural Research Service and with ADAS continues to exercise much thought. A great deal of time has been spent during the period under review by the staff in the exchange of information and in the planning and execution of joint projects with other organizations. Regular consultation or collaboration is maintained with the following institutes of the ARC:

East Malling Research Station (weed control in fruit)
Grassland Research Institute (sward deterioration and other topics)
Letcombe Laboratory (reduced tillage and soil-applied herbicides)
Long Ashton Research Station (weed control in fruit)
National Institute of Agricultural Engineering (herbicide application, minimum tillage)
National Vegetable Research Station (herbicide evaluation, herbicides in soil, weed biology)
Plant Breeding Institute, Cambridge (cereal tolerance of herbicides)
Rothamsted Experimental Station (weed biology)
Scottish Horticultural Research Institute (weed control in fruit)

The partnership between WRO and the ARC Letcombe Laboratory deserves special mention because of the now long-standing combination of complementary skills and resources of the two institutes. Good progress has been made with the joint-tillage and herbicide projects (see page 32) and with the Joint Biometrics Group. Experience in such collaborative research has demonstrated its value but also its problems which are perhaps not fully recognised by those who seek to promote it.

The extent of collaboration with ADAS and the important role in this of the ADAS liaison officers based at WRO has already been described in the Fourth Report. Probably the most effective joint activities in 1972-73 have been the dissemination and collection of information through courses, seminars and surveys. The implementation of joint development programmes has continued to be restricted by the modest resources and by the organization of ADAS for such work.

THE VISITING GROUP

The institute received a Visiting Group on 3rd and 4th May 1973. Members of the Group were: Professor J. L. Harley (Chairman), E. R. Bullen, J. T. Martin and Professor R. L. Wain, accompanied by the following from ARC Headquarters: W. M. Henderson, C. C. Webster, J. K. R. Gasser, J. V. Lake, E. Lester and G. M. P. Myers.

The proposed research programme was well received and the reorganization as described in the preceding section approved. The Group expressed particular pleasure at the initiative taken by WRO in developing a broad interdisciplinary programme on wild oats and their control, involving virtually all sections of the institute and extensive collaboration with other organizations. After the Group's departure, many of the staff expressed appreciation of the interest and helpful attitude of its members. Their advice and support is gratefully acknowledged.

REVIEW OF RESEARCH

WILD OAT IN CEREALS

Wild oat is currently the most important annual weed in British agriculture and the extent of the present concern was indicated by the launching of a national Wild Oat Advisory Programme by Sir Emrys Jones, then Director-General of ADAS, in February 1973. The programme, the result of collaboration by many official and commercial organizations, will continue for several years until farmers are fully persuaded of the seriousness of the problem and know how to choose and make use of the most effective control measures to suit their particular circumstances.

A greater knowledge of the biology of this weed and its response to systems of crop production, including the use of herbicides, is particularly important at the present time. Some results of recent WRO research on these topics are described here.

The wild oat problem surveyed

In 1972, a survey of the incidence of wild oat (*Avena* spp.) and blackgrass (*Alopecurus myosuroides*) in an area of about $4\frac{1}{2}$ million acres, representing some 47% of the cereal acreage of the United Kingdom,* was initiated by the Surveys Officer of the WRO Agronomy Section and completed with the help of six other organizations†. The results of the survey‡ were widely quoted in the national and agricultural press. Of the area surveyed it was estimated that not less than $2\frac{1}{4}$ million acres of wheat and barley were infested with wild oat and about $\frac{1}{2}$

*The area consisted of the ADAS regions: South East, South West, W. Midlands, Northern, Wales; also of East Scotland and Northern Ireland.
†ADAS, MAFF, Department of Agriculture for Scotland, East of Scotland College of Agriculture, Ministry of Agriculture for Northern Ireland, Rothamsted Experimental Station.
‡WRO Technical Report No. 23.

million acres with blackgrass. The amount of the infested acreage receiving herbicide treatment for these weeds varied, between regions, from 3 to 23% and, on average, 9% was rogued for wild oat. Farmers estimated that wild oat infestations had increased 55% in the last six years.

A new wild oat herbicide

WRO is actively interested in new herbicides for the control of wild oats and during the two-year period intensive evaluation of promising compounds obtained from the agrochemical industry was continued in both glasshouse and field investigations. Of particular interest was 1,2-dimethyl-3,5-diphenylpyrazolium methyl sulphate and work by WRO on this compound provides an excellent example of how closely the institute works with the chemical industry to the advantage of agriculture in the United Kingdom. Experiments were begun by the Herbicide Evaluation Section in spring 1972 and a free interchange of information and results with the manufacturers enabled complementary research programmes to be developed during 1972 and 1973. The compound has proved to be effective on wild oats at a range of growth stages from 2-3 leaves onwards at a dose of 0.75 to 1.0 kg a.i./ha. At these levels both barley and winter wheat appear to be resistant although some cultivars of spring wheat are somewhat susceptible. Work at WRO also indicates that weed meadow grasses (*Poa* spp.) are more susceptible than perennial ryegrass and clover which suggests the possibility of use on undersown crops. The compound is being marketed on a limited scale in 1974.

Cultivations and wild oat seed survival

Most of the seed produced by an infestation of wild oats finds its way to the ground; only a small proportion is removed in the harvested grain and straw (see Fourth Report, p. 10).

A study of the changes in wild oat seedling populations by the Agronomy Section in 1972-73 showed the value of controlling infestations before harvest. Prevention of seeding in 1972 proved to be the only way to reduce the seedling population in 1973. Once seeding had occurred, post-harvest operations could not prevent an increase in the seedling population but could only influence the size of increase.

The survival of newly shed wild oat seed was shown to be related to the length of time the seeds remained on the ground. Leaving the stubble uncultivated during the autumn resulted in large natural losses of wild oat seed and only a small increase in the number of seedlings the following spring. Early autumn cultivation of stubbles containing wild oat seed resulted in a large increase in the reserve of viable seed in the soil and, compared with the stubbles cultivated later, a two- to three-fold increase in the number of seedlings subsequently emerging. The increase in numbers of dormant seeds in the soil was such that, without any further seed shedding, there was even an increased population of seedlings in the spring of the second year, nineteen months after the first post-harvest cultivation. Burning the stubble prior to early autumn cultivation was not as effective as delaying cultivation in minimizing the increase in the number of wild oat seedlings emerging.

The kind of cultivation carried out in December was also important. Ploughing resulted in a smaller increase in the spring seedling population than did tine cultivation. However, if measures had previously been taken to reduce seed shedding, tine cultivation in December beneficially accelerated the rate of depletion of the seed in the soil.

The conclusion is that, while cereal production systems involving delayed stubble cultivation or direct drilling slow down the build up of a wild oat infestation, early stubble cultivation without subsequent ploughing can only worsen the situation and, if unavoidable, should be accompanied by straw burning prior to autumn cultivation and the use of herbicides in the following crop.

The survival of wild oats in winter cereals

Preliminary mention was made in the Fourth Report of an investigation by the Herbicide Evaluation Section of the hardiness of *Avena fatua* over-wintering in cereal crops. This was begun in 1970-71 and continued in the succeeding winters of 1971-72 and 1972-73, but unfortunately these winters, like the first, were relatively mild in the area concerned and the mortality of wild oats was low.

However, the original conclusion that the critical factor was the stage of growth of the wild oats at the time of onset of colder winter weather has been confirmed. The advantage of early growth persists until harvest; one leaf more in the autumn can result in as much as 100% more wild oat seed the following summer.

These experiments indicate that, in the absence of a specific herbicidal treatment, fields with a potentially high population of *Avena fatua*

WRO scientists 'ringing' newly emergent wild oat seedlings with coloured wire to identify those causing most crop loss at harvest.

which are sown to winter cereals relatively late in the autumn (late October—early November) will have lower populations of wild oats surviving to the following summer than if they are sown relatively early in the autumn.

Weed competition in spring barley

The Botany Section, in collaboration with the Agronomy Section, has recently been investigating the effects of wild oats (*Avena fatua*) on the yield of spring barley under a wide range of conditions. The results show that an important factor influencing the degree of crop loss is the relationship between the period of germination of wild oats and that of the crop. It was found that the earliest germinating weed plants caused most loss, suffered least natural mortality and produced most seeds.

The time at which competition between wild oats and spring cereals commences has been further investigated by the Botany Section. It was found that the onset of serious competition, under the conditions of the experiments, did not start as early as the 2-leaf stage of the crop, as suggested in the WRO Fourth Report, but at about the 4-leaf stage. This suggests that herbicides applied at or before the 4-leaf stage would prevent yield loss completely.

COUCH IN CEREALS

The keynote of early stubble cultivation in the successful control of couch in traditional systems of cereal production was discussed in the Fourth Report (p. 11). More recently, the Agronomy Section has investigated the possibility of a resurgence of the couch problem following the widespread adoption of minimum tillage systems of cereal production. The potential of a new herbicide to provide a solution to the new problem has also been examined. Further studies by the Botany Section on the biology of couch, continued with a view to devising new methods of control, form the subject of the separate article on p. 50.

Couch control in direct-drilled cereals

The importance of early stubble cultivation for couch control is well established but cultivations have no place in direct drilling methods of crop establishment.

An Agronomy Section experiment was therefore begun in 1970 in which the amount of couch developing in a succession of direct-drilled barley crops was compared with that developing when the crops were established by more traditional methods. After only two seasons, the amount of rhizome recorded in July on direct-drilled plots was over 14 times as much as in plots ploughed each December and over 600 times as much as that recorded in plots both cultivated in September and ploughed in December.

The tillage regime also affected the distribution and survival of *Agropyron repens* rhizomes. On the direct-drilled plots the rhizomes persisted in a viable state for a longer period, thus compounding the increase in the viable rhizome population. It was observed that the rhizomes occupied progressively shallower depths on the direct-drilled plots, the mean depth at the end of the experiment in 1973 being 2.7 cm compared with about 8 cm on ploughed plots.

This potential for couch growth, coupled with the disadvantages of the available herbicides, meant that, at least where winter cereals were grown, farmers could only be advised to direct-drill land on which the couch population was already low enough to enable control to be maintained with repeated applications of paraquat. In some spring barley experiments considerable success was achieved with dalapon and aminotriazole but persistence of these compounds in the soil makes timely sowing of winter wheat difficult or impossible. In addition, replacement of paraquat by the cheaper dalapon would leave a wide range of broadleaved weeds uncontrolled.

In the most recent experiments the new compound glyphosate has shown great promise for direct-drilling and, in some instances, total kill of *A. repens* has been achieved. Further details are given in the next section. If the price and availability of this compound prove satisfactory, one of the major constraints on this practice could be eliminated.

Glyphosate for the control of couch grass

The increasing acreage sown to winter wheat instead of spring cereals shortens the time available in the autumn for chemical or mechanical control of couch. It also reduces the time available for the dissipation of any herbicide residues in the soil which might harm the subsequent crop. The advent of minimum or non-tillage systems for cereal production requires simple couch control treatments which do not need associated cultivations. In the hope of finding feasible alternatives to dalapon, aminotriazole and TCA, the Herbicide Evaluation Section carried out several experiments during 1971-73 using the new herbicide, glyphosate. This herbicide is freely translocated throughout the plant; it is also inactivated in the soil so that normally there are no residue problems.

Good control of couch was obtained when glyphosate was applied at 1-2 kg a.i./ha to undisturbed stubble in the autumn of 1971 and 1972. The amount of foliage present at treatment appeared to be important but no benefit was derived from cultivation before or 8 days after treatment. The ability to dispense with cultivation as part of the couch control treatment is an important benefit as the post-harvest period is already a very busy one for the farmer.

In more detailed experiments, using the environmental control and monitoring facilities now available at Begbroke, the Herbicide Evaluation Section investigated the effect of the weather at, and several weeks beyond, the time of spraying on the performance of glyphosate.

All the experimental evidence indicated that high humidity and temperature a few hours before and after application were most conducive to uptake but, even under these favourable conditions, the herbicide entered the plant quite slowly. In a controlled environment experiment in which humidity was maintained at 80-90% r.h. and air temperature at 18°C, over 90% of the ^{14}C-labelled glyphosate applied remained on the leaf surface after 24 hours and over 50% was still present after 10 days. Although these were artificial conditions, the practical implication is clear; if heavy rain falls within a few hours of treatment the herbicide effect will be reduced. This was confirmed in a glasshouse pot experiment in which the foliage of treated plants was sprayed with large amounts of water revealing that herbicide activity was reduced dramatically if washing occurred sooner than 4 hours after treatment, moderately if between 4 and 8 hours after, and only slightly if between 8 and 24 hours after. On the other hand, light precipitation which does not result in 'run off' can improve performance. Thus, rewetting the foliage of experimental plants 24 hours after treatment increased herbicide performance; hence the occurrence of drizzle or dew after treatment could be an important factor in determining activity in the field.

Numerous experiments at WRO have indicated that once glyphosate has entered the plant its movement into the rhizomes is quite rapid. At an air temperature of 8°C and soil temperature of 10°C all 16-20 buds on the lengths of rhizome treated accumulated a lethal amount of herbicide in 24 hours. At an air temperature of 20°C it took only 9 hours. Experiments with ^{14}C-labelled glyphosate showed that the chemical first accumulated in the growing apex and then appeared in successive buds from the apex back towards the treated shoot. These experiments were performed under the humid conditions which are most conducive to uptake. Less favourable conditions in the field at the time of application would delay the transport of toxic amounts of glyphosate to the rhizomes. This factor should be taken into account in estimating the time that must elapse between application and subsequent cultivations, the implication being that as the temperature drops the soil should be left undisturbed for a longer period.

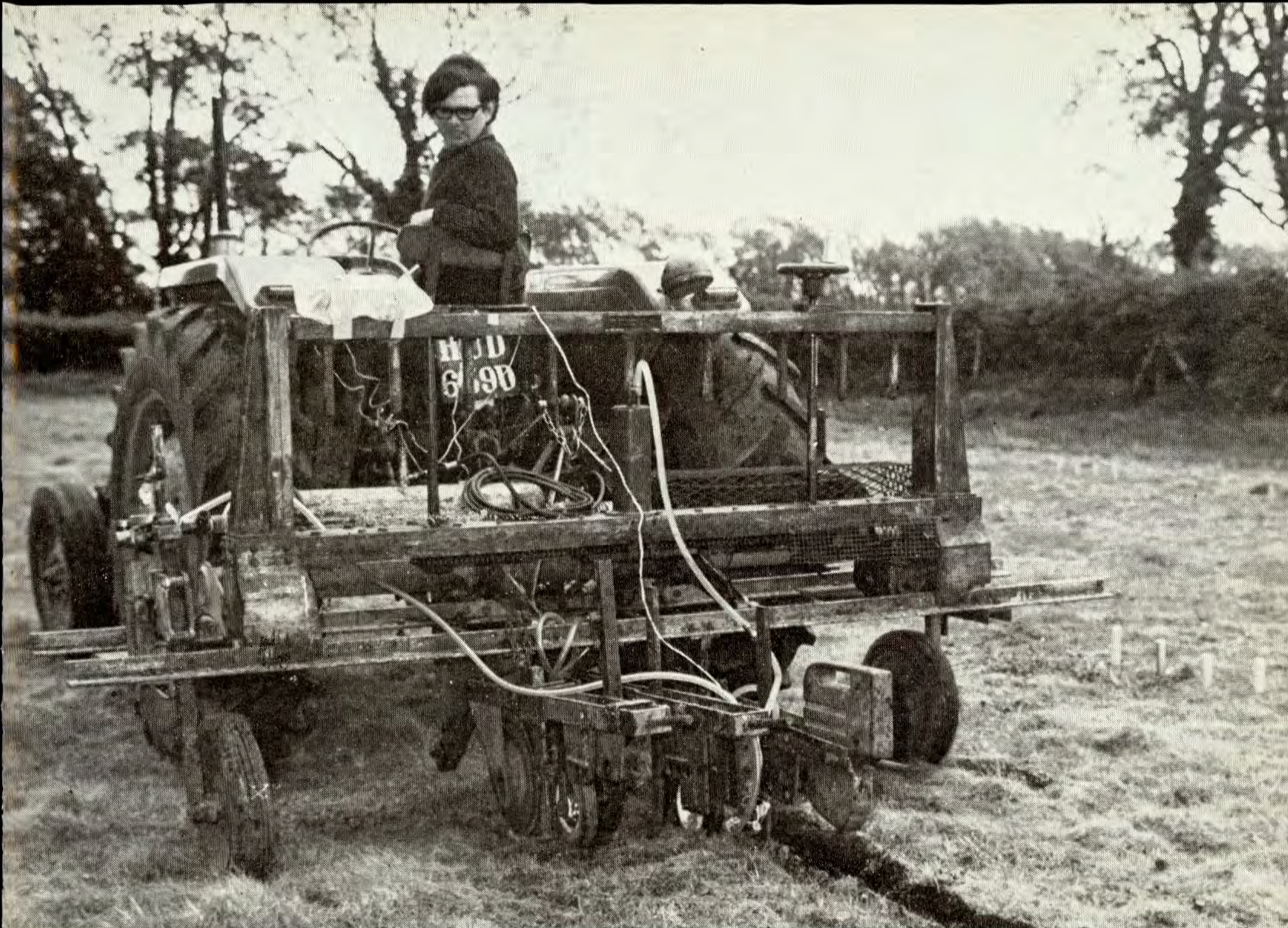
POTATO GROUNDKEEPERS

Volunteer potatoes or 'groundkeepers' can be a serious problem in a number of crops. They can interfere with the harvesting of cereals, contaminate pea and bean crops and compete adversely with slower growing row crops such as sugar beet and brassicas. They may also endanger the health of subsequent potato crops by perpetuating potato pests and diseases. Research into this problem began in 1972 with the appointment of an extra scientific officer to the Agronomy Section, financed by the Potato Marketing Board. Investigations in the field have shown that up to 350,000 tubers/ha may remain in the soil after the potato harvest. During the winter the tuber population is reduced by frost, by diseases, and by predators such as rooks and pigeons. The type and timing of cultivations in the autumn and winter also affects tuber survival; ploughing in the autumn buries tubers thus protecting them from frost, whilst tine cultivation keeps most of the tubers near to the soil surface where they may become frosted. Experiments completed to date have indicated that the standard herbicides used in cereals in the spring have little effect on any potato plants that are present in the field. In addition many of the potato plants emerge after the safe spraying period for cereals, thus making the control of potatoes in cereals very difficult. Currently, the possibility of control by using residual herbicides in the autumn is being investigated but the high doses already shown to be necessary may cause residue problems in following crops.

The main conclusions from the work carried out so far are that the potato groundkeeper problem is a complex one and that an easy solution is unlikely to be found in the short term.

TILLAGE RESEARCH

The first of a series of annual progress reports on the WRO/Letcombe Laboratory Joint Tillage Project, to be published alternately in the reports of the two institutes, appears on p. 32. The WRO contribution to this joint investigation of the effect of various reduced cultivation systems on cereal production in different soil types has been the responsibility of the Agronomy Section, but within so large a topic there has been a need for other, related investigations. The recent work on the perennial grass weed problem has already appeared on p. 9. The difficulty of establishing some crops in killed sward has also led our agronomists to re-examine existing seeding techniques.



The proto-type of an implement, designed at WRO, which removes the unwanted plant material from a series of narrow strips to allow the successful seeding and establishment of small seeded grasses and legumes.

New techniques of direct drilling grasses and legumes

After the use of herbicides for sward destruction, the 'seedbed' is composed of three main features: mineral soil, vegetable mat and dead trash. Two series of hand-seeded microplot studies by the Agronomy Section have shown that, if the mat or trash is removed, cultivation of the light mineral soils at Begbroke is not necessary for satisfactory germination, emergence and establishment of grass and forage crops; conversely, the presence of dead plant material around or over the sown seeds reduces emergence. The emergence of brassica forage crops with their vigorous seedlings was less affected by the mat and trash than that of the smaller seeded grasses and legumes. This accords with commercial experience where the acreage of direct-drilled brassica crops has expanded rapidly while the acreage of direct-drilled grass has remained small. A technique is being investigated in which the dead plant material is removed from the narrow strip to be seeded thus exposing the mineral soil and allowing full emergence and establishment.

The coulters of a conventional drill have a considerable draught requirement and when soil conditions are less than ideal they often produce smearing of the drill slit leading to poor crop establishment. In an attempt to overcome these problems, a prototype experimental drill has been developed at WRO which enables individual seeds to be injected into the soil without any other associated disturbance of the soil. The seeds are suspended in an alginate fluid and are propelled into the ground by compressed air. Further development of this technique is now in progress.

WEEDS IN GRASS

Effect of weed grasses on sward productivity

Recent surveys of British grassland have underlined the extent and rapidity with which sown ryegrass swards become invaded by indigenous grasses. At WRO, competition studies involving meadow grasses (*Poa* spp.) and S23 perennial ryegrass have been carried out by the Agronomy Section to measure the consequences of the gradual replacement of the sown species and to establish why it occurs. The results show that, under grazed conditions, ryegrass mixtures containing, on a leaf area basis, up to 50% of either *P. annua* or *P. trivialis* can produce more dry matter than ryegrass by itself. However, the greatest yields of the mixture were recorded during the first part of the growing season, when the nutritive value of the *Poa* spp was comparable to that of ryegrass. The presence of *Poa* spp. does, not, therefore reduce production in swards intended for early grazing or silage, but production might suffer during late summer if *Poa* spp were present in substantial quantities. Supplementary experiments have shown that the rooting systems of *P. trivialis* and ryegrass tend to be complementary in exploiting soil space and also that the ingress of *Poa* spp is usually a reflection of the weakening of ryegrass plants resulting from mismanagement.

Selective control of weed grasses

It is some years now since the dalapon technique of controlling the build-up of weed grasses in ryegrass swards—hence avoiding the need to reseed—was evolved at WRO. Since 1971 the Agronomy Section has been evaluating the success of the technique directly by measuring the liveweight gain of grazing beef cattle in a 6.5 ha field experiment. During the first year of the experiment, cattle production from the herbicide-treated areas was about 10% less than from the control areas. However, during 1972, and particularly 1973, liveweight gains on the herbicide treated areas increased in response to the improved botanical composition. Thus it appears that, after three years, meaningful differences in favour of the annual use of dalapon are becoming apparent.

Dock infestations surveyed

Although several herbicides for controlling docks have been marketed, none gives complete and lasting control in all situations. In 1973 the co-operation of ten Grassland Societies was obtained to conduct a survey of the situations in which docks are proving particularly difficult to control. The survey was conducted by means of a postal questionnaire, compiled by the Agronomy Section, sent to about 900 grassland farmers.

The results showed that the greatest concentration of docks occurred in the areas surveyed in Devon, Sussex, Monmouthshire and Cheshire. The occurrence of docks was closely linked with fields receiving high levels of nitrogen, especially those cut for silage, or poached by cattle. The application of slurry, too, was often linked with the appearance of docks.

WEEDS IN FRUIT

In addition to the research on bindweed which is reviewed in the article on page 56 the Horticulture Section has concentrated mainly on establishing the herbicide tolerance of perennial crops. In the field the long-term study of the use of high doses of chlorthiamid and dichlobenil on blackcurrants and gooseberries has been concluded and work has started with the new herbicide glyphosate. However, the main effort has been devoted to the development of methods of testing soil-applied herbicides in sand and culture solution.

High dose studies with chlorthiamid and dichlobenil

Growers have expressed concern about the possibility of adverse effects on crops and soils, not only from accidental overdosing but also from repeated annual treatments with soil-applied herbicides. Recent experiments at Begbroke showed that there were no adverse effects on blackcurrants which received up to five times the maximum recommended dose of chlorthiamid and dichlobenil for five successive years. Similarly at Stockbridge House EHS, where up to three times the maximum dose was applied to gooseberries, only the highest dose of chlorthiamid reduced growth and yield. These results are encouraging.

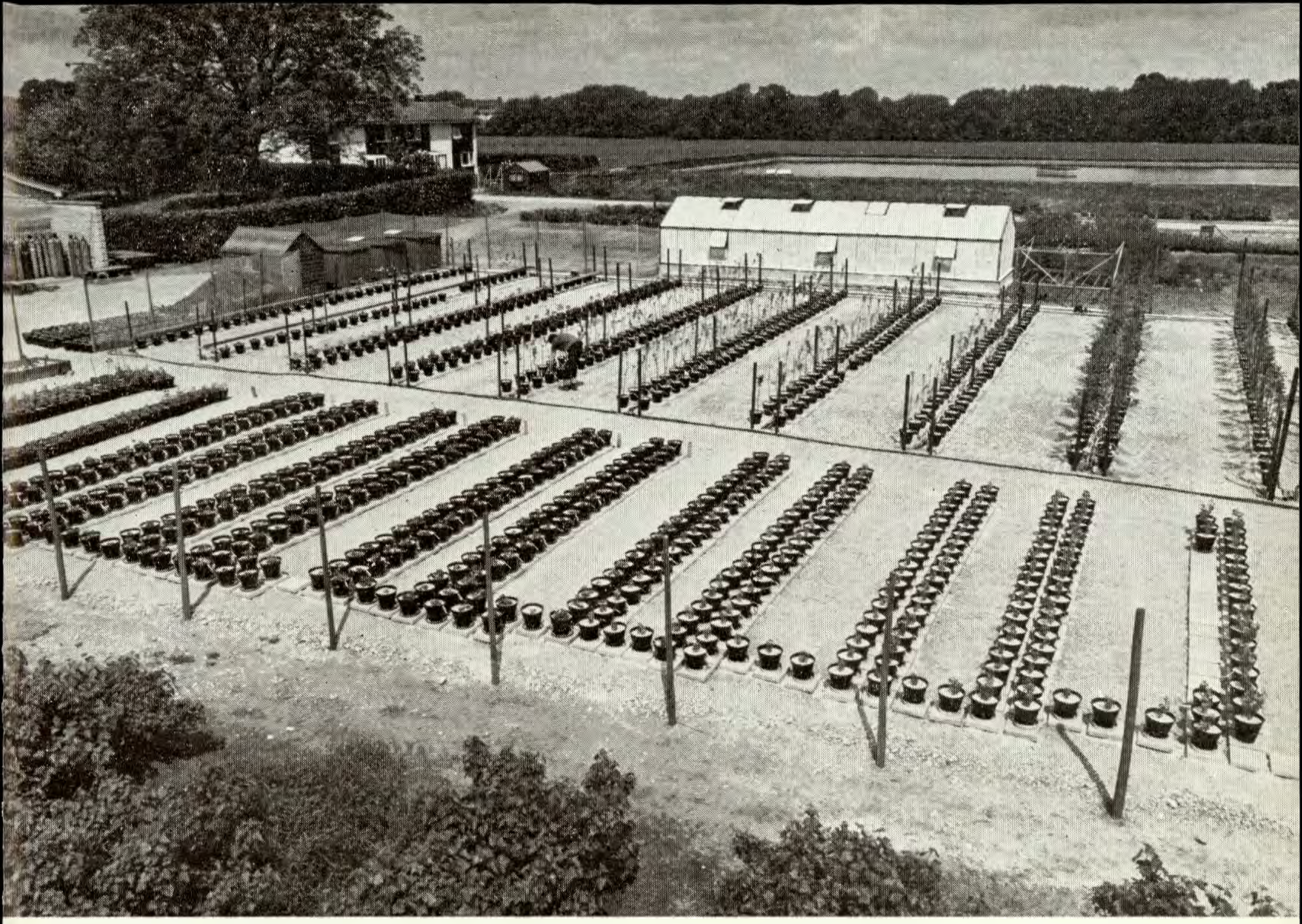
Determining crop tolerance of soil-applied herbicides

Fruit crops and ornamentals are now very largely grown with the aid of soil-applied herbicides. The safety of these herbicides to the crop has, in the past, been established by field experiments. A comprehensive field programme, taking into account variable factors such as soil type and weather, is expensive and often impractical in terms of time and the value of the crop used. Also, the results may be difficult to interpret. Absence of rain following treatment, high level of soil organic matter and deep-rooting crops can all obscure the potential of a herbicide to cause injury in commercial use.

Sand and water-culture methods of growing fruit crops and ornamentals enable precise information on their tolerance of herbicides to be obtained by exposing the roots of the crops to known concentrations of herbicides. Effects on roots can be observed and longer term effects studied by growing on the treated plants in herbicide-free media.

The relative tolerance of currently used herbicides shown by a range of fruit crops grown by these methods has been found to correspond closely to that inferred from commercial use in the field. Differences in varietal tolerance of herbicides by apple rootstocks and strawberries have been found. In 1973 a number of new herbicides, under development for other crops, were found to be appreciably safer on blackcurrants and strawberries than existing herbicides. The technique promises to be valuable both in the search for answers to current weed problems and in giving warning of herbicide susceptibility in newly-introduced cultivars.

Reassuring information has also been obtained on the likely effect of 'spot treatments' with large doses of residual herbicides used for the control of clumps of perennial weeds under fruit plants. Different proportions of the root-system of fruit plants grown in water culture have been exposed to a range of concentrations of herbicides like atrazine, dichlobenil and terbacil. In no instance has the amount of injury from a high concentration of herbicide applied to a small



View of the Horticulture Section's new sand-culture area at WRO where both crop and varietal differences in tolerance of new herbicides are established prior to field trials.

proportion of the root system given more damage than a proportionately lower concentration applied to the whole root system.

WOODY WEED CONTROL

Glyphosate found promising

The Herbicide Evaluation Section examined 12 new herbicides for the control of woody weeds in 1972-73 and, of these, glyphosate was undoubtedly the most interesting. This compound appeared to have great potential for controlling a wide range of woody species when applied to foliage at rates from 0.5 kg/ha to 4 kg/ha. The herbicide was relatively non-selective but some conifer species such as Norway spruce and Corsican pine appeared to tolerate rates of up to 2 kg/ha during the period in late summer and autumn after active growth had ceased. At this rate many herbaceous weeds and a number of troublesome woody species were controlled. While the herbicide is likely to be most useful for foliage spraying, it was also found to be active when injected into the trunks of woody species.

Ammonium salts enhance herbicide activity

The possibility of enhancing the activity of herbicides by formulation techniques is well known but has received relatively little attention by industry or research workers. This aspect has, however, been a continuous feature of the WRO research programme on woody weed control in recent years. In 1972-73 the work was extended to include ammonium salt additives; these cheap compounds have very low mammalian toxicities and have advantages over the phosphate esters, the uses of which were discussed in the WRO Fourth Report. Ammonium salts were used many years ago to 'activate' a number of herbicides such as DNOC and endothal. These herbicides are now largely outmoded. Recent work at WRO has shown that ammonium salts, at doses in the range 1-5 kg/ha, can sometimes enhance the effects of foliage-applied water soluble herbicides, including picloram, aminotriazole and glyphosate, by up to 400%. This means of increasing activity could be particularly useful in circumstances where the cost of an effective rate of application of the herbicide alone might be regarded as excessive.

WATER WEEDS

Terbutryne controls 'blanket' weed

Of all the freshwater weeds the large filamentous algae are some of the most difficult to control. These occur chiefly in lakes, ponds and drainage ditches where there is little or no flow. They usually start growth early in the spring and by mid-summer form an unsightly 'blanket' on the water surface.

One of these is *Rhizoclonium hieroglyphicum* and in 1970 this plant covered most of an ornamental lake near Peterborough. It was so thick that it was impossible to row through it and, on behalf of the owner, the local River Authority sought the advice of the Aquatic Weed Section.

The Section had been studying the algicidal properties of various triazine herbicides for some time and this infestation offered an opportunity to test, on a field scale, terbutryne which had been selected by the manufacturers for commercial development as an aquatic

A member of the WRO Aquatic Weed Section sampling an incipient infestation of 'blanket' weed consisting of several species of filamentous algae.

herbicide. In 1971 the Aquatic Weed Section treated small isolated enclosures in the lake with terbutryne at concentrations of 0.8, 0.4 and 0.2 mg/l. All of these treatments killed the alga which sank to the bottom. In the meantime experiments in plastic pools at Begbroke Hill with plant material taken from the lake showed the alga to be susceptible to much lower levels of the algicide. In 1973 the whole lake was treated with terbutryne at 0.05 mg/l. *R. hieroglyphicum* sank, decomposed and did not reappear throughout the summer and autumn of that year. Certain vascular plants, *Ceratophyllum demersum*, *Zannichellia* and *Potamogeton* sp., were also killed.

Terbutryne acts by inhibiting photosynthesis. Inhibition occurs within a few hours but the plant does not die for days, sometimes weeks, afterwards. Meanwhile it continues to respire, apparently living on its food reserves, and eventually dies of starvation. A serious effect of this continuing respiration is the rapid depletion of the level of dissolved oxygen in the water. Normally the oxygen evolved during photosynthesis in the day time is more than adequate to meet the requirements of all the respiring organisms in the water. When photosynthesis stops the dissolved oxygen is gradually used up and oxygen dependent organisms such as fish are put at risk.

It was therefore important to know what would happen to the oxygen levels in the lake after treatment with terbutryne. As expected, the level of oxygen dropped from super-saturation, 20 mg/l, to about 1 mg/l within a week of treatment. Fish in the lake showed distress and came to the surface for air. However, none died. The dissolved oxygen concentration gradually returned to normal within 10 weeks. Invertebrate zoo-plankton that were also monitored showed little or no effect. Regular water samples were analysed by the Chemistry Section for terbutryne residues and detectable levels (over 0.002 mg/l) were found in the water for 6 months after treatment.

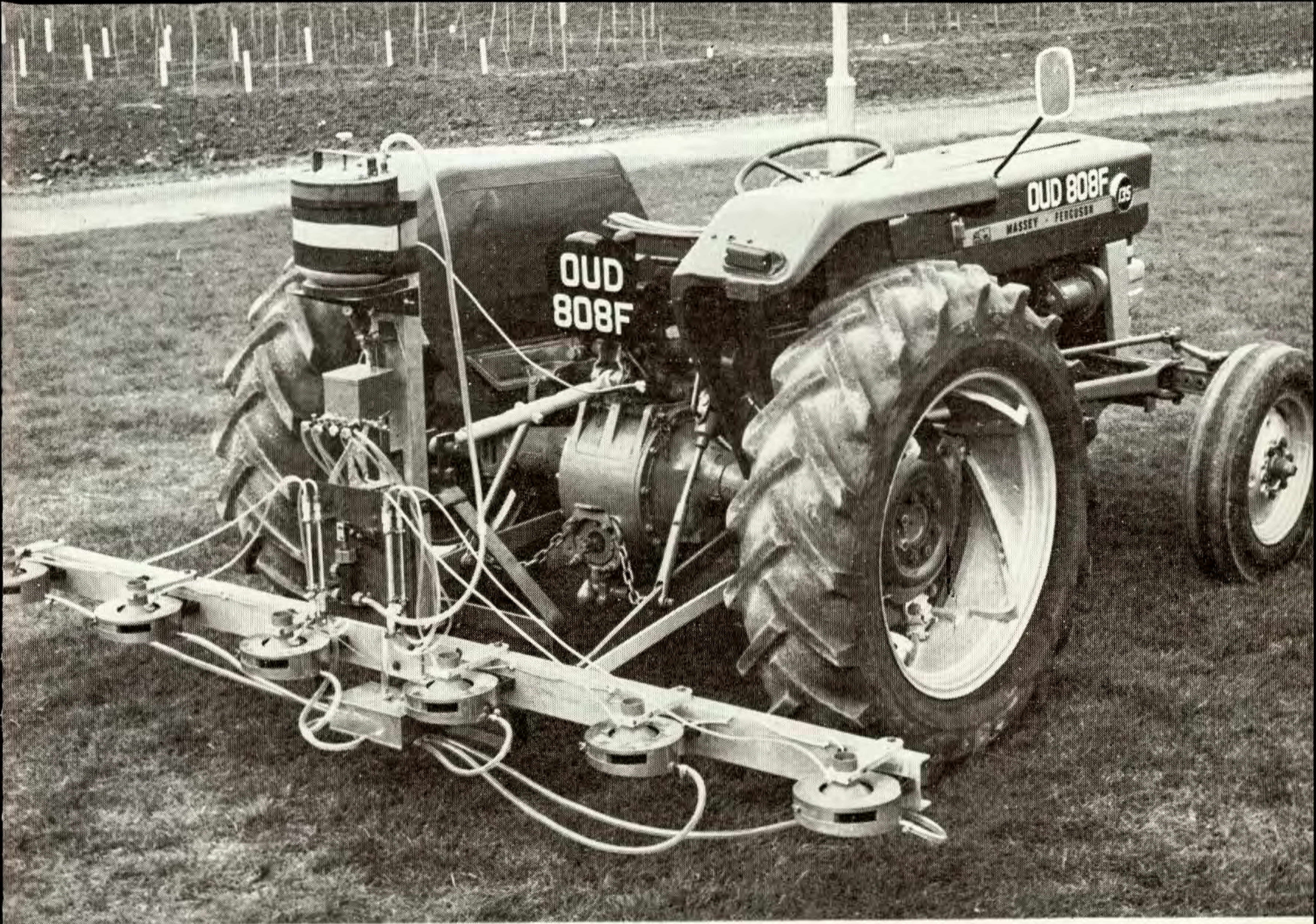
Partly as a result of this work terbutryne has now been given provisional clearance under the Pesticides Safety Precautions Scheme for use as a herbicide in freshwater. It is a useful addition to the range of herbicides available for water weed control but must be used with caution in water containing fish.

HERBICIDE RESEARCH

Application techniques improved

Many practical advantages might accrue if herbicides could be applied efficiently at very low volume rates with no reduction in biological effectiveness. Since only hand-held small scale equipment is commercially available for herbicides, a tractor mounted machine, embodying a series of shielded rotary atomisers mounted on a boom, was built in the WRO workshop. This enabled the application of volume rates in the range 5-20 l/ha to be made to experimental plots. In subsequent field trials by the Herbicide Evaluation Section, 2,4-D ester, barban and tri-allate were no less effective in controlling weeds when applied in this way than when applied conventionally through hydraulic fan nozzles at 165-200 l/ha. These promising results are being followed up on a larger scale during 1974.

The retention of spray by plant surfaces and the influence of droplet size on herbicide efficiency was also investigated, in part in collaboration with the National Institute of Agricultural Engineering. In a study on



This experimental spraying rig, built at WRO, has been used to apply 2,4-D, barban and tri-allate at very low volume rates without any loss in effectiveness of weed control.

wild oat, barban was most effective when the spray applied was composed of droplets 100 μm in diameter.

New methods of analysis developed

Provision of the analytical service essential to the research of other sections at WRO has involved the Chemistry Section in over 2000 herbicide residue analyses each year, involving 14 different herbicides, and has often necessitated the development of new methods of analysis.

In the last two years specially adapted methods for the determination of 2,4,5-T and picloram in upland forest and anaerobic mangrove soils from Vietnam and Thailand have been developed. The Section also compared and evaluated three methods of analysis for the measurement of triazine herbicides in water. This latter work stemmed from liaison with the Aquatic Weeds Section and the resulting publication has been of interest to Public Health and Water Authorities. To complement the existing range of analytical instrumentation a high pressure liquid chromatograph was recently acquired. It has already made a substantial contribution to the analytical service for the determination of methylthiotriazines in water, linuron in soils of high organic content, and shows promise for the determination of substituted uracil herbicides.

Disposing of unwanted residues in soil

The Chemistry Section continued to investigate the problem of unwanted herbicide residues in the soil. These may be caused by accidental overdose or, in some soils, by a herbicide persisting an unusually long time, perhaps because of atypical weather. The reduction in herbicide concentration in the soil solution that can be achieved by adding and mixing powdered charcoal into the soil has already been reported. More recently the Section examined the effect of common fertilizer treatments on the rate of decomposition of herbicide in the soil. The rates of disappearance of atrazine and linuron from two contrasting soils, with and without added nutrient material, were determined in the laboratory. Inorganic salts, straw, or a combination of both increased atrazine degradation in both soils. None of the treatments greatly influenced linuron breakdown. It was concluded that, in these soils, the step limiting the rate of atrazine degradation was microbiological rather than chemical. In practical terms it may be inferred that the persistence of atrazine would be reduced in soils of high fertility. Nevertheless, it seems doubtful if the effect is large enough for fertilizer additions to provide a useful means of overcoming unwanted phytotoxicity caused by accidental overdoses. However, the results of this experiment shed some light on the variable field performance that all too frequently occurs with some herbicides.

Calcium deficiency increases herbicide suppression of nitrogen-fixing bacteria

It is well known that herbicides can affect both the activities and populations of the micro-organisms of the soil. Since their numerous activities make an important contribution to soil fertility there is anxiety that the repeated application of herbicides, especially the most persistent, may adversely affect soil properties. Exploratory research was begun at WRO a few years ago to examine this possibility. To date over 50 chemicals have been tested for their gross effects on microbial populations and certain of their activities. While some herbicides clearly exert an influence on soil micro-organisms in Begbroke soils, adverse effects occur mainly at higher concentrations than those required to kill higher plants through root uptake. However, workers elsewhere have shown adverse effects at concentrations equivalent to field rates. That such variations could arise from differences in soil conditions was demonstrated in recent studies of the effect of asulam and linuron on the nitrogen-fixing bacteria in symbiosis with white clover. In agar culture asulam had little effect on the number of bacteria, even at 25 ppm, and linuron only reduced them slightly. However, in a growth medium deficient in calcium, bacterial growth was severely suppressed, particularly by asulam. Surviving bacteria, when inoculated into clover, gave rise to normal plants provided an ample supply of calcium was available.

These results, if reproducible under field conditions, may have practical implications for soils where there is a lack of lime. This may be of especial importance in the case of asulam used for bracken eradication when it may be desired to use the reclaimed area to establish a grass-clover sward.

Herbicidal activity in organic soils

The use of soil-applied herbicides on organic soils poses practical problems which, for some years now, have been the subject of a joint research programme between WRO and the Ministry of Agriculture's Arthur Rickwood Experimental Husbandry Farm. A full report on the WRO Fenland Team's activities is given in the article appearing on p. 43.

OVERSEAS ACTIVITIES

EFFECTS OF HERBICIDES IN VIETNAM

An unexpected though extremely interesting diversion during the period under review stemmed from an invitation to the Director from the United States National Academy of Sciences to become a member of the Academy's Committee on the Effects of Herbicides in Vietnam. The Committee, which was set up by direction of Congress in late 1970, was charged with obtaining factual and objective data on the ecological and physiological consequences of the massive application of herbicides from 1962-70 during the Vietnam War for defoliation of upland and mangrove forests and for crop destruction. In addition

A visiting scientist from Indonesia at work in the WRO Overseas Section, testing the susceptibility of *Panicum repens*, an important tropical grass weed, to glyphosate.

to the effect in Vietnam itself, the repercussions from this vast onslaught by a few herbicides for military purposes had resulted in violent reactions against herbicides in general constituting a threat to their continuing and vital role in agriculture. The task given to the Committee proved to be a formidable one and participation in the project involved the Director in two visits to Vietnam, two to the Philippines and 8 to the United States. The findings of the Committee were published in February 1974.*

ODA TROPICAL WEEDS GROUP

This group, previously called the Overseas Section, now embraces most of the staff and activities at WRO financed by the former Overseas Development Administration of the Foreign and Com-

*NATIONAL ACADEMY OF SCIENCES. *The Effects of Herbicides in South Vietnam—Part A, Summary and Conclusions* (1974). National Academy of Sciences, Washington, D.C.

monwealth Office. A new three-year contract began in 1972 and the research, liaison and training activities of the previous triennium were continued.

Research at WRO and overseas

Testing the susceptibility of tropical perennial weeds, particularly *Cyperus rotundus*, to glyphosate was a major feature of the herbicide evaluation programme. *Cyperus rotundus* proved highly susceptible and, with the help of a visiting worker, Umporn Suwunnamek from Thailand, glasshouse experiments indicated that the activity of glyphosate on this weed may be still further increased by inexpensive additions of ammonium sulphate or urea.

The same herbicide, glyphosate, was also found promising for control of *Orobanche* species on broad beans, tomato and tobacco. No herbicides were found to give selective control of *Striga* species on sorghum but, with new techniques, valuable information was obtained on host-parasite relationships, host resistance and the mechanism by which nitrogen fertilizers protect the host plant.

P. J. Terry, 'home-based' officer attached to the East African Community's Tropical Pesticides Research Institute in Tanzania, obtained very promising control of *Cyperus rotundus* and *Digitaria scalarum* in coffee with glyphosate. His work will enable this new compound to be brought rapidly into use once it becomes commercially available in East Africa. He also established the value of chlorthiamid and dichlobenil granules, used in conjunction with a mulch, for controlling *C. rotundus*.

G. W. Ivens completed his two-year project at the University of Ibadan, Nigeria, late in 1973. He was able to establish sound guidelines for the control of *Imperata cylindrica* by either mechanical or chemical means (dalapon) and also established the value of a 2,4-D/picloram mixture for control of *Eupatorium odoratum*.

Liaison with overseas countries

The Head of the Section made an advisory visit to the Sultanate of Oman and liaison visits to Nigeria, Kenya, Uganda, Tanzania, Ethiopia and Saudi Arabi and the USA. L. Kasasian made a prolonged visit to Indonesia and the British Solomon Islands Protectorate to conduct experiments and advise on weed control in tea.

LIAISON AND INFORMATION

THE LIAISON ROLE OF WRO

In common with many other centres for weed research, and being on the interface between research and practical agriculture, WRO has had to accept a burden of liaison activities which inevitably compete with the research programme in use of staff and resources. The reason for this needs some explanation. The chemical control of weeds and other vegetation has only developed into a major technology and a vital ingredient of developed agricultural systems during the past 25 years. In this time the number of organic chemicals recommended for weed control in crops in Britain has increased from about 6 in 1948 to more than 80 in 1974. Economic crop production in this and many other countries now depends on herbicides and the great majority of all crops grown in the UK are sprayed at least once each year. Whilst chemicals have been developed as the principal agents of weed control, a great deal of new information about the role of weeds in agriculture and their biology in relation to control has come to light, pointing the way to more economical and rational control measures based on the integration of chemical and cultural approaches. Such rapid progress in this new technology and its associated scientific disciplines has been accompanied by the need for effective communication. As the national centre for weed research in Britain, WRO has played an important role by becoming a focus for information, queries and advice, and in developing essential links between the many organisations and individuals who contribute to more effective weed control programmes on the farm. Whilst such work is accepted as a valuable and much needed role for WRO, it can make major inroads into the time available for research. During the period under review this conflict between research and liaison has provided some difficulties, as exemplified by the help which WRO gives to the British Crop Protection Council.

British Crop Protection Council (BCPC)

This Council was formed in 1968 by the amalgamation of the British Weed Control Council (BWCC) and the British Insecticide and Fungicide Council (BIFC). Members of the ARC Unit of Experimental Agronomy, who later formed the nucleus of WRO, played an important part in establishing the BWCC and in two of its principal activities: the development of recommendations for the use of herbicides and the now famous British Weed Control Conferences.

The unique herbicide recommendations, agreed by all major interests, were first published in a very modest format by BWCC in 1953 as the report of its Recommendations Sub-Committee. Due largely to the initiative of the Unit of Experimental Agronomy and, later, of WRO, and to the enthusiastic and entirely voluntary co-operation of weed specialists throughout the UK, the recommendations were developed over the years into the two-volume, 1000 page *Weed Control Handbook*. This is now compiled and edited at Begbroke.

The second activity—the British Weed Control Conference—has now been held biennially at Brighton for many years and has become a major international event. Its success depends on a blend of trade activities, efficient organization and a technical programme and published Proceedings of high calibre. The latter are the responsibility of a Programme Committee, based at WRO. The Chairman, a senior member of WRO, accepts both a heavy responsibility and, together with supporting staff from the institute, must spend a great deal of time on the exercise.

These two activities, as well as others sponsored by BCPC, are of great importance but unavoidably conflict with the research programme. An appeal for additional assistance, made both to BCPC and ARC, resulted in the latter generously appointing a full-time officer to the Information Department during 1973 to help with these and related activities, thereby reducing the load on the senior staff. It is hoped that this arrangement will enable WRO to continue to support BCPC in its important work as in the past but the increasing pressures on the senior staff and their willingness to take on this voluntary work will remain the determining factor.

PUBLICATIONS

Weed Abstracts

The acknowledged role of WRO as an international information centre for weed science owes much to the publication of *Weed Abstracts*. During 1972–73 the printing and indexing of all the journals of the Commonwealth Agricultural Bureaux, including *Weed Abstracts*, were computerized. As a result of this change *Weed Abstracts* has, since the publication of Volume 22 No. 1 in 1973, appeared monthly, in a larger format, and monthly indexes will replace the former annual index from Volume 23 No. 1 in 1974.

Weed Research

When H. A. Roberts, of the National Vegetable Research Station, retired from the editorship of *Weed Research* in 1971 after six arduous years, the Director became Chairman of a new Editorial Board with J. E. Y. Hardcastle, Head of the Information Department, as Secretary. A panel of 15 editors from several different countries was created to cover the principal scientific disciplines. All work in connection with the journal, which now appears six times a year and has a circulation of more than 1000 copies, is entirely voluntary.

Weed Control Handbook

Sponsored by the British Crop Protection Council, compiled at WRO and published by Blackwell Scientific Publications, the *Weed Control Handbook* is recognised as the authoritative source of information on weed control, not only in Britain but throughout Europe. By 1971, the appearance of new herbicides and the development of new techniques neccessitated yet another comprehensive revision of Volume 2, *Recommendations*. The 7th edition, published in November 1972, was the voluntary compilation of teams of specialists drawn from official organizations, universities and industry in the United Kingdom, once again edited by J. D. Fryer and R. J. Makepeace.

CONFERENCES

11th British Weed Control Conference

Some 1300 delegates assembled for the British Crop Protection Council's 11th biennial Weed Control Conference at Brighton on November 13-16, 1972. It was perhaps appropriate that more than 35% of the delegates came from Europe since the imminent effect of Britain's entry into the EEC dominated several sessions. WRO staff were prominent amongst the contributors, no less than 34 of the 181 papers presented emanating from WRO. The Proceedings are still available, price £8.00 from the Technical Officer, BCPC, Clacks Farm, Boreley, Ombersley, Droitwich, Worcs., UK.

EWRC Symposium on Parasitic Weeds

Members of the ODA Tropical Weeds Group at WRO, together with colleagues from the ODA Orobanche Research Project, based on the Royal University of Malta, played an active part in the organization of this symposium for EWRC which was held in Malta, at the university on 11-13 April 1973. Forty-five delegates attended. The Proceedings of the symposium, consisting of 32 papers, are available from the EWRC Secretariat PO Box 14, Wageningen, The Netherlands, price £3.00.

EWRC Symposium on Herbicides and the Soil

Owing to the illness of the Secretary of EWRC the Director, in his capacity as President of the EWRC, had to take over, at short notice, organization of the programme of this symposium held in the Palais de Congres, Versailles on 10-11 December 1973. The symposium proved very successful and was attended by 366 delegates from 21 countries. The proceedings are available, price £2.25, from J. H. Görtz, Acting Secretary EWRC, IBS Weed Control Department, Bornsesteeg 65, PO Box 14, Wageningen, The Netherlands.

WRO Wild Oat Symposium

In anticipation of the launching of the National Wild Oat Advisory Programme, this two-day symposium was held in Oxford on 7-9 February 1973. It was organized by J. Holroyd of the Herbicide Evaluation Section with an emphasis on informal discussion periods and was attended by nearly 40 wild oat experts from industry, ADAS, WRO and other research institutes. The symposium effectively focussed attention on existing deficiencies in knowledge which must be remedied if control is to be improved.

PUBLIC RELATIONS

Major exhibits of WRO research were prepared for the meetings of the Society of Applied Biology, 11th British Weed Control Conference and the NIAB Cereals Conference in 1972, and the International Dairy Event and Oxford Agricultural Show in 1973. In addition 'Weed Control in Your Garden' proved to be a very popular theme for the WRO section of the ARC exhibit at the Chelsea Flower Show in both years. The second WRO 'Weed Workshop' which took place at Begbroke in June 1973 was visited by nearly 600 farmers, growers, advisers and weed scientists from commercial and official organisations who came to see and hear about topical aspects of WRO research. Two films were made by COI at Begbroke; one about the disposal of herbicide containers and another about the wild oat roguing glove.

View of the WRO display 'Weed Control in Your Garden', part of the Agricultural Research Council's exhibit at the 1973 Chelsea Flower Show.

WRO also featured in several radio and television farming programmes and over 3,200 scientists, farmers and students visited the station in 1972/73.

TRAINING, EDUCATION AND ADMINISTRATION

WRO—AN ASSOCIATED INSTITUTE OF READING UNIVERSITY

A highlight of the period under review was the announcement by the University that Senate had approved recognition of WRO as an Associated Institute and the appointment of the Director as a Visiting Professor. This followed many years of collaboration between members of the University and the institute in joint supervision of higher degree students, organization of training courses and other activities. This gesture was much appreciated by WRO staff, several of whom received the title of Member of the Academic Staff. It is particularly pleasing in view of the applied nature of much of the research carried out at Begbroke.

EDUCATIONAL ACTIVITIES

Participation of WRO staff in the provision of formal training courses is necessarily limited by the prior claims of the research programme. Nevertheless, in 1972/73, the 2-day introduction to the principles and practice of weed research was again provided for the 10-12 overseas plant protection workers taking part in the annual, ODA financed, Silwood Park Pest Management Course. In 1973 these students were joined by ten members of the new, ODA supported, 13-week Reading University course in tropical weed control.

Collaboration, sponsored by ODA, with the new SEAMEO* Regional Center for Tropical Biology (BIOTROP) at Bogor, Indonesia involved L. Kasasian, J. C. Caseley and T. O. Robson in visits to that country to assist with short training courses in tropical biology.

ADMINISTRATION

The able manner in which the scientific work of the institute has always been supported by the former Administration Section, under the leadership of the Secretary, was recognised by its elevation to departmental status during the recent re-organisation. The Administration Department provides all secretarial and other office services, is responsible for accountancy and the organization of supplies, and administers all personnel matters. It also has a photographic section, a well equipped engineering workshop and staff who are responsible for the maintenance programmes for buildings, plant, vehicles and equipment.

Flexibility of working hours

A major change in working conditions was introduced in October, 1972, when, after full discussion with Staff Association Representatives and Section Heads, an experimental scheme of flexible working hours was introduced. This allowed staff considerable choice in the arrangement of their individual working week subject to the over-riding provision that the needs of the job must take priority. The scheme has operated successfully for 14 months without any of the problems which it had been felt might arise with seasonal pressures of field experiments. It has attracted considerable interest from other institutes.

*SEAMEO—South East Asia Ministers of Education Organization.

Cereal production by minimum cultivation

Progress in the WRO/Letcombe Joint Tillage Project*

J. G. ELLIOTT and F. POLLARD
Weed Research Organization

in collaboration with

R. Q. CANNELL, F. B. ELLIS, B. T. BARNES and K. R. HOWSE
Letcombe Laboratory

Given a good standard of husbandry, will cereal crops grow and yield as well as in uncultivated soil as in cultivated? In view of the laborious and energy-consuming nature of tillage this is today a most relevant question. However, long before the present energy problems arose, research workers began to exploit the opportunity that herbicides offer of reducing or eliminating tillage in crop production. Reduced cultivation techniques have been increasingly developed and adopted by British farmers so that, in 1973, there were some 90,000 hectares of direct-drilled crops (including cereals) and a much greater acreage of crops sown after cultivation without ploughing. Parallel developments are occurring in many other countries.

It has long been evident that there can be no one clear-cut answer to the question of whether or not it is necessary to cultivate. Even within the cereal crop it was predictable that the requirements of a light free-draining soil would be different from those of clay; that differences in weather from year to year might dictate changing methods of soil management. This proved to be the case; the development of minimum cultivation has been punctuated by instances of poor crop performance for which there have been all too few explanations. The core of the problem is the need to know more about the intimate relationship between the aerial growth of a crop plant, its roots and the soil. Although in the past decade the amount of information on the subject

*By agreement between WRO and ARC Letcombe Laboratory, a report of the past year's progress in the joint project is to be published each year. It will appear alternately in the reports of the two Institutes. This report reviews the results for the 1973 cropping season and follows that contained in the Report of the ARC Letcombe Laboratory for 1972.

has increased considerably, there are still many gaps and it was to this vital aspect of reduced cultivation that members of WRO and the Letcombe Laboratory turned their joint attention in 1968. The subject is of major interest to both institutes. Reduced cultivation depends on the use of herbicides, which are the concern of WRO, and work on the relationship between soil conditions and root growth forms an important part of Letcombe's research programme.

In the field experiments of the Joint Project, WRO has particular responsibility for the general agronomy and weed control while Letcombe undertakes an extensive study of root development in relation to soil physical conditions. The project covers three contrasting soils on which spring barley and winter wheat are grown over a period of years (see Table 1). In each experiment the primary cultural treatments compared are:

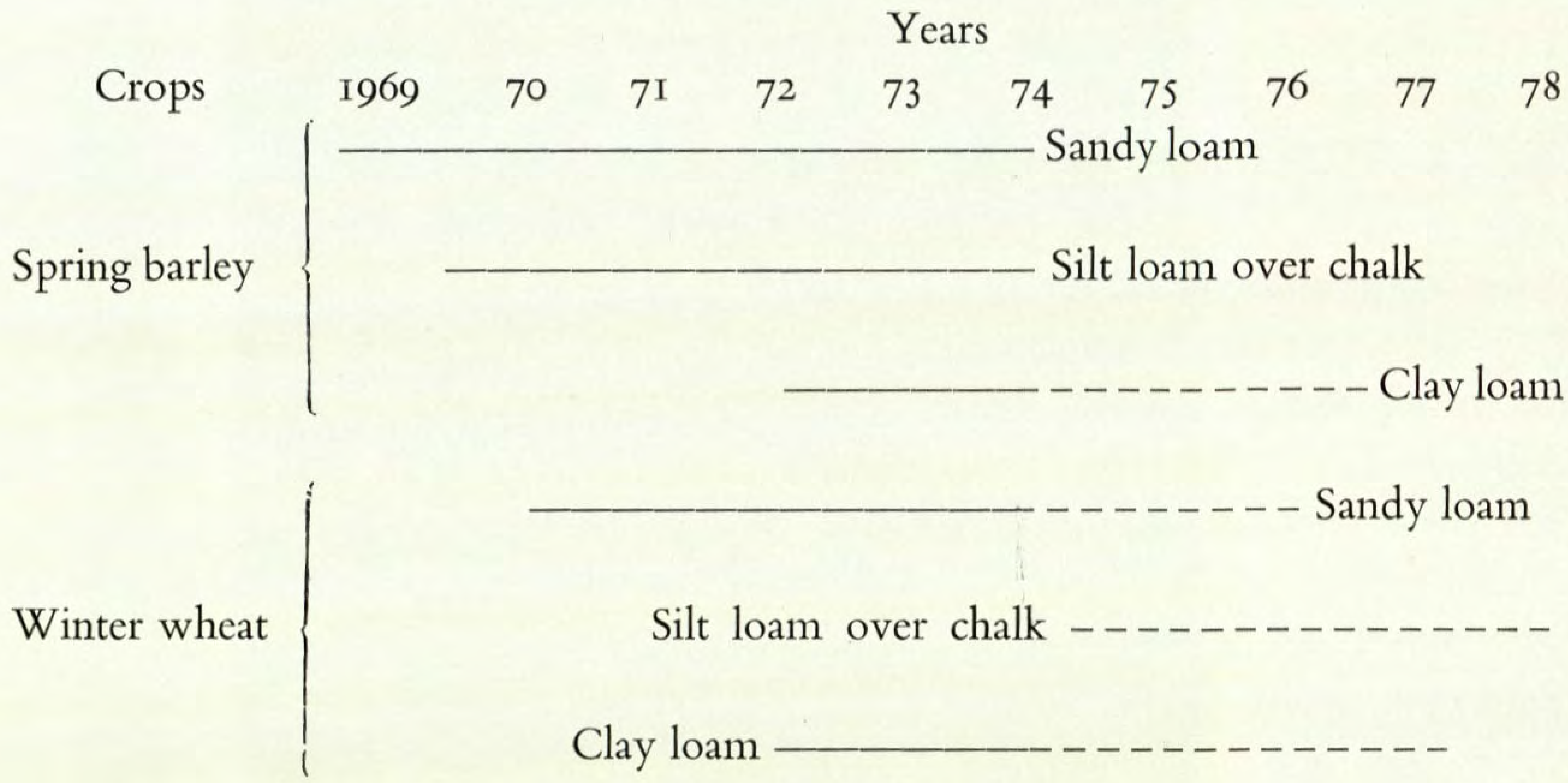
DD	No cultivation (direct drilling)		
ST	Shallow tine cultivation	(about 7 cm)	followed by secondary seedbed preparation as appropriate
DT	Deep tine cultivation	(about 15 cm)	
P	Mouldboard ploughing	(about 23 cm)	

The central object of the experiments is to measure, over several years, in the absence of weed competition, the cumulative response of cereal plants to a soil environment modified by changes in primary cultivation. Earlier work on this project has been reported by Cannell *et al* (1972) and by Elliott (1972). Detailed papers describing results of the first experiments to be undertaken are being prepared for publication.

The purpose of this article is to review progress in the experiments during the 1973 season, to present a few significant results from the enormous quantity of data and, since most of the experiments have some years to run (see Table 1), to draw some practical, albeit tentative, conclusions.

The weather during the autumn of 1972 and the winter of 1973 was exceptionally dry and mild. However, after spring rain, warmth and sunshine encouraged vegetative growth during April, May and June. Rainstorms in early July caused substantial lodging of the crops and concern over possible grain losses, but dry sunny weather allowed an easy cereal harvest.

Table 1 Progress of the Joint Tillage Project experiments



EXPERIMENTS ON SANDY LOAM SOIL

Spring barley

The spring barley experiment on the sandy loam soil at Begbroke Hill began in 1969 and was the first experiment of the project. After 3 years' intensive assessment, it was continued with a reduction in the number of observations made. Although less work was carried out on the experiment during 1973 than on the others in this series, the results are of particular interest because the primary treatments had been imposed for five consecutive years prior to the 1973 crop.

Table 2 Growth and yield data from the spring barley experiment on sandy loam soil, 1973

	Date	DD	ST	DT	P	SE(±)
Length of seminal root (cm)	26.3.73	9.8	10.3	13.5	13.5	1.50
No. of seminal roots/plant	26.3.73	5.8	5.7	5.9	5.7	0.12
Tillers/plant	4.5.73	2.3	2.2	2.3	2.0	0.05
% lodging	28.6.73	45.0	36.7	63.3	53.3	11.5
Yield of grain (tonne/ha, 85% d.m.)	8.8.73	5.10	5.33	5.05	5.23	0.19
Yield of straw (tonne/ha, 85% d.m.)	8.8.73	2.73	2.80	2.75	3.06	0.134

P=0.05

The 1973 results in Table 2 typify the general progress of the experiment since the first year: a good and uniform establishment of healthy barley plants on all treatments, with a suggestion of shorter seminal roots on the direct-drilled plots. Over the years, treatments have had little effect on tillering but in 1973 there were slightly more tillers/plant on direct-drilled plots than on ploughed. Lodging occurred in 1973 for the first time and the figures suggest an increased tendency to lodge associated with deep cultivation. The significantly greater yield of straw associated with deep cultivation would tend to support this impression. However, at the end of the season the grain yields were not significantly different. When experiments such as this are carried on over a period of years, it is frequently noted that individual aspects of crop performance vary up or down from year to year, but when all the results for all the years are put together there may be no difference between treatments. This has substantially been the outcome of the barley experiment on the sandy loam at Begbroke.

Winter wheat

The winter wheat experiment on light loam at Begbroke entered its second year in 1973. The variety used was Cappelle Desprez, not the most modern one but perhaps the most likely to endure for the life of the experiment. Some indication of the intensity of work that went into this experiment can be gauged by the fact that 153 sets of measurements were sent for statistical analysis; even so this experiment was not as heavily assessed as the experiments on the clay. A brief selection from the large collection of data is given in Table 3.

Table 3 Growth and yield data from the winter wheat experiment on sandy loam soil, 1973

	Date	DD	ST	DT	P	SE(±)
Penetrometer at 7.5 cm	20. 3.73	189	158	74	72	6.2
Plants/m²	15.12.73	266	215	251	251	15.1
Length of plumule (mm)	23. 3.73	14.6	15.3	15.4	17.4	0.27
Total length of nodal root/plant (cm)	26. 3.73	16.3	15.5	18.3	17.8	1.41
Yield of grain (tonne/ha, 85% d.m.)	13. 8.73	4.04	3.47	3.44	3.32	0.291
Yield of straw (tonne/ha, 85% d.m.)	13. 8.73	5.92	6.32	6.93	6.23	0.523
						P=0.05

As in the previous year the primary tillage treatments resulted in significant differences in the strength of the top soil as shown by resistance to a penetrometer; in March 1973 the non-cultivated plots proved more resistant than those which were cultivated, with the ploughed plots showing least resistance to the greatest depth (Table 3). The bulk density of the soil was on the whole unaffected. All the plots were sown on the same day (2 November 1972). The seeds germinated, emerged and established uniformly without being affected by the differences in soil, apart from a greater length of plumule on the ploughed plots indicating deeper sowing. No differences in root length were observed.

In the spring of 1973 the wheat on all plots tillered and developed in a similar normal healthy manner. In March the average dry weight of the plants on direct-drilled and on ploughed plots was significantly lower than of those on tine-cultivated plots. As growth progressed the differences diminished but the trend was still apparent in May. However such differences in aerial or root growth that occurred in May and June were small and most assessments indicated no difference between treatments.

During the rain storms, less lodging occurred on the uncultivated plots than on the cultivated. Whether or not this resulted in a difference in the subsequent development of the crop is difficult to judge. In the event the yield of grain and straw was not significantly different (Table 3). Assessments of the broadleaved weeds in April indicated no differences apart from more *Polygonum* spp emerging with increased cultivation. These weeds were controlled on all plots with a selective herbicide (ioxynil+mecoprop). Counts of wild oats *Avena fatua* in July showed the numbers to be small and similar for all treatments.

THE EXPERIMENT ON CHALK SOIL

Spring barley

With the co-operation of the ARC Institute for Research in Animal Diseases, an experiment involving the production of spring barley on the chalk down land at Compton in Berkshire entered its fourth year in 1973. Over the years the soil has proved to be easily amenable to the contrasting cultural treatments. However, a problem arose in 1972 due to a variable incidence of cereal cyst eelworm which caused an irregularity in barley growth unconnected with the tillage treatments. In 1973 a similar difficulty was encountered and it was decided

Crumb structure developed on the surface of the chalk soil after 4 years of direct drilling

to terminate the experiment. As the land is now being sown to ley it may be possible to revive the experiment in the future.

As in previous years, the primary tillage treatments carried out in autumn 1972 produced marked differences in penetrometer readings in March and April, the soil in ploughed and deep-cultivated plots being looser to a greater depth than in the shallow cultivated and direct-drilled plots. However, these differences in compaction were not associated with differences in the bulk density of the soil or with differences in top soil moisture during the period of 9 days before to 12 days after drilling.

No differences attributable to the tillage treatments were detected in germination, speed of emergence, numbers and length of seminal roots, tillers per plant, and yield of dry matter and grain. The last are given below:

	DD	ST	DT	P	SE(±)
Yield of grain (tonnes/ha, 85% d.m.)	3.91	4.03	3.76	4.01	0.214 (P=0.05)

From the crop performance point of view, it was an encouragingly negative year but there were two aspects of the experiment which displayed interesting differences. A count of earthworms, obtained on 12 October 1973 by the combined use of potassium permanganate solution and digging, showed that the earthworm population on the non-cultivated plots was approximately four times that on the ploughed plots ($42/m^2$ versus $10/m^2$); populations on the two tine-cultivated plots were intermediate. Studies of the weed population revealed that *Sambucus nigra* (elder), rarely encountered as a weed, had somewhat unexpectedly tended to increase with tine cultivation.

EXPERIMENTS ON THE CLAY LOAM SOIL

Winter wheat

After a preliminary crop of spring barley in 1972 to check the performance of the land and to gain some experience of working it, the winter wheat experiment on the clay loam soil at Buckland, Berkshire, started in autumn 1972. It so happened that the period of land preparation in September-November was the driest for many years. In consequence those concerned with the agronomy found themselves, somewhat ironically, having difficulty in forcing a tilth on the conventionally cultivated plots (DT and P) while the other plots (DD and ST) waited in an admirable state for sowing. Eventually all the plots were sown in October to Cappelle Desprez wheat. The differences in soil compaction between tillage treatments, as measured by the penetrometer, were similar to those found on other sites in previous years; the lack of difference between treatments in the bulk density of the soil also confirmed previous findings. The effect of the different seedbeds on germination and emergence was quickly apparent: the less the cultivation the more uniform and rapid the wheat emergence, to the extent that on 21 November a mean 282 plants/m^2 had emerged on the direct-drilled plots but only 33 plants/m^2 on the ploughed plots. In fact, parity of population was never achieved and counts on 5 April 1973 indicated significantly less wheat plants on ploughed plots than on the others.

The direct-drilled wheat got away to an early start, the consequences of which were still apparent in March 1973 (Table 4). The situation began to change as spring growth developed. In the deep-cultivated plots where the wheat populations were reduced, enhanced tillering occurred and growth started to catch up with that on the reduced

Crumb structure developed on the surface of the clay loam soil after 1 year of direct drilling.

cultivation plots to the extent that by 31 May there was no significant difference in total weight of dry matter/m^2. It would have been extremely interesting to have watched the further uninterrupted growth of the wheat. However this was not to be. Rainstorms in June caused substantial lodging. This did not appear to be associated with the tillage treatment and aerial photographs, supplied by the ADAS Aerial Photographic Unit at Cambridge, showed that, in fact, the lines of lodging were associated with an old ridge and furrow system.

The experiment was harvested on 16 August and grain yields were less than had been expected before lodging. The yields from deep-tined cultivation were significantly lower than those from shallow-tined cultivations or ploughing (Table 4). This result does not indicate any logical trend and should therefore be treated with reserve until additional results are to hand.

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