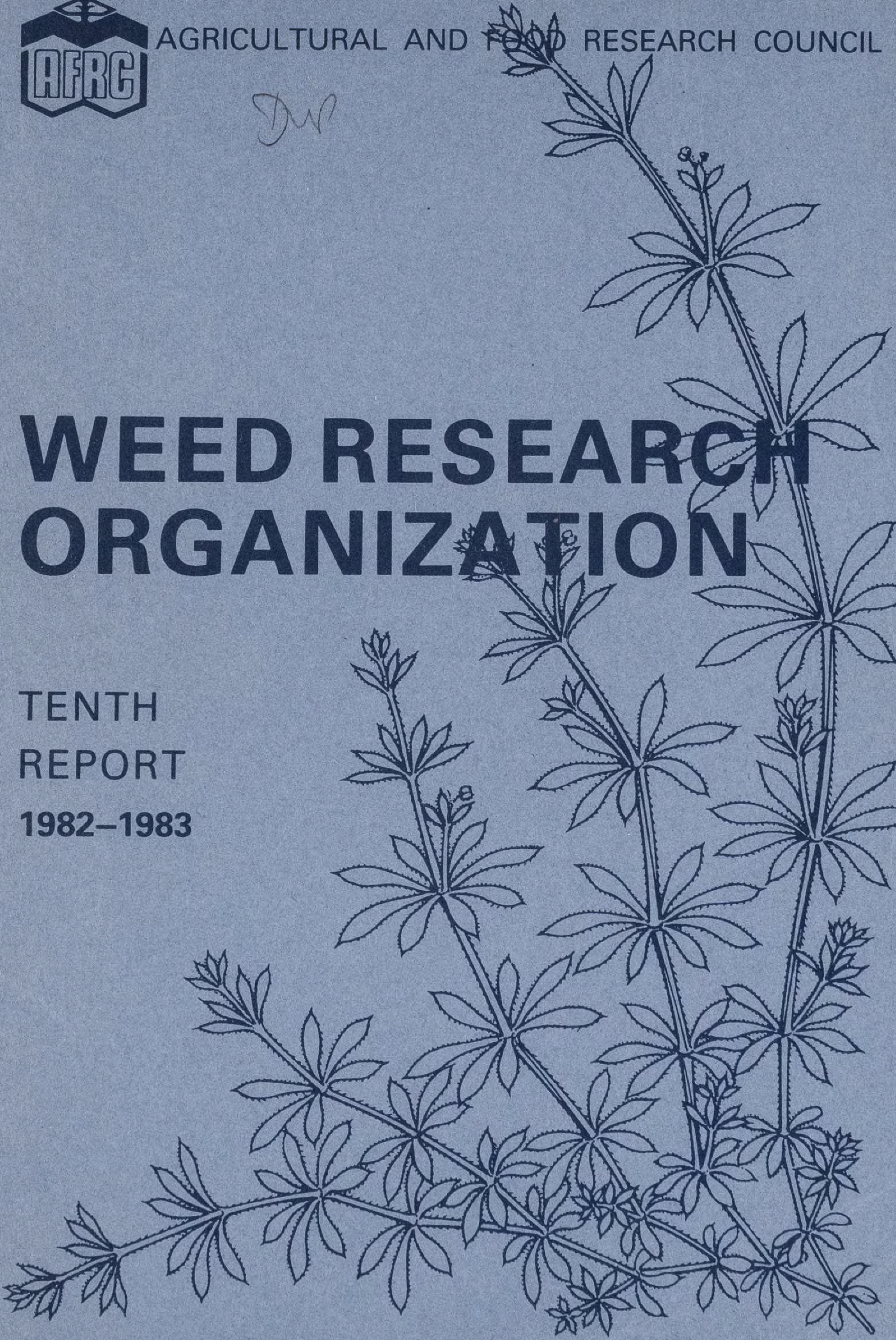
AFRC AGRICULTURAL AND FOOD RESEARCH COUNCIL



WEED RESEARCH ORGANIZATION

TENTH REPORT

1982–1983

IMPORTANT NOTE

This Report describes research which has been in progress during 1982–83. The information presented should not be construed as constituting recommendations for the control of weeds in particular situations. In many instances an ongoing process of validation in a wide range of circumstances would be required before such recommendations could be made. In particular, practical use of herbicides should comply with clearances for their use and the guidance of manufacturers should be sought on this matter.

Cover: *Galium aparine L.*

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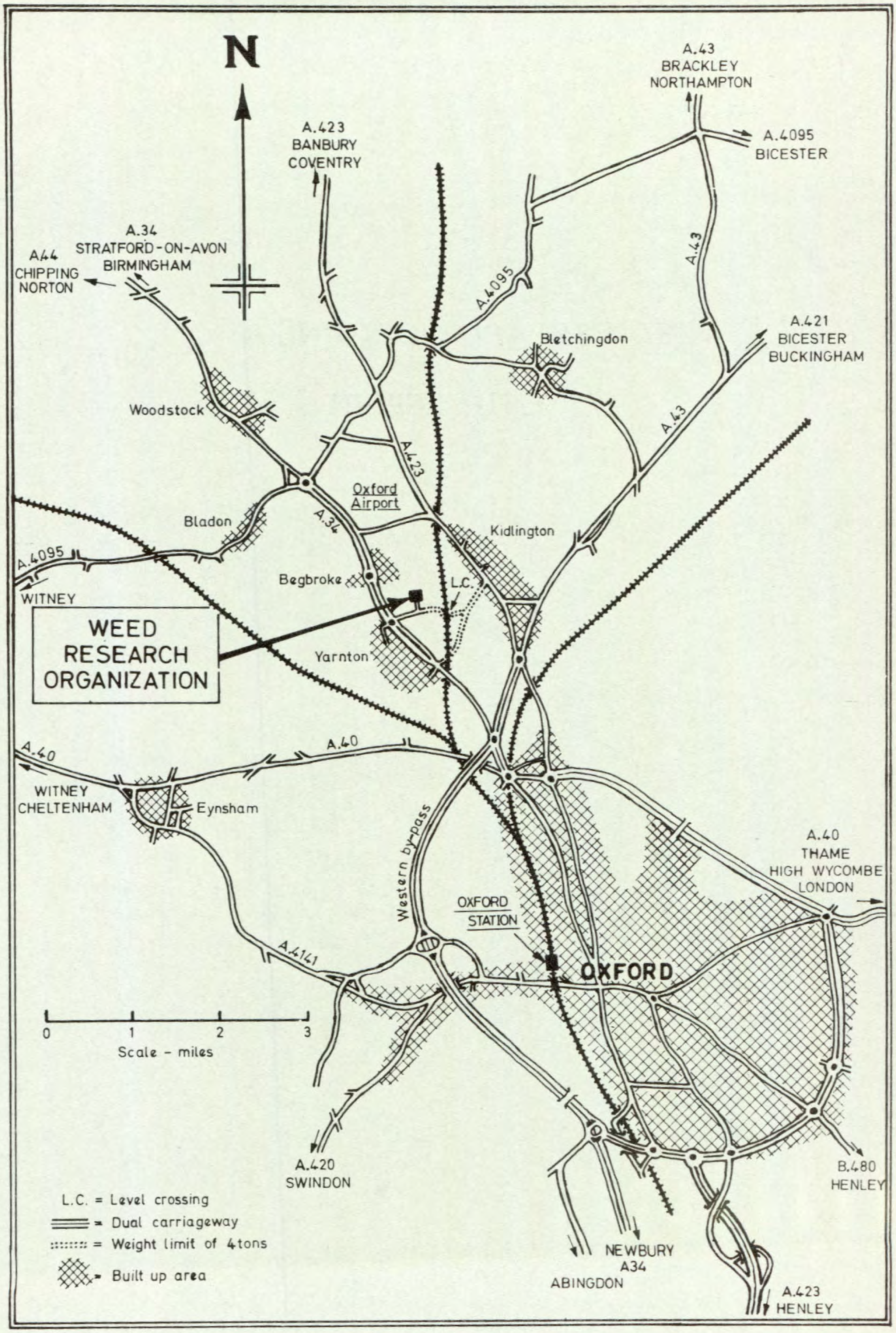
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A.420
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B.480
HENLEY
L.C. = Level crossing
= Dual carriageway
= Weight limit of 4tons
= Built up area
NEWBURY
A34
ABINGDON
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HENLEY

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TENTH REPORT
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Published December 1984

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DIRECTOR'S INTRODUCTION

CLOSURE OF WRO

In December 1983 the Agricultural and Food Research Council (AFRC) decided to close WRO as part of its strategy for responding to reduced levels of funding by the Government and to new priorities in research. In the Council's first Corporate Plan the decision was reported in the following terms: 'The proposals for the next five years are: . . . to link WRO's work on weeds more closely with the programme at Long Ashton Research Station on hormonal control of plant growth, crop protection chemistry, cereal pests and diseases, and spray application. After reviewing the programme of the two institutes and associated research at the Rothamsted Experimental Station, the work to be continued will be consolidated at Long Ashton within an integrated crop protection theme.' . . . 'Work at Rothamsted, Long Ashton and WRO on strategic aspects of plant pathology, zoology, weed science and spray application will be reduced to secure savings of about £1.4M.'

The Council intend that the merger should be completed by 1986–7 or at the latest by the following year. At the time of writing (July 1984) no decision has yet been taken concerning the future of Begbroke Hill Farm, together with the laboratories, glasshouses and many other buildings and facilities which have been developed specifically and at great cost to meet so well the requirements of a weed research programme. However, their probable sale in due course has been proposed by the AFRC Headquarters.

To those who are unfamiliar with WRO and who believe that large institutes are more economical and efficient than small ones, to those who consider that herbicide technology has advanced to the point that the role of WRO has largely been fulfilled, or to those determined that the AFRC should cut back on the number of its institutes at any price, the Council's decision may well be regarded as a constructive step. It has indeed been applauded as a movement towards the so-called rationalization of agricultural research in Britain and the attainment of greater economy through staff losses, programme reductions and savings in overheads. That in the process a comparatively small and young institute is disbanded and its remaining elements are merged with a larger, much older institute some 80 miles to the south west of Oxford may seem a matter of little importance. Reductions and change are, after all, inevitable in these days of diminishing budgets. Moreover, the AFRC has repeatedly stated its commitment to continue to support a strong programme of weed science albeit at a different location.

Yet, to others: those who have benefited from the work of WRO and appreciate its unique functions, those in other countries who have experienced the decimation of effective weed research programmes by organizational change such as that now planned, those who are aware of the meagre support given to weed science throughout the world and who understand the importance of this discipline in combating the constant and ever-changing threat to agriculture posed by weeds, the decision to close WRO has caused consternation and dismay—and continues to do so. The role of the institute as the world's leading centre for weed research is recognised far beyond the shores of the United Kingdom. From the Solomon Islands to the United States, from Australia to China, from Indonesia to Brazil, from Norway to Nigeria, letters have been written to the AFRC and to its sponsoring Ministries, also to the government department responsible for British overseas technical aid, protesting at the proposed closure of WRO—a clear testimony to the institute's vital role in world agriculture. It seems however that national and international recognition of past performance and future needs has no part to play in influencing decisions such as this, where organizational and economic factors, and expediency are seen as of over-riding importance.

In the last report, I referred to the generous tributes to WRO made by the distinguished guests who spoke on the occasion of the institute's 21st anniversary celebrations. That WRO has been—and is—a success is not in question. What must now be a matter for grave concern is whether the essential ingredients for an equally successful future for British weed research in its national and international roles will still remain by the time the decision of AFRC has been fully implemented. Amongst the most important are:

A personal commitment on the part of the director and other senior staff to the concept and practice of weed science as a distinct discipline of agricultural research and to the advancement of the technology of weed control and vegetation management—also to helping others with similar beliefs and aspirations wherever they may be.

A mix of interactive scientific and agronomic expertise and of laboratory and field work, the programme embracing both short-term problem solving research and longer-term strategic and innovative research.

Active links with farmers and growers, with the agricultural industry including its relevant service industries, with advisers and regulatory authorities, with related research institutes and in universities, and with government and other agencies concerned with fostering agriculture and international collaboration world-wide.

The necessary services and physical facilities to support the scientific programme and associated activities, together with a level of financial provision which is appropriate both to the fundamental role of weeds in agriculture and to expenditure by the State on research in the other disciplines of crop protection.

Access to a directly controlled research farm with suitable soil, topography, climate and services and of sufficient size to allow realistic crop rotations to be practised, where weed populations, crop performance and herbicide-soil interactions are well understood and where long-term experiments can be carried out with confidence that security and effective control will be maintained.

A location which allows ready access to the main agricultural areas of the country and to a university with active research and teaching programmes in related scientific and agricultural topics.

After nearly twenty-five years of development as a specialised weed research centre WRO has, with the generous support of the Agricultural Research Council, been fortunate in achieving all these ingredients at Begbroke Hill. Some will or can be made available at Long Ashton if the substantial finance required is provided. Others cannot. Much of what already exists at Begbroke will inevitably be lost. It is but meagre consolation that, as emphasized by the AFRC, some aspects of the WRO programme will be strengthened as a result of the merger by the bringing together of a wider range of scientific expertise than can be supported at either institute on its own.

On 1 October 1984, a new director to be appointed at Long Ashton (LARS) will assume responsibility for WRO and the two institutes will then officially merge. By then I shall have had the privilege of leading WRO for 20 years, helping it to evolve from a small group of pioneers housed in converted farm buildings to the superbly equipped research institute it is today with a staff complement of around 140 supplemented with great benefit by visiting research workers and students from many parts of the world. To my colleagues, past and present, who have helped in this task, I extend my warmest thanks and gratitude. To those who remain I wish every success. On them will fall the burden of responsiblity of ensuring that as much as possible of what we have built up together is not lost. My good wishes also go out to colleagues at Long Ashton who have experienced traumatic changes in recent years and who now have to face further readjustments to accommodate weed research in their institute's programme at the further expense of traditional and renowned elements. The challenge to create a new institute specializing in crop protection and providing a new home for weed science is, whilst unwanted, an exciting one, which in my view, can only be met: if an equable balance is maintained between its component disciplines, if there is the will on the part of all concerned to co-operate and give and take, if the physical facilities are adequate and if links with university research, the commodity research institutes and with the industry as a whole are effective. To achieve a successful outcome must now be the primary objective of the staff of both WRO and LARS, of colleagues at AFRC Headquarters and, perhaps especially, of members of the Council itself. Nothing short of outstanding success will be sufficient to compensate for the damaging consequences of the Council's decision.

Finally I should like to thank warmly all those who took the trouble to write in support of WRO both before and following the closure decision. Although the decision was not reversed, many influential people connected with agricultural research in Britain will now, as a result, be much better informed than hitherto about weed research and the important role of WRO. The staff and I express our gratitude for the encouragement we received from this correspondence and for the benefit it will undoubtedly bring to weed research in the future.

PEOPLE AT WRO

The reputation of this research station has been built on the skill and energy of the individual people who make up the staff at all levels and who have made many and varied contributions.

It is particularly sad to have to record in this final report the sudden and untimely death of one of the institute's most distinguished members. **Jimmy Elliott,** who died in August 1983, whilst on holiday in Cornwall with his family, devoted boundless energy, enthusiasm, and initiative to the advancement of British agriculture, to the development of WRO, and to the role the institute has played in pioneering new techniques of weed control and crop production. That WRO is so well known and respected throughout the agricultural community is in no small measure due to his innovative ability and his outstanding talents in communicating the institute's work to the farming industry, in challenging established attitudes and in leading the development of new practices. In the months which followed his death, we have been reminded time and again of the enormous contribution Jimmy Elliott played in the running of the institute and the many related outside activities to which he so freely gave his energies and time. Those of us who shared with Jimmy the responsibility of building up WRO since its establishment in 1960 are deeply conscious of the loss of a loyal friend and an outstanding colleague. On behalf of all the staff I express our deepest sympathy to his wife Alison and to his children Michael, Simon and Frances, also our deep admiration for Jimmy as a person and for all that he achieved for the institute and for agriculture.

Another early pioneer of WRO left us in 1983, fortunately in the best of health. **Brian Wright** who retired in January 1983 was amongst the first to set up an office at Begbroke when the farm was acquired by the ARC in 1960. As Institute Secretary he administered WRO with impeccable efficiency and unswerving loyalty. He was widely respected throughout the Agricultural Research Service for his leadership and wise judgement, his efficiency and for the deep concern he felt for people. His belief that the sole purpose of administrators in the ARS is to help oil the wheels of research he put fully into practice at WRO with great benefit to the scientific programme and to those participating in it. Like most of us who have worked at Begbroke, Brian had, and still has, a warm affection for the place. His outstanding service was recognised by Her Majesty the Queen in 1981 when he was awarded the MBE. I am deeply grateful to Brian for the help, support and friendship he gave me for more than 23 years, and we shared both personal problems and those of WRO. I wish him and his wife Grace much happiness and joy in future years.

Following Brian Wright's retirement in January 1983 the post of Institute Secretary remained vacant for 9 months whilst we searched for a successor who would be worthy both of Brian and WRO. We were indeed fortunate that **Lieutenant Commander L D (Larry) Poole MBE RN** applied for the job and accepted the ARC's offer of appointment. Despite the fact that within a week of his coming to Begbroke on 1 October I had to tell him that WRO was under threat of closure, he set to work with vigour, skill and great cheerfulness to make Begbroke shipshape and to provide a much needed boost to morale. During the long gap between Brian Wright retiring and Larry Poole joining, Geoffrey Young our Assistant Secretary took the administrative helm and did a really splendid job on temporary promotion to Acting Secretary.

Jimmy Elliott's tragic death enforced a re-organisation of the management structure of the institute which took effect from 1st January 1984. The most notable features were that the two research departments were abolished and **Dr Keith Holly** was appointed Deputy Director, the research group leaders reporting directly to him. The revised organisation adopted, which is referred to on page 135, has proved very effective in helping us to cope with the many difficulties of the last year. I should like to record here my deep gratitude to all the Group Leaders and others who willingly adjusted to the new arrangements, have shouldered additional responsibilities and shared the many problems that have arisen. In particular I wish to record my appreciation of the stirling support given to me and colleagues throughout the institute by Keith Holly. His contribution both to the domestic affairs of WRO and to our negotiations with AFRC and Long Ashton has been an outstanding one. I should also like to express my thanks to George Cussans who took over many of the jobs previously undertaken by Jimmy Elliott, and to Chris Parker for the great help he has given to me in many ways.

Since the success of agricultural research institutes depends, like most organizations, on people more than any other factor, I make no excuse for recording further gains and losses in staff at WRO.

On the positive side we were fortunate in securing two new Band 1 research posts as an outcome of the 1981 MAFF Cereals Commission Review. **Dr Victor Breeze,** who brought with him a rare combination of expertise in physics and biology, joined the staff in January 1983 to lead a new project on the problem of damage to non-target crops caused by vapour drift of certain widely used cereal herbicides. We were also glad to welcome in March 1983 **Dr Roger Cousens** and his valuable experience and skills in modelling biological systems. These he is applying with great benefit to the comprehensive data available at WRO on the biology and behaviour of weeds in cereal based cropping systems. Another important addition to the talents available at Begbroke came through the appointment of **Mrs Jill Webb,** a highly qualified electronmicroscope technician, to assist Dr John Sargent in providing an EM service for WRO and neighbouring AFRS institutes.

The benefits of voluntary premature retirement can provide an attractive alternative to facing an uncertain future in the AFRS and a number of staff have taken advantage of it following the closure decision. Here I should like to refer briefly to a few senior colleagues who for one reason or another have moved on after giving long and meritorious service to the institute.

T O (**Dale**) **Robson,** who retired on 23 December 1983, joined WRO on 1 October 1963 on a temporary appointment to undertake a survey of the problem in England and Wales caused by aquatic weeds in land drainage channels. The results of the survey were such that the ARC were persuaded to establish a small research team under the leadership of Robson at Begbroke to investigate methods for controlling aquatic plants. WRO quickly became the focal point in the UK for research, information and advice on this subject. The annual liaison meetings organised by the team continue to attract a wide range of people concerned with aquatic weeds—from university researchers to drainage engineers. Dale Robson is now a leading world authority on the subject and he and his colleagues have contributed much to the development of new and ecologically acceptable methods for controlling aquatic weeds and to the training of those involved. For many years he was leader of the Aquatic Weeds Committee of the European Weed Research Society, in which capacity he organised a series of very successful international conferences in various European countries.

Although **Dr J G** (**John**) **Davison** did not actually become a member of the WRO staff until 1970, he was amongst the very early residents at Begbroke. The reason for this was his appointment by the Ministry of Agriculture in October 1960 as the first herbicide liaison officer for the Agricultural Chemicals Approved Scheme (ACAS). His close contacts with the agrochemical industry and his unrivalled knowledge of new herbicides proved an invaluable aid to WRO colleagues and he and ACAS in turn greatly benefited from the independent research and expertise of the institute. From 1967 until his retirement in December 1983 John Davison was leader of the WRO Perennial Crops Group and was responsible for the institute's horticultural research. He was widely known and respected by growers, ARC and ADAS specialists and by the horticultural industry at large for his practical approach to growers' problems, the many innovations in weed control practices made by his Group and for his willingness to communicate the results of WRO research to growers' meetings and technical conferences. From its inception in 1965, John Davison was Chairman of the ARC Weed Control in Fruit Group which did and still does a splendid job in providing co-ordination of research, information exchange and encouragement for official research workers and advisers throughout the UK.

Of the many other contributions John Davison has made to WRO I should like to mention two. As Safety Officer he established a happy compromise between over-reaction and indifference. His balanced view of potential hazards, especially to staff handling chemicals was much appreciated. Another activity was his supervision of the ornamental grounds at Begbroke, often in the evenings or at weekends. His deep interest in plants found full expression in the low-upkeep gardens and amenity areas he planned and which give so much pleasure to staff and visitors and serve as a fitting backcloth to the new as well as to the old buildings.

When John Davison resigned from ACAS in 1967, he was succeeded by **R J (Dick) Makepeace** who became one of Britain's leading experts on herbicides. Although not a member of the staff he became very much part of WRO. He did an immense amount to foster weed science and herbicide technology and will be remembered in many countries for his vigorous and entertaining participation in meetings and conferences. He and his family were enthusiastic participants in WRO activities and his stimulating if provocative personality and his technical expertise were much missed when he left the Service.

Finally, in this section, I want to place on record my appreciation of the work of two ex-colleagues who played an important part in the information role of WRO.

W L (Bill) Millen started work at Begbroke in November 1962 as an abstractor in the team responsible for the production of *Weed Abstracts*. His meticulous attention to detail, his high regard for scientific accuracy, and his linguistic abilities were ideally suited to the development of the journal progressively within the framework of the Commonwealth Agricultural Bureaux (CAB). Bill Millen was appointed editor in 1970 and devoted himself to maintaining the high standards and productivity of the WRO team during the difficult period of adjustment to computer production which ended when the Commonwealth Bureau of Pastures and Field Crops took over responsibility for the journal on 31 December 1982.

Weed Abstracts was, until its transfer to CAB, the foundation of WRO information activities. The data base for weed science was physically located at Begbroke in the form of a series of manual indexes of published literature developed since the early 1950's, complemented by a unique world collection of reprints and library holdings. These, coupled with the wide range of expertise in weed science built up by WRO staff over several decades, constitute an unrivalled world information resource. Since the early days of the ARC Unit of Experiment Agronomy in Oxford University, the progenitor of WRO, provision of information on weeds and their control became widely recognised as an important and unique service for world agriculture. The progressive development of the information and public relations role of WRO owes much to **J E Y (John) Hardcastle OBE** who was appointed Head of the Information Department in October 1969. His talents, energy and efficiency proved of inestimable value to WRO. Nothing was too much trouble nor any task too daunting. He did an immense amount to improve communication of the institute's research through the biennial Weed Workshops, through publications and through exhibits at agricultural and scientific events. His artistic flare combined with great organising ability and drive led to the production of displays of exceptional quality. As many visitors to Begbroke will know panels depicting the latest research of WRO are a distinct feature of many corridors in the institute and a testimony to John Hardcastle's initiative. A further notable achievement was the vital contribution he made to the establishment of the European Weed Research Society of which he became the first Executive Secretary. The outstanding performance of John Hardcastle at WRO did not go unnoticed by the Agricultural Research Council and in 1982 he was invited to become the Council's permanent liaison officer at the National Agricultural Centre at Stoneleigh. He left WRO in May of that year.

WRO DIRECTOR'S ADVISORY GROUP

I have pleasure in recording my warmest appreciation, also that of WRO colleagues, of the support, advice and time that successive members of the Group have so generously given to the institute's affairs. Their visits to Begbroke have always proved constructive and enjoyable occasions and of great value to all taking part. In particular I wish to acknowledge with gratitude the help and encouragement unstintingly given to me over the past ten years by the two chairmen of the Advisory Group: Professor Hugh Bunting of Reading University and Dr John Braunholtz of ICI Plant Protection Division. I thank them for their stimulating and wise leadership of the Group's discussions of WRO affairs.

WRO FORWARD LOOK

During the period under review a great deal of time was spent by the Director's Advisory Group and the staff on a WRO Forward Look exercise. The purpose of this was to assess the future requirements for research and related activities appropriate to an evolving WRO in preparation for the next Visiting Group scheduled for 1985. Independent advice was sought from a wide range of individuals and organisations throughout the UK concerning future trends which might have affected the role of WRO. The WRO Forward Look was in an advanced state of preparation when the institute was threatened with closure. Despite its relevance to a consideration of the AFRC's future support for weed research, its findings were not taken into account in formulation of the Council's policy and its eventual decision to close the institute.

WEED RESEARCH PAST, PRESENT AND FUTURE—A PERSONAL COMMENT

Development of chemical mastery over weeds

My career in weed research began early in 1948 when I was instructed by the managing director of the firm I worked for as a plant pathologist to take responsibility for developing the company's new weedkillers based on the then revolutionary synthetic plant hormones MCPA and 2,4-D.

Agriculture in Britain in those post-war years was indeed a 'struggle with weeds'. Enormous areas of grassland had been ploughed up during the war to grow arable crops, yet many farm workers had left the land for wartime duties never to return to mundane farm work like hand-weeding. Mechanised weed control still had tremendous limitations. Rotational husbandry was standard practice and obligatory, largely for weed control reasons. An inability to kill weeds in cereal crops forced farmers to revert after 2 or 3 years of growing wheat or barley to row crops which could be machine- and hand-hoed—or to a grass break. Efforts to overcome this problem by the application of chemicals for selective weed control in crops had been made since the end of the 19th century. It may come as a surprise to readers that by 1902, a 4th annual report* on 'destroying charlock in growing corn crops' had been published by one of the pioneers of chemical crop protection, G F Strawson, who claimed that his method of using copper sulphate "had been adopted by hundreds of farmers and that thousands of acres had been profitably sprayed". In the 1930's sulphuric acid was widely used as a selective weedkiller in cereals. However, such chemicals had obvious and serious drawbacks and by the end of World War II the vast majority of cereals grown in this country received no direct weed control treatment. It was not until the safe, cheap and highly selective hormone weedkillers were marketed from 1946 onwards that the weed

* contained in G F Strawson (1903) "Standard Fungicides & Insecticides in Agriculture" Spottiswoode & Co. Ltd. London.

problem of cereals could be brought cheaply and safely under control, making possible the intensive system of cereal production so widely practised today.

In contrast to the handful of chemicals available for selective weed control in the late 1940's, farmers and growers can now choose from some 80 active ingredients marketed in the form of many hundreds of commercial products. For the vast majority of crops which are grown, a product can be purchased which will kill a wide range of weeds. With such an armoury of chemical weapons, backed by the great expertise of agrochemical manufacturers and distributors, is there still a need for independent weed research funded by the public sector? Does not the closure of WRO by the AFRC perhaps reflect the view that the weed problems of British agriculture have largely been beaten and that any remaining ones can be safely left to industry?

Some scientists I have met hold opinions of this kind. Farmers, who run profitable livestock/arable enterprises and whose rotational husbandry systems allow them to get by with the modest use of herbicides may conceivably share them. However, many farmers and growers whose livelihood depend on effective weed control have no such illusions and are convinced that the need for public sector weed research such as that pioneered by WRO will not only continue but will increase, perhaps dramatically, as impending changes in our agriculture and in society's attitude towards agriculture begin to take effect.

A changing agriculture will enhance the need for weed research

The pragmatic substitution of the hoe by the sprayer with the common objective of killing as many as possible of the weeds in a crop (preferably all) is certain to be increasingly questioned if for no other reason that the high cost of so doing will be more difficult to sustain as chemical costs increase and excessive production of agricultural commodities in Europe leads to reduced commodity prices. Herbicides have become a major item in the variable costs of arable crop production and economies in their use may become essential if the present systems are to remain viable. In any event, more enlightened farmers and growers are realising that profitability of crop production can often be increased by more discriminating weed control.

But the pressures are not only economic. The changing attitude of the nation towards agriculture is bound increasingly to influence decisions about the acceptibility of modern farming practices. The blanket spraying of large areas of our countryside is, like straw burning, coming under critical, albeit often uninformed scrutiny. Herbicides, which are used routinely, year after year, crop after crop, are particularly vulnerable. The sorry tale of 2,4,5-T, however distorted for political ends or profit-making motives or out of ignorance, also by its gross misuse in Vietnam, does nothing to encourage the public to believe that herbicides are as safe as the manufacturers and official regulatory schemes suggest. Moreover, in recent years, there has been a remarkable upsurge in public interest in the conflict between intensive herbicide-dependant agriculture and the amenities and the landscape value of the countryside.

'Lower input agriculture', 'farming with conservation and wild life' are phrases much heard today and indicators of a new phase of agriculture in Britain, in which greater recognition is at last being given to the farming ecosystem of which weeds form a part. The link between field margin weed floras and the survival of partridge chicks has, for example, been well established by the excellent work of the Game Conservancy. The role of low populations of weeds in encouraging beneficial predators of crop pests is already receiving greater attention, spurred on by some outstanding successes overseas.

To destroy weeds totally in a field by herbicides, the traditional and wholly understandable aim of most farmers, may on many grounds not always prove to be the best course. Nor may this always be feasible in the future because of economic, social or political pressures. To deviate from such a clear-cut objective is, however, full of pitfalls and farmers who are forced to or wish to do so need to be much better informed through the results of research if they are not to place the investment in their crops at risk. This is where the work of WRO has such a vital role to play.

The detailed understanding of weed behaviour, of weed problems, of their relation to crop production and to land use and of their interaction with chemical or cultural control measures has been a major objective of our research over many years. The programme has also generated much new information, unavailable to manufacturers, of the factors which influence the performance of herbicides. Such work, extended in collaboration with ADAS, other research institutes and industry, provides the fundamental knowledge and the practical experience essential if farmers and growers are to respond appropriately and with confidence to changing circumstances. If for economic or environmental reasons herbicide inputs have to be reduced and weed management as distinct from weed destruction has to be practised the agrochemical industry on its own cannot be expected to provide all the answers for the new weed problems which inevitably will occur.

Moreover, the capacity of herbicide manufacturers to continue, let alone expand, all the roles in British agriculture which they have so successfully played in the past has to be questioned. Increasing costs, competition for market sectors and ever more stringent regulatory requirements are forcing the industry to limit new product development to major world markets. National problems albeit of great local importance may have to rate low in their list of priorities. Where this is so public sector research and development will become even more important in finding solutions to new problems and in helping agrochemical manufacturers and distributors to formulate recommendations and, in the case of so-called minor uses, obtain registration. By present-day standards all crops grown in the UK, except cereals, are classified by most companies as minor in this context. Impending pesticide legislation in the UK will inevitably focus attention on this requirement in the near future.

Weed research and the countryside

It is slowly becoming accepted that agriculture is no longer just about growing crops, also that the role the weed scientist can usefully play is not restricted to weed control. In Britain, increasing costs of crop and animal production, reduced returns, and now milk quotas, are forcing many farmers, particularly those in marginal areas, to look elsewhere for income. At the same time the public appetite for country parks, conservation areas, rural pursuits and recreational activities is rapidly increasing. New methods for managing vegetation on land that is not used for crop production to make it suitable and attractive for the public are eagerly sought where grazing is not feasible and frequent mowing is uneconomic or impracticable. In recent years, the expertise of WRO in the manipulation of plant communities and use of selective herbicides and growth retardants has, with the help of the Countryside Commission, been harnessed to investigate alternative management techniques for use in rural areas. This ecologically based research has an important part to play in the future in helping farmers and landowners to supplement their income and in managing the countryside for the benefit of both the public and wild life. Difficulties in pursuing such work, inherent in the existing division of responsibilities between government departments and research councils, have been highlighted in recent evidence given to the House of Lords Select Committee on Science and Technology. If they can be overcome this component of public sector weed research will become of increasing importance.

The Director receiving the Congress Medal from Professor L Broadbent, President of the 10th International Congress of Plant Protection, in November 1983 in recognition of his 'outstanding contribution to crop protection on a global basis'.

Concluding remarks

The AFRC and WRO can be proud of the achievements that the institute has made to the benefit of British and world agriculture and to the status of weed science. The programme, expertise and facilities that we have developed at Begbroke during the past quarter century will be increasingly needed not just for Britain but to underpin efforts to help developing countries to grow more food. The institute's unique international role was recognised publicly by FAO when it established in 1983 a statutory Panel to help the promotion of improved weed management in the third world.

I am anxious that adequate recognition is given to the tremendous contribution made by WRO colleagues, past and present, to the development and achievements of the institute. Their friendly, enthusiastic and professional spirit has been the subject of comment by visitors to Begbroke from all over the world. I am privileged to have had the support of an outstanding team and wish to record my warmest thanks and appreciation.

Looking back on more than 35 years spent on weeds, I am deeply conscious of the potency of the technology man has created to influence and, if wanted, to kill plant growth. As with so many great achievements success needs to be moderated by humility and caution. With very few exceptions, the herbicides and plant growth regulators developed over this period have been used wisely and with great benefit. I am glad that WRO has played its part not only in their development but also in helping to minimise misuse and the problems that inevitably occur when a revolutionary technology is quickly adopted. Such a 'watchdog' role is not classed as research and where economies, rationalization and re-organization are the order of the day it may easily become a casualty. I believe it is important that this should not be allowed to happen.

I should like to end with a salute to those plants which have plagued man's activities since the beginning of history and which he has chosen to call weeds. Not only have they survived the onslaughts of modern technology but they have allowed me to have had a fascinating career, enriched by friendships made during its pursuit in many parts of the world.

J. D. FRYER
Director

Weed control in winter oilseed rape—a WRO view

P J W LUTMAN

INTRODUCTION

In recent years oilseed rape has become an increasingly important crop in the UK. The area sown has increased rapidly from 90,000 ha in 1980 to over 250,000 ha in 1983, making it the largest non-cereal arable crop. The importance of the crop and the dearth of research into weeds and weed control indicated that there was need for research into this subject so that better guidance could be given to the large number of farmers now growing the crop. Two areas of particular importance were identified. Firstly, although a range of herbicides was available for the control of weeds in this crop, there was a lack of information on the competitive effect of weeds on its growth and yield. It had often been stated that early weed control was essential to achieve maximum yield, but there was little research to support this assertion. It was necessary that this research should also investigate the interactions between times of drilling and weed control because these appeared to have an important influence on crop growth and yield. Secondly, there was reason to believe that some of the herbicides used in rape were having an adverse effect on its growth. Dalapon, for example, had been found sometimes to discolour and scorch the rape just after application (Proctor & Finch, 1976), but what was not clear was how this affected final yields. Hence both weed competition and crop tolerance have been studied over the last three seasons at WRO.

WEED PROBLEMS IN OILSEED RAPE

Grass Weeds. The most important weeds to affect oilseed rape are volunteer cereals. Rape is normally sown, often with minimal cultivation, immediately after the harvest of the previous crop. Consequently the grain shed at harvest emerges in the rape rather than in the stubble. High densities, particularly in the combine swaths, can have a severe effect on the establishment of the crop. Other autumn emerging grass weeds, e.g. black-grass (*Alopecurus myosuroides*), wild-oats (*Avena fatua*) and annual meadow-grass (*Poa annua*), can also cause problems, as they do in autumn sown cereal crops. Similarly, perennial grasses such as couch-grass (*Elymus repens*) also occur.

Broad-leaved weeds. The broad-leaved weed spectrum of oilseed rape mirrors that of winter sown cereals, chickweed (*Stellaria media*), speedwells (*Veronica* spp.) and field pansy (*Viola arvensis*) being common. However as rape is normally sown late in August or early in September, some late summer germinating species such as red dead-nettle (*Lamium purpureum*), dove's-foot crane's-bill (*Geranium molle*) and parsley-piert (*Aphanes arvensis*) are more common than in later drilled cereals. Weeds belonging to the Cruciferae, shepherd's-purse (*Capsella bursa-pastoris*), charlock (*Sinapis arvensis*) and wild radish (*Raphanus raphanistrum*) are a particular problem, as few rape herbicides will selectively control them. Species that are able to grow rapidly upwards with the crop in the spring or have a scrambling habit such as mayweeds (*Chamomilla* spp.) and cleavers (*Galium aparine*) are also a serious problem. In addition seeds or seed heads of both species can contaminate the harvested rape seed.

All these grass and broad-leaved weeds may affect the development of the crop by competing for water, light and nutrients. The WRO experiments were set up to investigate this aspect in more detail.

EFFECTS OF WEED COMPETITION ON OILSEED RAPE

Broad-leaved weeds. A number of experiments have been carried out to investigate the effects of broad-leaved weed competition on the growth and yield of rape. In these, volunteer cereals were absent or were only present at very low densities (< 20 plants m^{-2}). Summarised data from five typical trials are give in Table 1, more detailed results are given in Lutman (1984).

Table 1. The effects of broad-leaved weeds on the growth and yield of oilseed rape

		March/April assessment			July assessment		
		Rape dry weight g m^{-2}		Weed dry weight g m^{-2}	Rape yields t ha^{-1}		
Experiment	Harvest year	Weeds controlled	No weed control	No weed control	Weeds controlled	No weed control	ESE ±
1	1980	5.0*	5.5*	80	4.16	4.13	0.27
2	1981	316	337	1	1.77	1.89	0.18
3	1981	433	440	58	2.56	2.13	0.21
4	1982	189	207	25	2.21	2.09	0.28
5	1983	213	200	133	3.41	2.95	0.24

* Fresh weights kg m^{-2}

Although weed numbers in the autumn exceeded 100 plants m^{-2} in many trials, spring dry weights were less than 100 g m^{-2} and no significant effects on seed yields were recorded. In the trials harvested in 1983 there was a very vigorous weed population in the spring which continued to grow well into the summer in the prevailing wet conditions. As a consequence, although weights of rape in the spring were clearly not reduced, rape seed yields appeared to be somewhat lower where weeds were not controlled.

Volunteer cereals and other grass weeds. Data from a number of trials indicate that grass weeds, especially volunteer cereals, are more competitive than broad-leaved weeds. In the six trials included in Table 2 yield reductions were recorded in three. These tended to be associated with the highest weed populations and with the highest weed biomass m^{-2} in the spring. Yields from plots infested with volunteer barley were generally not

Table 2. The effect of volunteer barley on the yield of oilseed rape

		Volunteer barley		Seed yields t ha^{-1}			
Experiment	Date drilled	Autumn population plants (m^{-2})	Spring dry weight (g m^{-2})	No barley	Volunteer barley	Volunteer barley (sprayed)*	ESE ±
1	29.8.80	88	18	1.79	1.90	1.70	0.18
2	1.9.80	78	62	1.81	1.90	1.69	0.25
3	4.9.81	268	196	2.09	1.59	2.50	0.28
4	28.8.81	335	—	3.36	3.33	3.49	0.29
5	7.9.82	184	—	2.63	2.06	2.75	0.20
6	7.9.82	149	175**	2.95	2.68	3.41	0.24

* herbicides applied in November
** there was also a substantial population of other weeds (133 g m^{-2}) on the unsprayed 'no barley' plots

reduced if the barley was controlled with herbicides in the autumn (November). There was also an indication that the early September drillings were more affected by the weeds than those drilled late in August.

This work suggested that time of drilling and establishment might have a critical effect on weed competition. This has been confirmed in several experiments which showed that rape established in mid-September was more sensitive to barley competition than that established late in August. An example from a 1982/3 experiment is given in Fig. 1. Yields of plots drilled on 25 August or 7 September were similar in the absence of weeds and were only slightly reduced by the presence of weeds. However, yields

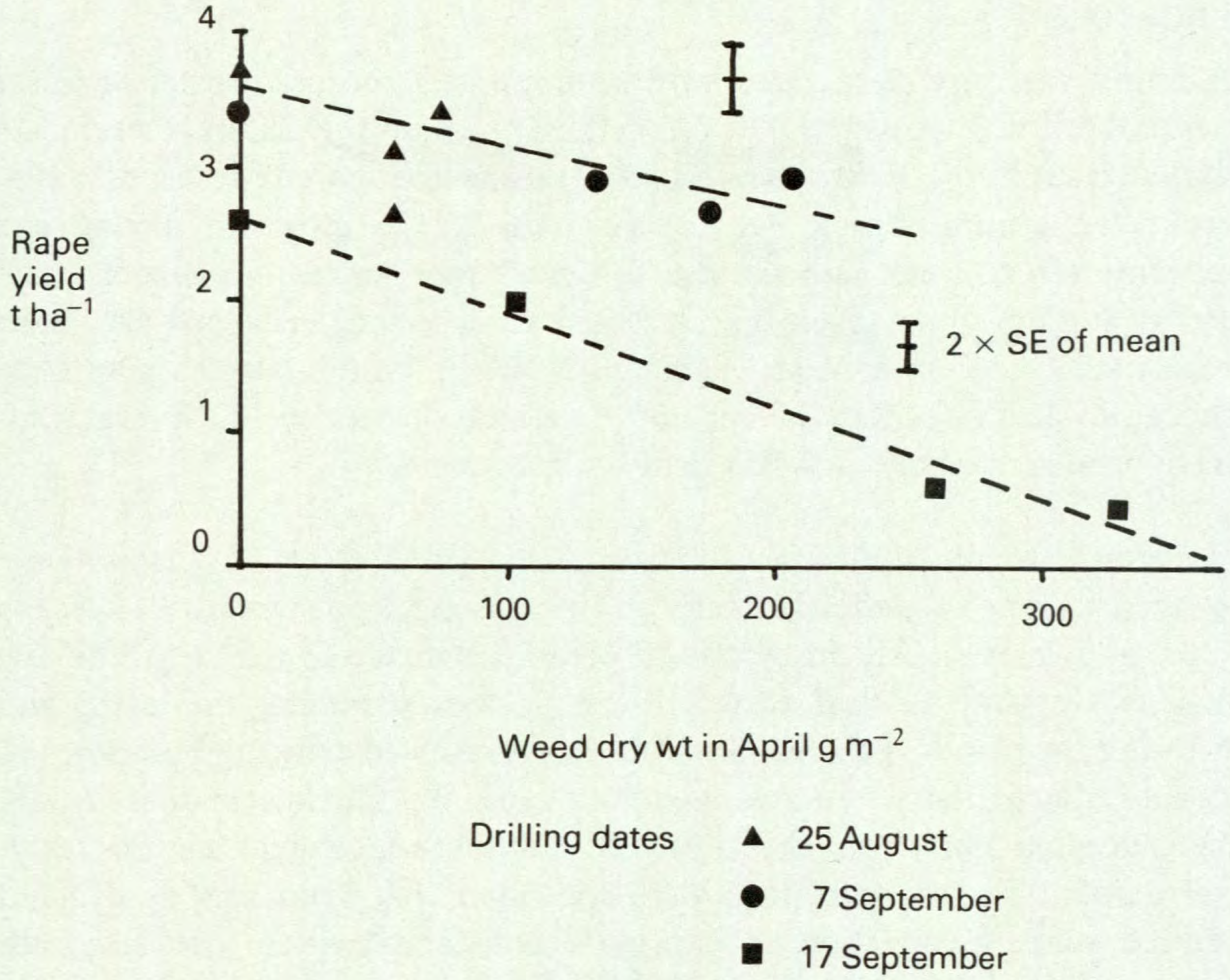

Fig. 1. The effect of weeds (volunteer barley) and drilling date on the yield of oilseed rape (1983)

from the plots drilled on 17 September were severely reduced. These results agree with those summarised by Orson (1984) which indicated that early drilled, well established rape was not very sensitive to weed competition, whereas later drilled, slower growing crops appeared to be more at risk.

In much of the WRO work on barley competition, herbicides were applied on more than one occasion but there was little evidence in those experiments where the weeds affected the crop, that early removal was essential for maximum yield. In most experiments yields were not impaired provided that the weeds were removed by the end of the winter. Indeed there were clear indications in one trial with a high density of grass weeds that herbicide performance was of more importance than timing. Early applications resulting in poor weed control gave lower rape yields than later, more effective ones. Again the ADAS results reported by Orson (1984) and also by Ward (1982) support the conclusion that early weed control is not essential in many circumstances to maintain optimum yields.

CROP TOLERANCE

A number of rape herbicides have been noticed to cause greater or lesser degrees of foliar damage to the crop after application. Dalapon, a herbicide widely used in the 1970's, was found to dewax and scorch the leaves and to stunt the plants (Proctor & Finch, 1976). TCA although having less extreme effects, was noticed also to dewax rape leaves (Rawlinson *et al*, 1978) and in some instances increased disease incidence has also been recorded (Gladders & Musa, 1982). However it has not been easy to relate these physical effects in the autumn, to effects on seed yield. Several trials have been carried out at WRO to investigate this.

Dalapon. In six similar trials in two seasons three doses of dalapon were applied to rape crops, either early in the season (2–5 leaves) or 2–3 weeks later (4–7 leaves). All doses caused obvious damage to the crop, the low doses only affecting leaf waxes, the high ones scorching the leaves and stunting the plants. The yields were severely reduced at the highest dose (10 kg ha^{-1}) particularly when applied 'late' (Fig. 2). The lowest does (2.5 kg ha^{-1}) applied 'early' was the safest and did not reduce yields significantly. Subsequent experiments in 1982/3 indicated that even this dose could reduce yields. Hence there appears to be considerable risk of yield loss from the use of this herbicide, although the 2.5 kg ha^{-1} dose could be used safely in some years.

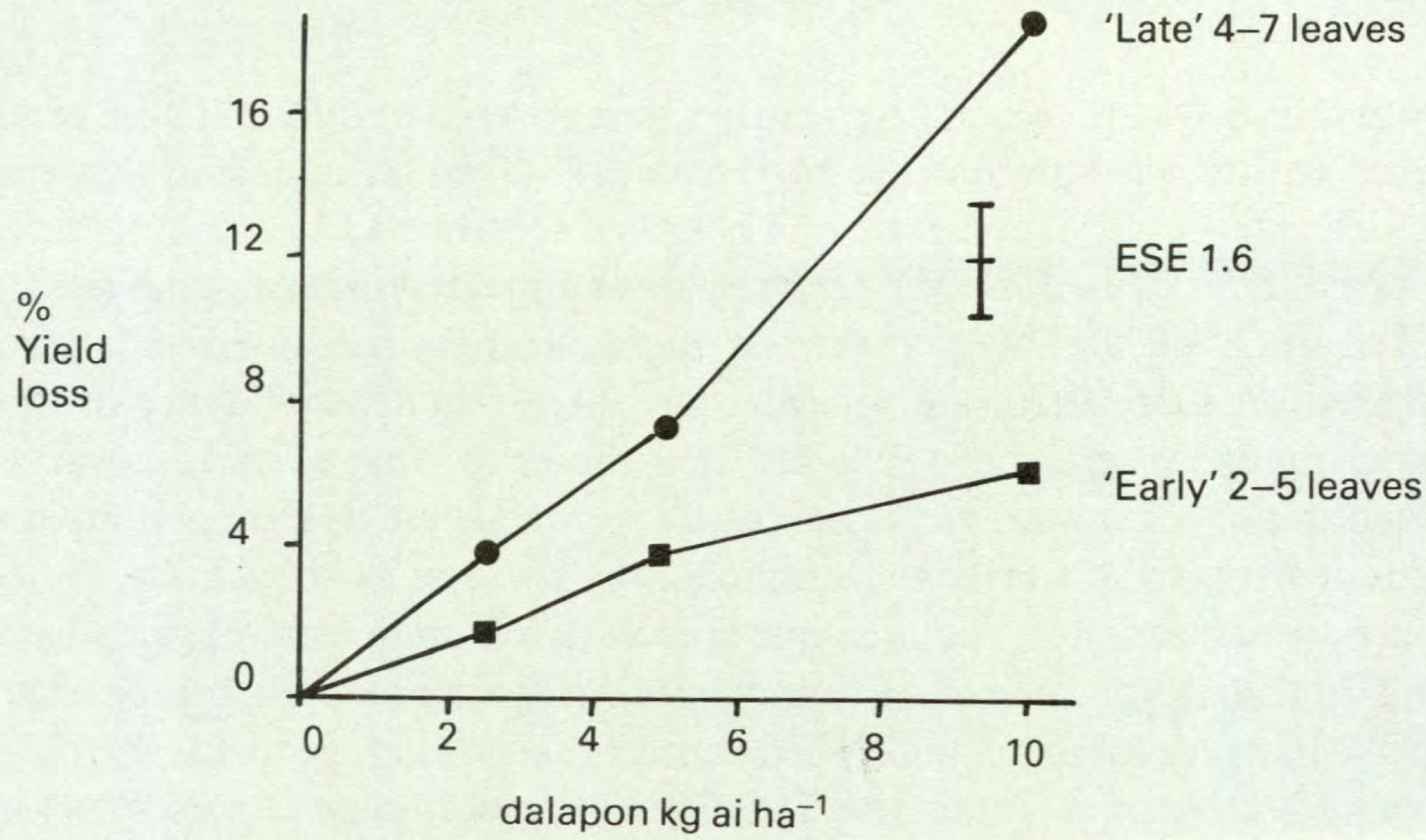

Fig. 2. Effect of dalapon on the yield of oilseed rape (mean of 6 trials 1980/81)

TCA. The physical effects on the crop, of even very high doses of this herbicide, were much less marked than those of dalapon. In most trials the only visible effect was a slight change in the colour of the leaf and in its ability to retain moisture, indicating effects on the leaf waxes. This effect was still noticeable in some trials 5-6 months after application. Between 1979 and 1982 three doses were studied and in 1982/3 two doses. All were applied pre-emergence.

Yields were not as severely affected as those following the use of dalapon and in many of the ten trials no statistically significant yield reductions were recorded. However in eight of the ten, plots treated with TCA, even at its lowest dose, yielded less than equivalent plots not treated with this herbicide. By combined analysis of these data it can be shown that, on average, a 6% yield reduction resulted from the application of only 10 kg ha^{-1} (Fig. 3). Higher yield losses followed the higher doses.

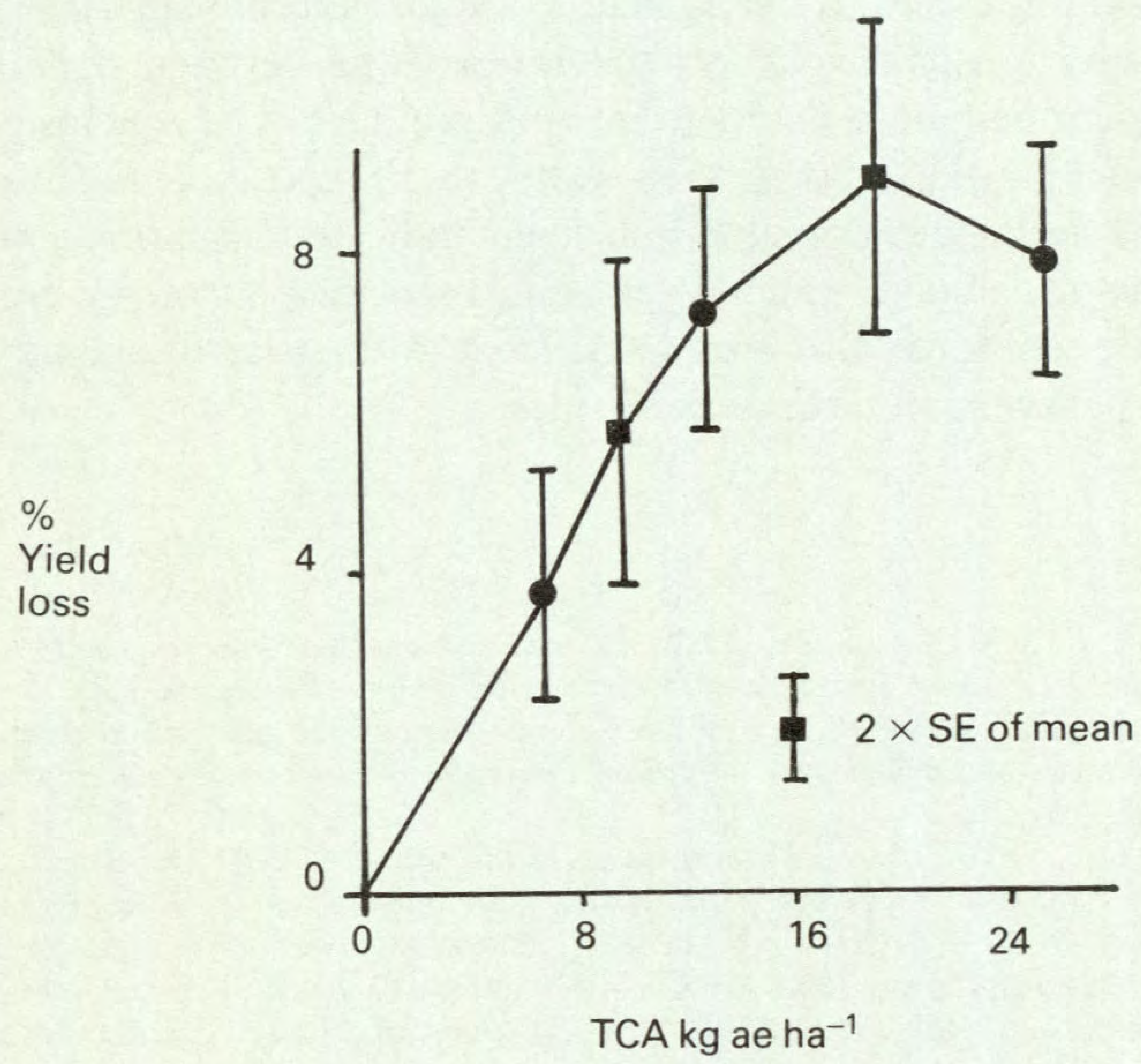

Fig. 3. Effect of TCA on the yield of oilseed rape
(● 7 trials 1979–81, ■ 3 trials 1982)

Other herbicides. The effects of several other herbicides on oilseed rape have been studied in more recent experiments. Preliminary results have indicated that fluazifop-butyl does not appreciably affect the crop and yields have not been reduced. Metazachlor, at high doses, has reduced the rape population though this has not been reflected in significantly lower yields. Recommended rates of propyzamide, benazolin with clopyralid and tebutam were all used in the TCA and dalapon experiments outlined above but no interactions were evident, nor did they appear to affect the growth of the rape. Slight visual effects on the crop have been noted from the recommended rates of the mixture of carbetamide and dimefuron but no yield reductions ensued.

CONCLUSION

The results from the WRO oilseed rape programme have indicated that well established rape is not very sensitive to weed competition. In consequence, pre-emergence or early post-emergence weed control is not essential to ensure maximum yield. Later drilled, less vigorous crops appear to be more sensitive and further work on the interactions between drilling date, establishment and weed competition is in progress. The conclusions from the weed competition studies when related to the increase in the numbers of grass weed herbicides available to farmers indicate that farmers no longer have to rely on dalapon, which is damaging to the crop, or on pre-emergence TCA whose safety has also been questioned. More trials are being done on the safety of several other rape herbicides.

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Straw disposal and its effects on weeds

S R MOSS

While the controversy over straw burning continues, the agronomic implications have to some extent been overshadowed by environmental and sociological issues. It has been estimated that 58% of the wheat straw, 19% of winter barley straw and 18% of spring barley straw was burnt in England and Wales in 1983. With an agronomic practice as widespread as this even small effects of burning on weeds could have severe consequences on future populations.

WRO has for some time examined weed response to disposing of straw in this way. One beneficial effect of straw burning is the destruction of weed seeds. The proportion killed depends on the temperature achieved and the position of the seeds. Seeds with a shallow covering of soil usually survive while many of those on the soil surface are destroyed.

Very high temperatures can be achieved in the straw burning process. In an experiment in which three different quantities of straw were spread and burnt over wheat stubble on which black-grass (*Alopecurus myosuroides*) seeds had previously been spread, the temperatures recorded (Table 1) and

Table 1. Temperatures at the soil surface beneath burning straw

	Temperatures at soil surface	
Amount of spread straw tonnes/ha^{-1}	Peak temp °C	Duration (secs) of temp above 200°C
2.1	143	0
4.2	225	10
6.3	270	35

the reduction in plant populations (Fig. 1) were directly related to the quantity of straw burnt (Moss, 1980). On farm sites with natural infestations, burning killed between 40 and 80% of black-grass and 40 and 97% of barren brome (*Bromus sterilis*) seeds (Froud-Williams, 1983).

In similar experiments with wild-oats (*Avena fatua*), in which combine swaths were burnt, seed kill averaged 32% (Wilson & Cussans, 1975). It was higher than this directly beneath the straw swaths but lower between them. The average peak temperature reached was around 500°C and temperatures exceeded 200°C for between 1 and 2 minutes at the soil surface beneath the swaths.

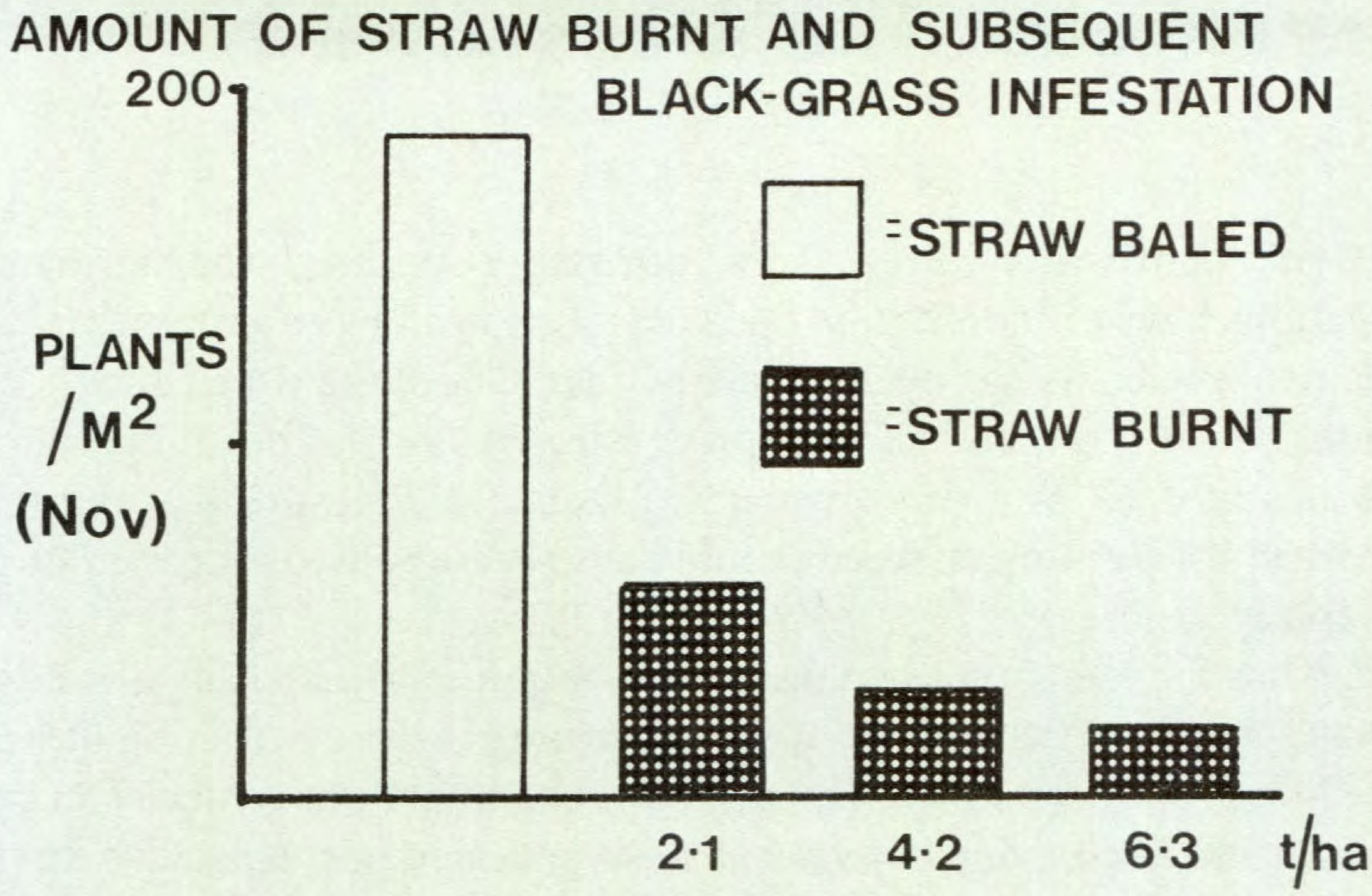

Fig. 1. Effect of the amount of straw burnt on the numbers of *A. myosuroides* plants in direct-drilled winter wheat.

In practice, the weed control achieved by straw burning will depend on the intensity of the burn. This is likely to depend on the amount and moisture content of the straw, its distribution in the field—whether spread or in swaths, and on the wind strength.

Straw burning also reduces the dormancy of surviving wild-oat seeds and creates ideal conditions for surviving black-grass and barren brome seeds to germinate (Froud-Williams, 1983; Moss, 1980; Wilson & Cussans, 1975).

Thus one of the most obvious visible consequences of straw burning is a much earlier flush of autumn germinating seedlings (Moss, 1981). If seedlings emerge before a crop is sown or before it emerges, a contact herbicide will kill them. However, the trend to earlier drilling now puts crops at risk from these early autumn germinating weeds which can be much more competitive, and difficult to kill, than those germinating later in the autumn or in spring.

Minimum tillage encourages many grass weeds because seeds remain close to the soil surface from where plants can readily emerge. Populations of black-grass, for example, can increase rapidly, by up to 10 × a year. Straw burning can be effective, as part of an integrated control system, in keeping the weeds under control and in reducing the influences of tillage on their population (Table 2).

Table 2. Changes in density of black-grass seedlings m^{-2} due to the interaction of methods of cultivation and straw disposal (Moss, 1981)

Cultivation method	Straw disposal	1975-76	1976-77	1977-78	1978-79
Ploughed	Baled	8	3	7	49
	Burnt	—	5	12	27
Tine cultivated	Baled	88	63	546	1654
	Burnt	—	15	56	97
Direct drilled	Baled	91	102	815	1275
	Burnt	—	9	48	48

All plots seeded to simulate a population of 100 seedlings m^{-2} in 1974-5

Simple mathematical models have been developed to calculate the percentage of weed kill required from a herbicide to maintain a weed population at a static level. (Cussans & Moss, 1982; Wilson, 1983). Table 3 shows that straw burning by reducing weed populations, reduces the demands made on herbicide treatments. One problem that can occur in

Table 3. Population models for black-grass and wild-oats showing the percentage kill required of a herbicide to maintain a static population in continuous winter cereals.

	Black-grass		Wild-oat	
	Straw burnt	Not burnt	Straw burnt	Not burnt
Ploughed	50	65	70	80
Tine	—	—	75	85
Direct Drill	88	92	—	—

minimum tillage/straw burning systems is the production of an adsorptive surface soil layer. This can inactivate soil-acting herbicides and result in inadequate weed control (Addala, Hance & Drennan, 1984; Cussans *et al*, 1982; Moss, 1979; Nyffeler & Blair, 1978), because without soil inversion, burnt straw residues accumulate at the soil surface, thus increasing the capacity of the soil to adsorb herbicides (Embling, Cotterill & Hance, 1983). Although this problem occurs on only a relatively small proportion of fields, it can be extremely serious because of the importance of the soil-acting herbicides for weed control, particularly black-grass.

In this context WRO is working on simple laboratory techniques for the rapid determination of the adsorptive capacity of soil.

One method of reducing the risk of herbicide inactivation is to plough once every four or five years so as to bury the adsorptive surface layer (Cussans & Moss, 1982). Rotational ploughing also directly reduces weed populations by burying large populations of weed seeds.

Our studies show there are a number of factors involved in determining the effects of straw burning on weed populations. Indeed, the straw itself can, in some cases, substantially reduce herbicide activity (Moss, 1979).

Any restriction or ban on straw burning is likely to have substantial implications on weed populations. The influence of straw disposal method on weeds is clearly of sufficient significance to warrant further research.

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Weeds of cereals in Central Southern England

R J CHANCELLOR and R J FROUD-WILLIAMS

Agriculture is characterised by gradual and continuous change and this is reflected in arable weed populations. Major changes of recent years have been the shift from spring-sown to autumn-sown cereals and a reduction in cultivations. As a result weeds which germinate in the autumn have now become dominant, especially grasses which can germinate at or near the soil surface. In addition, the increasing specialisation in agriculture has resulted in the selection of particular species. Consequently, more information is needed on their occurrence and distribution. In the past, there have been sporadic surveys of a few individual weeds but no systematic or regular surveying. Occasional reports (Anon. 1982) have been made of newly introduced species, such as awned canary-grass (*Phalaris paradoxa*), and reports of changed weed status of plants formerly of no agronomic importance, such as barren brome (*Bromus sterilis*) (Froud-Williams *et al.*, 1980). The uncertain status of barren brome which had been widely reported in the farming press as a serious problem in cereals led to the decision at WRO to make a survey of its occurrence.

PRELIMINARY ASSESSMENT OF BARREN BROME

Initially, farmers were asked at four agricultural shows in 1981 to indicate on a map of England where barren brome occurred as a problem. It appeared that the main areas were Lincolnshire (10% of these records), Cambridgeshire (8%), Essex (7%) and Gloucestershire (6.5%) (Froud-Williams, 1982).

THE GRASS WEED SURVEY, 1981

To follow up these indications a field by field survey, was made in the same year using an area bounded by Lincolnshire, Essex, Gloucestershire and Hampshire (Froud-Williams & Chancellor, 1982). For convenience, nine areas were selected to represent a range of cropping systems and soil types. In each area, 250 winter cereal fields were assessed and where possible 100 spring barley fields. Although the main purpose of the survey was to record the occurrence of barren brome, all other grasses were also recorded at the same time. A circuitous route was followed along minor roads in each area and all cereal fields adjacent to the road were assessed irrespective of size.

Each field was surveyed by searching field margins and headlands in detail and the whole field scanned from suitable vantage points to assess the distribution and density of the flowering heads of the grasses present. Distribution and density were recorded in six categories of occurrence which have been condensed into two levels of intensity as shown in Table 1. The only common grass which could not be surveyed by this method was annual meadow-grass (*Poa annua*), which is obscured by the crop.

Table 1. The occurrence in 1981 of the nine most frequent grasses and their general levels of infestation in cereals.

	Winter wheat			Winter barley			Spring barley		
	% fields infested	% light	% heavy	% fields infested	% light	% heavy	% fields infested	% light	% heavy
Wild-oats	32	76	24	31	71	29	52	62	38
Rough meadow-grass	29	52	48	6	57	43	0	0	0
Couch-grass	26	75	25	20	81	19	53	67	33
Black-grass	23	50	50	9	71	29	11	72	28
Barren brome	12	68	32	4	64	36	0	0	0
Italian ryegrass	10	74	26	6	76	24	5	67	33
Bents	9	75	25	5	75	25	4	82	18
Timothy	6	78	22	2	77	23	4	94	6
Onion couch	4	72	28	1	90	10	2	56	44

This survey by WRO was made just before harvest and represents those species which had survived herbicide applications or had not been treated. The occurrence of the nine most frequent grasses and their general levels of density are given in Table 1.

As barren brome was the main interest of this survey and because this grass is a frequent hedgerow species particular attention was paid to its distribution within each field. In addition, records of headland management prior to harvest designed to prevent the ingress of this species were made.

THE OCCURRENCE OF BARREN BROME

Only 9% of the winter cereal fields surveyed contained barren brome and none of the spring barley fields. This species was widespread, but most frequent in Bedfordshire and Cambridgeshire, which supports the data obtained from farmers. Its absence from spring crops is due to its lack of seed dormancy which ensures autumn germination. In addition to the infested fields of winter cereals a further 7% of these fields had barren brome growing in the hedge or field margin. So 16% of winter cereals were infested or liable to infestation by this species. Of the infested fields, 60% had barren brome only in the headlands indicating its spread from the field margins. Seven percent of winter cereal fields had headlands sprayed or cultivated against weed invasion, indicating an increasing awareness of the problem.

THE OCCURRENCE OF OTHER GRASS WEEDS

There were four very common grass weeds, wild-oats (*Avena fatua* and *A. sterilis* ssp. *ludoviciana*), couch-grass (*Elymus repens*), rough meadow-grass (*P. trivialis*) and black-grass (*Alopecurus myosuroides*), which occurred in more than 20% of winter cereals. Other grasses were very much less common. Barren brome was the fifth most frequent grass.

An important discovery resulting from this survey is that rough meadow-grass is one of the most frequent weeds, occurring in no less than 22% of winter cereals. It is surprising that this grass has received so little publicity although it is a much more serious problem than barren brome. It could be that the wet spring of 1981 hindered herbicide applications and encouraged establishment of this grass. Rough meadow-grass was more frequent in the west, notably in Warwickshire and north Gloucestershire.

Infestations of rough meadow-grass and black-grass were generally more severe than those of wild-oats or couch-grass although these latter two were more widespread (Table 1). This may reflect the greater awareness by farmers of these two species, which has resulted in increased control measures against them. In complete contrast to rough meadow-grass, couch-grass has a markedly eastern distribution. There was a surprising number of infestations of Italian ryegrass and timothy. These occurred mainly in the west, where short-term grass leys are a feature of the cropping systems.

THE WEED SURVEY 1982

A repeat survey was made in the same areas during summer 1982, in order to observe how far climatic and agricultural variables influence grass weed occurrence (Chancellor & Froud-Williams, 1984). As there is a paucity of information on the occurrence of dicotyledonous weeds, these were also included in this WRO survey.

Assessments in this second survey had to be made in greater detail because most of the dicotyledonous weeds are not very tall and so difficult to see without walking through the crop. In view of this more detailed method only 1021 fields were assessed as compared with the 2626 in the first survey, but 24 grasses were recorded as opposed to 19 in 1981. Annual meadow-grass, which had necessarily been omitted in the first survey, was included in this one, where it occurred in 14% of fields.

The hierarchy and distribution of the nine most frequent grasses changed little between the two years, but, the frequency of individual species varied. Wild-oat species were the most frequently recorded grass weeds in winter cereals in both years. There was a slight increase in their occurrence in winter wheat from 32% in 1981 to 39% in 1982.

Winter wild-oat (*A. sterilis* ssp. *ludoviciana*) was recorded separately from spring wild-oat (*A. fatua*) in 1982 and occurred as 17% of the wild-oat infestations. In view of the recent increase of winter cereals it is surprising that winter wild-oat, an autumn germinator, is not more frequent, for even in 1951 it comprised 13% of occurrences in a limited survey (Thurston, 1954). Couch-grass, which was the second most frequent grass weed in 1981, was recorded more often (42%) in winter wheat in 1982, but in winter barley it showed a slight reduction (to 14%). Of the three next most frequent grasses in winter wheat, both black-grass and barren brome increased, while rough meadow-grass (*Poa trivialis*) remained unchanged. These apparent increases may have been due in part to the more detailed assessment techniques. Conversely, the exceptionally wet spring of 1982 may have reduced the opportunities for spraying these weeds.

Although spring barley comprised only 16% of fields assessed in 1981 and 12% in 1982, they nonetheless showed an interesting difference in weed floras from those of winter cereals. Only two grasses were of any importance, wild-oats and couch-grass; in winter cereals there were four.

DICOTYLEDONOUS WEEDS

A total of 62 species of dicotyledonous weeds was recorded. The percentage occurrence and level of infestation of each of the twenty most frequent are given in Table 2. The most striking feature of these results is that the percentage occurrence of even the most frequent did not exceed 12% in contrast to the grasses of which four exceeded 20%.

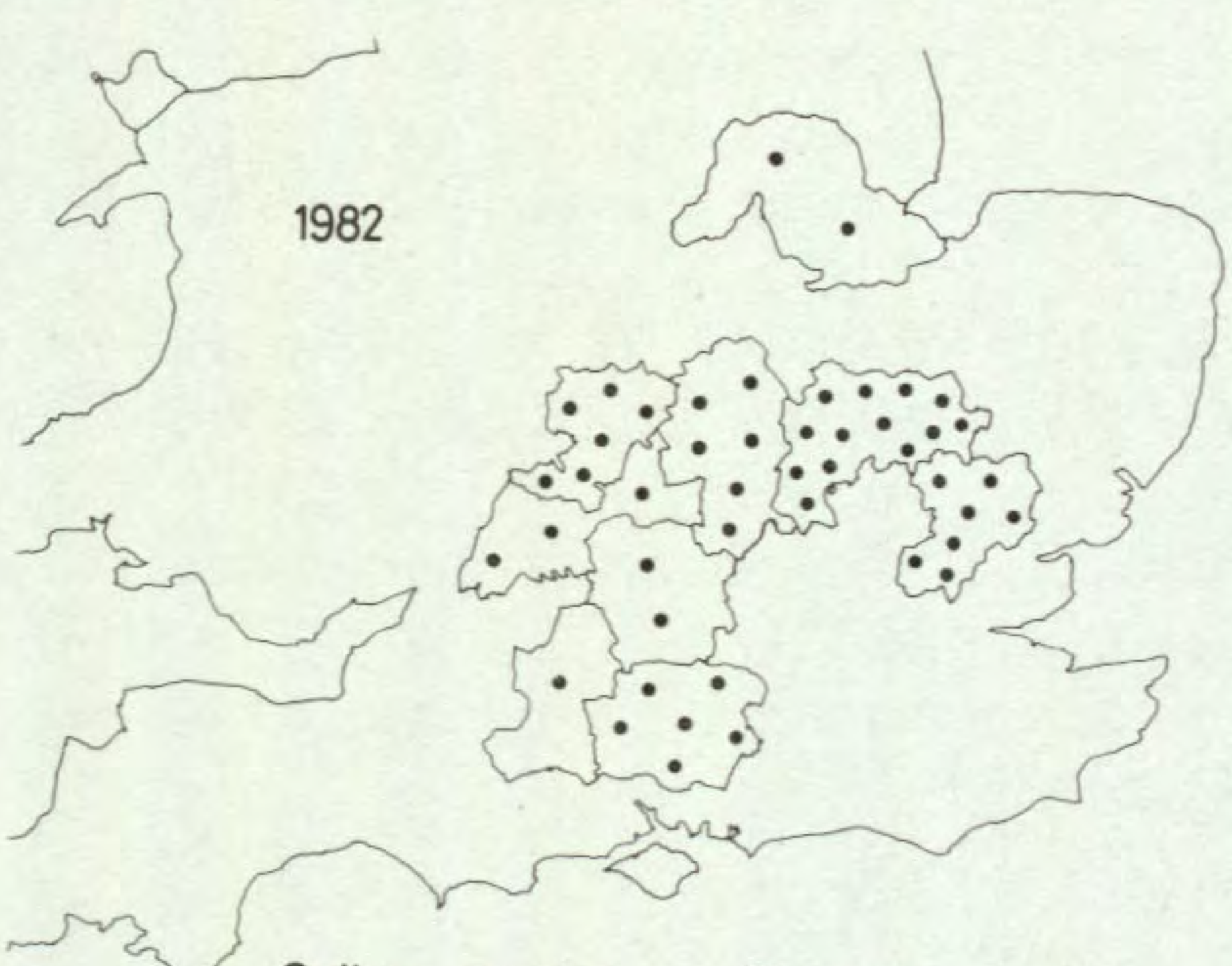
Of the ten most frequent dicotyledonous weeds, it is surprising that three are perennial species, for perennials are normally discouraged by cultivation. Another interesting feature is that of the twenty species in

Table 2. The percentage occurrence of the twenty most frequent dicotyledonous weeds and their relative levels of infestation in winter cereals in 1982.

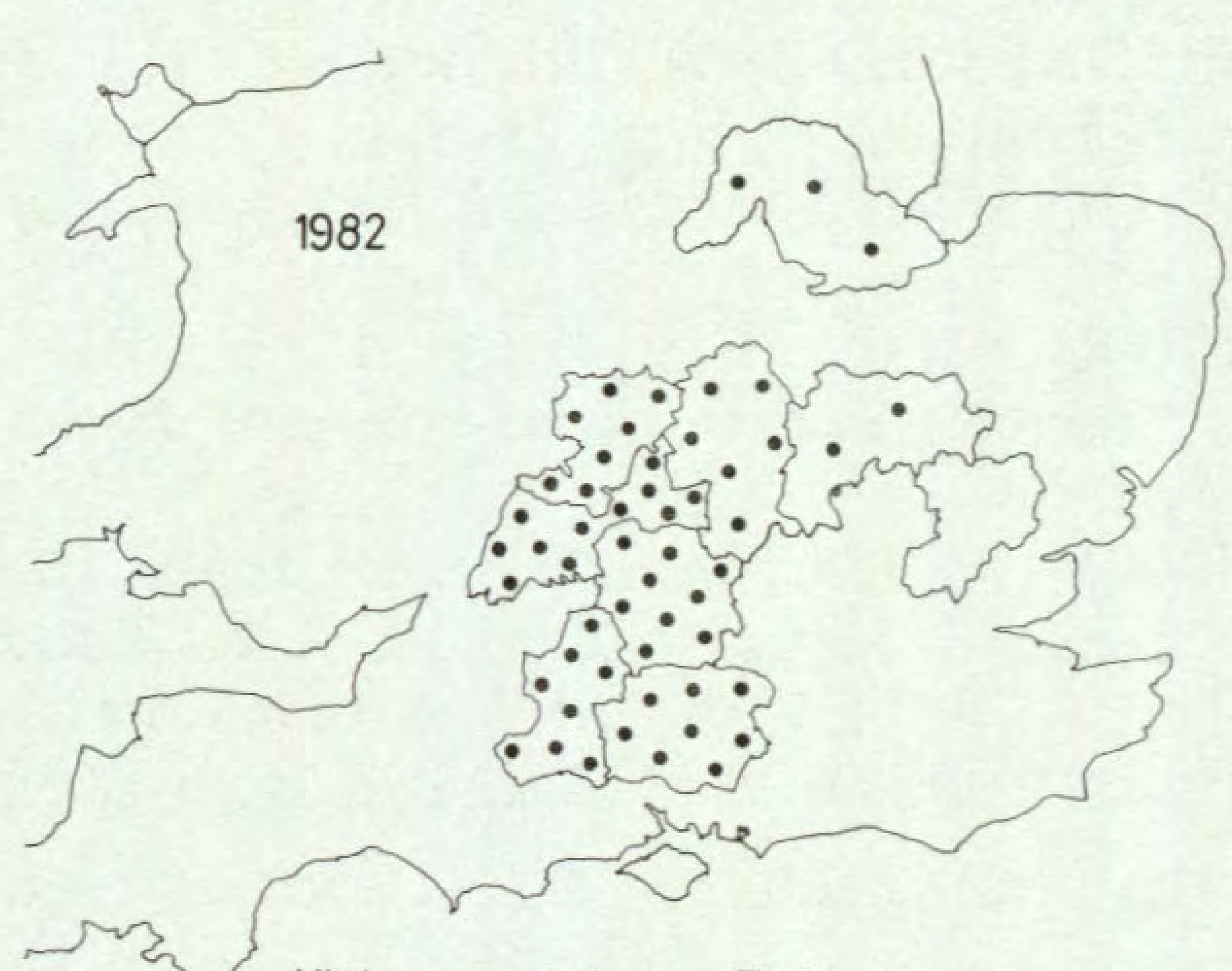
Species	% fields infested	% of infestations light	% of infestations heavy
Field pansy	11	74	26
Cleavers	10	73	27
Chickweed	6	86	14
Field forget-me-not	6	80	20
Field bindweed	6	73	27
Knotgrass	6	77	23
Black-bindweed	4	85	15
Red dead-nettle	4	88	12
Broad-leaved dock	4	97	3
Creeping thistle	3	86	14
Common poppy	3	78	22
Common field-speedwell	3	96	4
Hogweed	2	100	0
Scentless mayweed	2	71	29
Fools parsley	2	80	20
Redshank	2	82	18
Pale persicaria	2	81	19
Wall speedwell	2	88	12
Fat-hen	1	91	9
Henbit dead-nettle	1	100	0

Table 2, no less than five germinate only in spring despite the current preponderance of autumn-sown cereals.

Most species were fairly uniform in distribution, but several showed geographical gradients. Distribution of field bindweed (*Convolvulus arvensis*) and cleavers (*Galium aparine*) was mainly in the east. Creeping thistle (*Cirsium arvense*) was similar but much less frequent. In contrast, field pansy (*Viola arvensis*) and to a lesser extent chickweed (*Stellaria media*) and knotgrass (*Polygonum aviculare*) were more western in distribution.



Galium aparine   Cleavers



Viola arvensis   Field pansy

Earlier surveys of dicotyledonous weeds in the 1960's show considerable differences to the present survey in the composition of weed floras (Dadd, 1962; Elliott, Cox & Simonds, 1968; Fisons, 1968; Evans, 1969). They listed chickweed, charlock (*Sinapis arvensis*), knotgrass, redshank (*Polygonum persicaria*), black-bindweed (*Bilderdykia convolvulus*), etc. as the most frequent species, which contrasts with field pansy, cleavers, field forget-me-not (*Myosotis arvensis*) and field bindweed in this survey. However, chickweed remains very frequent. The earlier surveys were made largely in spring barley crops and the difference in season of planting will undoubtedly have affected the occurrence of individual species.

The results obtained in these two surveys are of great importance for, although they were concerned solely with those weeds which have survived weed control measures, where these had been applied, they are the weeds which will seed and consequently be the problems of tomorrow. These surveys are the most comprehensive of recent years and have focused attention on the species that need further research. It now remains to make surveys in other areas and to repeat them regularly to highlight where government and industrial research teams should direct their attention.

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Black-grass and wild-oat population trends on a commercial farm

B J WILSON

Black-grass (*Alopecurus myosuroides*) and wild-oats (*Avena fatua*) remain a threat to cereal growing. If the general profitability of cereal farming declines, then the presence of such weeds will become more significant. Although most infestations in this country remain at low levels not affecting yield (Elliott *et al.*, 1979), control measures have to be maintained because of the potentially rapid build-up if such weeds are left uncontrolled in modern cereal growing systems. Research into the population dynamics of black-grass and wild-oats (Moss, 1980; Wilson, 1981) has demonstrated the factors which influence the build up and decline of populations. Viable seeds have been shown to decline fairly rapidly in cultivated soils which suggests that the continued presence of these weeds on farms is due more to the inadequacy of control, allowing new seeds to add to existing reserves, than to the persistence of seeds in the soil. To find out if this is the cause it was decided to study weed levels on a whole farm over a long period of commercial control measures.

This long term study is being carried out jointly by the Weed Research Organisation and the Agricultural Development and Advisory Service to monitor wild-oats and black-grass annually, and to relate population changes to control measures. Neville's Farm, near Wantage, Oxon was selected in 1976. This farm was chosen as typical of many heavy land cereal farms with a history of bad infestations of grass weeds, and for the willingness of the farmer to co-operate in the study. It is a mixed arable and dairy farm of 173 ha on heavy clay, and prior to 1976 the original heavy infestations had been brought down to low populations, generally too low to affect yields. An annual control programme is needed to prevent populations increasing and so threatening yields in the long term.

The main block of land of 121 ha (13 fields) is farmed with a rotation based on three years of grass ley followed by five years of cereal crops. A smaller block of 21 ha (3 fields) remains in continuous cereals, and the rest is permanent grass. The straw in more than three quarters of the cereal fields is burnt, the remainder being baled to provide for the dairy herd. In autumn 1977 most cereal fields were ploughed; in the following three years more crops were established by reduced cultivations but in 1981 there was a return to ploughing and about one third of the fields were ploughed in 1982.

Most commercial herbicide applications have been for the control of grass weeds. The herbicides used, and their costs which have been standardised to typical retail prices for 1981 (Ministry of Agriculture, Fisheries and Food, 1981) to compare annual herbicide expenditure, are shown below:

		£/ha		£/ha
Isoproturon + ioxynil				
+ bromoxynil	—autumn	48	Trifluralin + linuron	25.8
	—spring	40	Pendimethalin	42.6
Isoproturon	—autumn	47.5	Methabenzthiazuron	40.9
	—spring	39.9	Difenzoquat	35.5
Chlortoluron	—autumn	46.9	Benzoylprop-ethyl	43.2
	—spring	36.8	Flamprop-isopropyl	39.5
Triallate granules -	normal dose	25.6	Flamprop-methyl	40.8
	high dose	38.4	Diclofop-methyl-low dose	17.8
			*Chlorsulfuron + methabenzthiazuron	30.2

* 1983 price

Herbicides for grass weed control were applied to most of the cereal crops grown between 1977 and 1983 (Table 1). Of the 80 crops grown, 4 received no herbicide for grass weed control, 26 received one herbicide and 50 crops received two separate herbicides. The greatest expenditure was in 1977/78 when eleven out of thirteen fields were sprayed twice with chlortoluron or isoproturon for black-grass followed by a wild-oat herbicide. Since then economies have been made by changing to less expensive sequences which are proving to be more cost effective for grass weed control.

Surviving weeds are assessed each summer. Black-grass heads and wild-oat panicles (after wild-oat roguing) are surveyed in each field by a team of three or four people walking tramlines and counting at intervals. From the

Table 1. The frequency of herbicide use, and the total cost of herbicides used (at 1981 prices)

	76/77	77/78	78/79	79/80	80/81	81/82	82/83
No. fields with							
no herbicide	2	0	0	0	2	0	0
one "	3	2	6	4	4	7	0
two "	7	11	4	6	5	5	12
Total cost herbicides — £	5502	7193	4442	5997	3882	5224	4609
Total arable area — ha	104.1	110.6	94.4	95.2	96.8	101.5	88.1
Cost/ha — £	52.9	65.0	47.1	63.0	40.1	51.5	52.3

six to seven survey points/ha maps are drawn to show the distribution and average density of each weed. Analysis of all surveys over the seven years of the study shows that wild-oats and black-grass were absent from about two-thirds of the survey points, and only 2-3% of points contained infestations likely to cause significant yield loss after spraying. However, if herbicides had not been used a further 10-20% of the area would have been at risk of yield loss, illustrating the dependence on herbicides to safeguard crop yields.

Table 2. Changes in populations of wild-oats and black-grass

	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83
Wild-oat panicles m^{-2}							
Continuous cereals (3 fields)	0.06	0	0	0.02	0.06	0.01	0.01
Ley/arable (13 fields)	0.62	0.17	0.47	0.33	0.26	0.03	0.02
Mean (whole farm)	0.47	0.13	0.33	0.23	0.21	0.03	0.02
Black-grass heads m^{-2}							
Continuous cereals (3 fields)	1.51	1.32	0.05	2.42	3.86	3.98	3.79
Ley/arable (13 fields)	5.83	6.92	5.75	4.40	3.72	2.40	3.75
Mean (whole farm)	4.75	5.63	4.04	3.81	3.76	2.80	3.76

Over the whole farm wild-oats have declined while black-grass populations have remained fairly stable (Table 2). Wild-oats have remained low in the continuous cereal fields, but there has been an increase in black-grass on this area. The ley/arable fields have seen a significant reduction in wild-oats in the last two years to low levels; average black-grass levels, after an initial decline, appear to have stabilised at between 2 and 4 heads m^{-2}.

The persistence of average populations over seven years indicates the ability of plants surviving herbicide treatment to maintain seed reserves. Wild-oat levels, however, appear to be on the decline, due it is thought to the additional benefit of hand roguing backing up the herbicide. Roguing has been carried out where possible but there have usually been some fields with too many survivors to be successfully rogued by hand. In the last two years all fields were roguable following good control by herbicides, and in 1983 no panicles were recorded in 7 fields. There does seem a prospect that herbicide use may be reduced by relying on roguing alone to control wild-oats, at least in some of the fields.

Black-grass represents more of a threat because of a faster potential rate of build-up than wild-oats and the impossibility of hand roguing this species. Generally herbicide control has been less successful than against wild-oats, with wet autumns resulting in poor seedbeds and greater reliance on soil acting herbicides. Experiments have shown that a high level of control is needed to prevent an increase of black-grass seed reserves in minimally tilled land (Moss 1980), and clearly more reliable control over several successive years is needed here to effect a real decline in populations.

Black-grass seed reserves have been estimated from soil samples taken each autumn from transects across some of the fields. Under continuous cereals seed reserves, although fluctuating have been generally maintained. A three-year grass break considerably reduced but did not eliminate viable seeds in the soil, and did not prevent a recurrence of black-grass in the first cereal crop after the ley. It is unlikely that many seed heads would have formed in the grass which was cut early for silage each year, so that the decline of seed reserves under grass is a true reflection of seed persistence. Failure to eliminate both black-grass and wild-oats in the first cereal crop allowed new seeds to enter the soil with the prospect of a further long programme of control on those fields.

Herbicide costs have been reduced by changing to cheaper alternative products which have given satisfactory control and not allowed populations to build up. It is considered by the farm management that the cost of containment cannot at present safely be reduced much more. A further saving of herbicide costs might follow if wild-oats could be reduced sufficiently to be controlled by roguing alone. In 1981 herbicides cost £40 ha^{-1} and yields averaged 6.9 t ha^{-1}, which suggests that a realistic target for the cost of containment (to include application and roguing costs) of 5% of the value of the gross output should be achievable. Since that year herbicide costs have increased to over £50 ha^{-1}, and of course a reduction in grain prices would significantly increase the relative cost of containing these weeds.

This study is continuing and it is hoped to complete one cycle of the eight year rotation. Results for the first six years have been published in a preliminary report (Wilson and Scott, 1982) which gives more details of the herbicides used and the population trends for individual fields.

ACKNOWLEDGEMENTS

I wish to thank Mr J. M. Wilson and Mrs J. L. Scott of the Agricultural Development and Advisory Service for their co-operation in this joint project, and Mr Richard Smith and Mr Tim Hickman of Neville's Farm for their help in providing information on cropping and herbicide use and for allowing us to walk the fields of Neville's Farm.

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The WRO Fen Soils Project—a review of twenty years fruitful collaboration with the Arthur Rickwood EHF

M J MAY

In Great Britain there are over 90,000 ha of soils used for agriculture that have more than 20% organic matter content. Of these the largest area of agricultural importance (65,000 ha) is the Black Fens of East Anglia where the organic matter is derived from sedge and reed fens and usually overlies Fen Clay. These soils require specialised husbandry, mainly because of their physical characteristics and weed control has been recognised for a long time as a particular problem. In 1945 a scheme was prepared for a network of Husbandry Farms and this included one in the Black Fens. Due to lack of finance one was not set up at that time, but in 1963 the late Arthur S. Rickwood CBE handed over his 150 ac Paradise Farm as a gift to the Nation for this purpose. The farm is situated near Chatteris in Cambridgeshire and is now known as the Arthur Rickwood Experimental Husbandry Farm. A farm advisory committee was set up which included local farmers and regional scientists and they established a list of priorities for the farm. The problem of weed control was second only to peat/subsoil mixing. It was because of this that the WRO became so closely involved with the farm. Initially field teams from WRO broadened their projects to include organic soils and travelled across to do experiments at the EHF. In 1967, as a response to a direct request from NAAS (as ADAS was then known), the ARC sanctioned the establishment of a permanent team to work on weed problems of the fens. This Team, whilst based at WRO, spent much of the spring and summer at the EHF. The remit of the project was to develop methods for the control of weeds on highly organic soils in Britain. The Team has always worked closely with the EHF and its staff, this collaboration extending beyond the simple supply of field sites and crops. In general WRO has conducted the initial screening for herbicide activity on organic soils, basic studies on weed problems and herbicide performance in relation to the soil and the EHF has integrated relevant findings into Fenland husbandry. In practice the links have been closer than this implies and there has been twenty years of successful collaboration between the EHF and WRO.

WEED EMERGENCE

Fertility and moisture contents of organic soils are high and the surface layers of soil warm up quickly in the spring. Growth tends to be rapid and vigorous for both crops and weeds. The weeds are liable to emerge as large flushes during the spring and early summer. A typical flush is usually dominated by one or two annual broad-leaved weed species. During the spring of 1983 over 6,500 pale persicaria (*Polygonum lapathifolium*) seedlings m^{-2} were recorded on one commercial field at the Arthur Rickwood EHF by the WRO Fen Soils Team. On a typical 25% organic matter arable soil 1,400 or more weeds m^{-2} can be expected to emerge each spring. Even with a 95% kill of the first flush 40 weeds m^{-2} may survive with, on average, another 400 still to emerge. The number emerging will obviously be affected by the number of seeds shed the previous season. Direct drilling has been shown to reduce considerably the number of weeds emerging in the spring but has not been successful in practice. Yields of many crops, including sugar-beet, barley, onions and wheat have been poorer and weed control from soil-applied herbicides has been more variable than where normal cultivations have been used.

HERBICIDE ADSORPTION

In addition to the problem of weed number and vigour, the physical characteristics of the soil influence the performance of soil-acting herbicides. The large amount of organic matter present reduces the effectiveness of many herbicides by adsorption. Results obtained on mineral soils cannot be extrapolated to organic ones with any degree of accuracy. The Team's policy has been primarily to examine soil-applied or soil-acting herbicides, with less emphasis on purely contact or foliar herbicides which act similarly on most soil types.

The Team has shown four main ways of increasing the weed control activity of soil-acting herbicides on these organic soils. The first, and obvious way, is to increase the dose used. Several herbicides, including simazine and linuron, can be used as pre-emergence treatments if twice or more than twice their normal mineral soil dose is used. Most of the residual herbicides in commercial use on organic soils are used at rates higher than on mineral soils. However, there are herbicides such as chloridazon that do not give adequate residual weed control, even at ten times their mineral soil dose.

The second method of improving weed control activity is to incorporate a herbicide thoroughly into the top 5 cm of soil so that it is in the germination zone of weed seeds. Lenacil, which is virtually inactive as a surface application, becomes very active when incorporated in this way. This was discovered in 1967 and it led to a complete rethink on the use of soil-applied herbicides on organic soils. Incorporation will double the weed control activity of many herbicides such as simazine and metribuzin. Linuron is one of the few herbicides whose activity is reduced (or diluted) by incorporation. This reduced activity applies to certain other urea herbicides while some, such as isoproturon, are more active incorporated than surface applied. Incorporation can affect selectivity and isoproturon is more selective in radish as an incorporated treatment than when surface applied. In most cases rotary cultivation is needed for thorough incorporation and because of the cost of this operation and its effect on the crop seedbed few herbicides are used in this way. However, metribuzin has a specific recommendation for use pre-planting incorporated on potatoes growing in the organic soils of East Anglia. This technique was developed by the WRO Fenland Team in conjunction with the Arthur Rickwood EHF and Bayer UK Ltd. The herbicide is incorporated by the last seedbed cultivation before planting and then into the potato ridge by post-planting cultivations. It offers the opportunity for season long weed control without herbicide losses due to soil erosion or leaching from the top of the ridge.

Thirdly, the activity of many of the important soil-applied herbicides can be increased by applying them as a layer 2.5 cm below the soil surface. This method works for those herbicides whose activity is improved by incorporation as well as others, such as linuron, that are not. Unfortunately no economic, commercial method has been found to place herbicides at such shallow layers below the soil surface.

Finally, the use of surfactants or oils can sometimes improve the residual weed control from soil-applied herbicides on organic soils but their results have been variable. Synpernonic surfactants tried by the Team and the AFRC Letcombe Laboratory gave spectacular results in many pot tests and in one field experiment. The results suggested that doses of simazine similar to those used on mineral soils could be considered for use in the fens. However, subsequent field experiments showed the effect to be very variable under field conditions. The theory behind the technique was that the additives would increase the solubility of the herbicide and allow it to be leached into the soil rather than being locked onto the surface layers. None of the other additives tried were as promising as the synpernonic surfactants in that one successful field experiment. Although many pot experiments showed the potential of this method for improving the weed control activity of other residual herbicides, field results were always variable. Experiments to determine the cause of this variability failed to find a reason but they did show that soil moisture, precipitation, organic matter content of the soil and soil pH were not, on their own, the cause.

REPEATED LOW DOSES

One way of overcoming the problem posed by successive weed flushes is not to rely on a single application of a high dose of residual herbicide but to use sequential doses of herbicides, either with foliar or combined soil and foliar action. This is the general principal used in the 'repeated low dose' technique developed for onions and sugar-beet. The WRO Fen Soils Team played a major part in the collaborative work to establish the current commercially used techniques. When farmers first used the technique for weed control in sugar-beet, high spray pressures were believed to be responsible for the good weed control that could be achieved. Studies by the Team showed that while increased spray pressure could, in some situations, increase retention of herbicides on both crop and weed, this seldom resulted in increased weed control activity. However, if the crop was under stress, high spray pressures could result in reduced yield. Early work showed that the key to the technique's success was early application of treatments to weeds at the cotyledon stage.

Work by the WRO Team and the Arthur Rickwood EHF showed that the combination of high doses of pre-emergence, soil-applied herbicides followed by post-emergence herbicides were likely to reduce yields of onions and of sugar-beet. Further experiments showed that for sugar-beet on organic soils, a true pre-emergence residual herbicide was unnecessary (and undesirable) for good weed control. The timing of the first treatments is made according to weed growth stage and this usually coincides with the emergence of the crop. This work on low dose sequences also confirmed a phenomenon which could be predicted by knowledge of the degradation behaviour of these compounds (Walker, 1974). Repeated low doses progressively build up a soil residue so that more is present at the end of a sequence than would be achieved by a single early dose of the same amount of active ingredient. The difference appears to be significant in practice and to contribute to control of the later flushes of weeds. The long delay between drilling onions and the recommended stage for post-emergence herbicides means that pre-emergence residual herbicides are essential for this crop on organic soils. However, recent work by the Team has indicated that reduced doses of pre-emergence applications, with the rest of the residual herbicide applied post-emergence, could make optimum use of the herbicide activity to give reliable weed control and improve crop safety. This approach may allow the safe use of higher and/or earlier applications of post-emergence herbicides.

A spin-off from the work on repeated low dose programmes has been the development by the Team and R. N. Harvey of the WRO Photography Group of a quick, infra-red, photographic technique for the rapid assessment of experiments. This allows a pictorial record of crops and/or weeds to be taken at frequent intervals. The photographs can then be processed later; plant species can be identified and counted manually, an image analyser can be used to record numbers and ground cover and sequential photographs can be used to trace the fate of individual weeds or weed species.

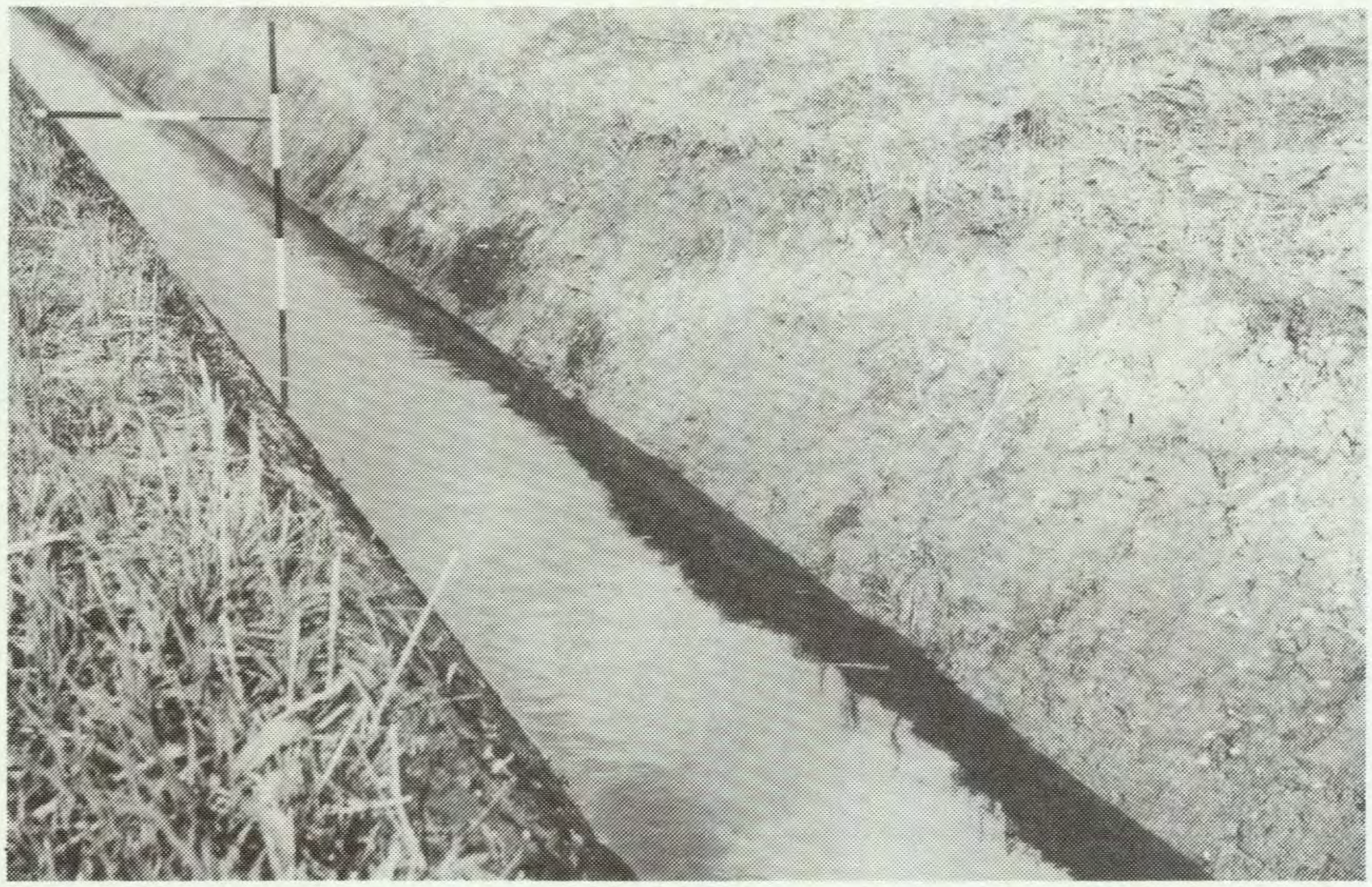
APPLICATION

Over the years the Team has looked at the feasibility of using new application techniques for weed control on organic soils. Rotary atomisers were found acceptable for the application of soil-applied herbicides. However, they were not as good as normal hydraulic sprays for post-emergence applications in the repeated low dose technique for sugar-beet.

Low ground-pressure vehicles have been used with success in sugar-beet experiments. Very low doses can only realistically be achieved using a fast, low ground pressure vehicle. This is partly because earlier work showed that the herbicide concentrations in the spray solution of phenmedipham or metamitron should not be reduced. In addition, very fine nozzle orifices are required to apply volumes less than 80 l/ha at conventional speeds. Work in progress when the project finished indicated that the doses of some, or perhaps all, of the herbicide applications could be considerably lowered. In some situations this might mean more applications but even with an increased number of sprays this still results in substantial savings on herbicide and application costs. In recent experiments the vehicle also left less visible wheeling damage than conventional tractors and no difference in yield of sugar-beet was recorded where the vehicle had crossed the plot six times compared to where there were no wheelings.

SOIL MIXING

At the turn of the century the area of peatland in East Anglia was estimated to be 140,000 ha but by 1967 48,000 ha had been converted to skirtland; that is where the peat top soil has become so shallow that the underlying clay, gravel or sand has been brought up and mixed with it. This reduction in the depth of topsoil is caused by continuous slow shrinkage of the peat due to oxidation of organic matter under arable agriculture. Because the underlying mineral floor is usually undulating, a patchwork of soil with varying amounts of organic matter occurs once the depth of peat topsoil



The undulations of the clay subsoil can be clearly seen in this exposed dyke bank. Photograph courtesy of the Arthur Rickwood EHF.

becomes shallow. Amongst other problems this makes the dose of residual herbicide difficult to determine. One way round this is to mix the soil with special deep tine implements or double digger ploughs. Although this appears to remove the problem of mineral soil outcrops, preliminary investigations by the Team found few cases where reduced doses of residual herbicides gave consistent weed control on these mixed soils. Measurements by the Team (with help from the ADAS Soil Scientists at Cambridge) showed large point to point variations in organic matter content on areas of mixed soils, these differences being larger than those found on

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