THE BAWDEN MEMORIAL LECTURE

This lecture is arranged under the auspices of the British Crop Protection Council in memory of the first President of the Council, Sir Frederick Bawden.

RESEARCH AND DEVELOPMENT FOR BRITAIN'S FUTURE FOOD SUPPLIES

by

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Mr. President, Ladies and Gentlemen -

It is for me a deeply felt personal privilege to give the second Bawden Memorial Lecture, since I have been proud to be able to count Fred Bawden as a trusted friend and as a lively and exciting scientific colleague. Sir Henry Plumb's splendid tribute last year gave such an excellent description, both of his personality and his career, that I can only add some insights as to how he tackled a new area and a new set of problems overseas.

When the Federation of Rhodesia and Nyasaland broke up 10 years ago, the three countries which became Malawi, Rhodesia and Zambia agreed to continue with a regional research council, conducting research in all three countries as a statutory body outside government organisation and based on an Order in Council at Westminster. As Director of the organisation I appealed to Sir Frederick Bawden for help and advice. He was already over-committed to the heavy task of directing Rothamsted and finding time to carry responsibilities in both the West Indies and Nigeria, together with many professional offices, including the Presidency of the British Crop Protection Council. He none-the-less responded generously and at the invitation of the Agricultural Research Council of Central Africa, he became our Chairman.

My wife and I had the pleasure of introducing Sir Frederick and Lady Bawden to some of the splendid scenery and the sharp scientific problems of the high-altitude tropics. Bawden's questions went first to the farmers and his ability to discuss tropical crops startled many of them. He in turn met some agricultural surprises. On one large farm which grew about 800 acres of maize at very high yields, Bawden commented that the farmer appeared to be applying a very heavy nitrogen fertiliser regime most successfully and asked how he decided on the amount to apply. The farmer replied that he soil sampled thoroughly every year, sending bulk samples from every 50 acres to the Government laboratory for assessment of the total mineralisable nitrogen. He then added an allowance per ton of expected crop from a curve worked out for his soil type. In the previous season, he had aimed at 50 bags, that is 4½ tons, and had achieved 55. In the current year he was fertilising for 60 bags, or 5½ tons of threshed grain per acre. Bawden turned to me and commented that there were quite a lot of cereal farmers in Britain who could learn from a visit to darkest Africa.

We visited several research and experimental stations, where his manifest impatience with formality caused some surprises. He flatly refused to tour through laboratories and insisted on being allowed to discuss research with the individuals who were doing it.

When the occasions required formality, however, he could be extremely charming and I have a photograph of a happy occasion on which he presided over the opening, by President Kaunda, of a new laboratory in Zambia.

While we were on tour I showed him a manuscript of a scientific paper by one of our research staff and I was both fascinated and envious, not only at the speed with which he read it, but by the way he flicked a pencil backwards and forwards along the line as he read, eliminating words and shortening phrases like a gardener weeding and singling with a hoe.

When discussing experimental results with our research staff, he was insistent on the practical agricultural applications and on the need to quote the yields achieved in recognisable terms - "you can't sell relative yields" - was characteristic of his attitude.

Later, in the UK, when I joined him as a fellow Director in the ARC system, I remember the rather heated discussions on the sharply controversial Rothschild Report. Bawden's occasional abrupt comments brought many of the arguments to the point of decision.

Sir Frederick Bawden died at the close of an era of unprecedented expansion in British agricultural research and development to which he had made outstanding contributionsboth as a research worker and as a leader. We must recognise also that this was at the close of an era of world food surpluses, generated from the vast grain fields of the New World. Both of these changes strongly affect agriculture in Britain today and I shall consider them separately, looking first at the scientific field.

THE END OF AN ERA IN BRITISH AGRICULTURAL SCIENCE

Britain has played a leading role in the historical search for the scientific explanations which underlie agriculture, particularly by experimental studies in the field. We are proud that Rothamsted is the world's oldest continuing research station, with some of the field experiments laid down by Lawes and Gilbert over 130 years ago, still continuing. Many other research foundations were established by groups of British citizens, mainly by landowners and scientists. Like Rothamsted, their success led to their growth rapidly outstripping their financial resources, so that Government grants were necessary to sustain them.

The Haldane doctrine, accepted by Government in 1919, declared that science must be insulated from politics and that Government should support the development of the sciences as well as their application. As a result, when the Agricultural Research Council (ARC) was set up in 1931, it was established as a statutory body insulated from the machinery of Government by reporting directly to the Privy Council. The ARC then built up a unique system by grant-aiding the various independently established agricultural research stations with the minimum interference in their governance.

Two wars in 30 years administered very salutary shocks to the nation's rather casual attitude to agriculture. The value of advisory staff was demonstrated and a Government Board of Agriculture expanded to deal with statutory functions of certification and control; technical advice was taken over from the county authorities and the necessary regional experimental stations were developed.

Both the Agricultural Research Council and the Agriculture Department systems grew, independently, with different outlook and purpose, during the two decades 1950-1970. These were, in retrospect, an era of plentiful support and encouraging progress. The combined effects of the two systems on British agriculture were highly successful: total output increased in real terms by over 50% in spite of a loss of over 1 million acres of farmland to development. The doubling of output per man throughout one of Britain's largest industries was an achievement based very directly on research and development, with chemical control of weeds playing an important role.

To those of us old enough to remember the weedy pastures and colourful corncrops of pre-war Britain, the transformation made by herbicides was dramatic, changing the picture of crops and pastures from a taxonomic botanist's delight to a very good approximation to pure stands of whatever the farmer had sown. The credit for the success story of British agriculture over this period is shared by the research and development workers and advisory staffs, the chemical industry which invested heavily in the development and manufacture of fertilisers, herbicides and pesticides, the processors and food manufacturers who shared the innovations, the enterprising farmers who put their own resources and effort into the production, the banks who backed them and the Ministry which, since 1960, has channelled around £520 million of Government grants into farm improvements.

In this period, however, Britain's two publicly funded forces of agricultural science and technology had developed very different philosophies. While the staffs of the Research Council's institutes and of the Ministry's agricultural services made contact and cooperated freely as individuals, the two commands had very little organised contact and no joint planning. Both systems were large and geographically dispersed, with a substantial measure of autonomy both in the ARC institutes and also in the Ministry Regions and Experimental Stations. A further separation of forces occurred at the Scottish border where the advisory services are conducted by the Agricultural Colleges associated with the Scottish Universities.

THE ROTHSCHILD REORGANISATION

In 1970 the growth rate in research and development began to fall off rapidly and an era of restricted resources was initiated with a severe pruning of the Ministry's advisory staff. It was unfortunate that this occurred at the time of an ambitious reorganisation, from the former National Agricultural Advisory Service to a combination of all the technical services into the present Agricultural Development and Advisory Service. The reorganisation was made sharply difficult by the cut in resources.

Then came the turn of the research side. Lord Rothschild's recommendations, over the whole of civil science, aimed to bring scientists whose work is supported by public funds to a more direct recognition of the problems for which these funds were voted.

Sir Frederick Bawden was a leading critic, mainly on the grounds that the Ministry did not have a sufficient machinery of scientific policy and decision making and therefore did not have enough knowledge of the resources and potential of the ARC system to control a majority share of the Council's income.

The White Paper of June 1972 included Lord Rothschild's recommendation for a Chief Scientist's Organisation to focus the views of a large and complex Ministry on the Research and Development needs of British agriculture and food industries and to arrange commissions for research and development with the ARC, the Research Associations, the Universities and other research agencies; this includes a total of over 100 research and development centres.

I took on the task of Chief Scientist with much trepidation, for it was a new post surrounded by serious controversy. Very serious responsibilities were defined far more clearly than were the resources to meet them. The sudden loss of Fred Bawden was a personal blow at this time, for he was the friend to whom I would have turned most often and most confidently for advice.

The details of the reorganisation have been explained many times and I would only comment now that the White Paper demonstrated the characteristic British style of compromise. The eggs were placed, not all in one basket, but in three, with the pattern divided at the Scottish border. ARC, the Ministry of Agriculture, Fisheries and Food (MAFF) and the Department of Agriculture for Scotland (DAFS) all have independent funds for sponsoring research and development but these are heavily committed to ongoing work. The total funds this year for R & D in MAFF, DAFS and ARC are well over £40 million.

From the history of our research centres, their finances were considered individually, station by station, both in the Research Council and Ministry systems. An immediate major benefit of the Rothschild proposals was to provide the impetus for the re-definition of research programmes in terms of specific objectives. This led directly to the study of how resources of staff and of money were allocated to objectives, not only within centres of research and development, but across the whole national pattern of publicly funded work in these fields. Only in this way can recommendations on priorities be turned into practice by selective reinforcement.

The whole new system would have been of immense help 10 years ago, when resources were expanding and new support could have been channelled to the priority tasks.

By an ironic twist of history, the system is being implemented, as with the earlier reorganisation of the advisory services, in a period of unprecedented financial stringency.

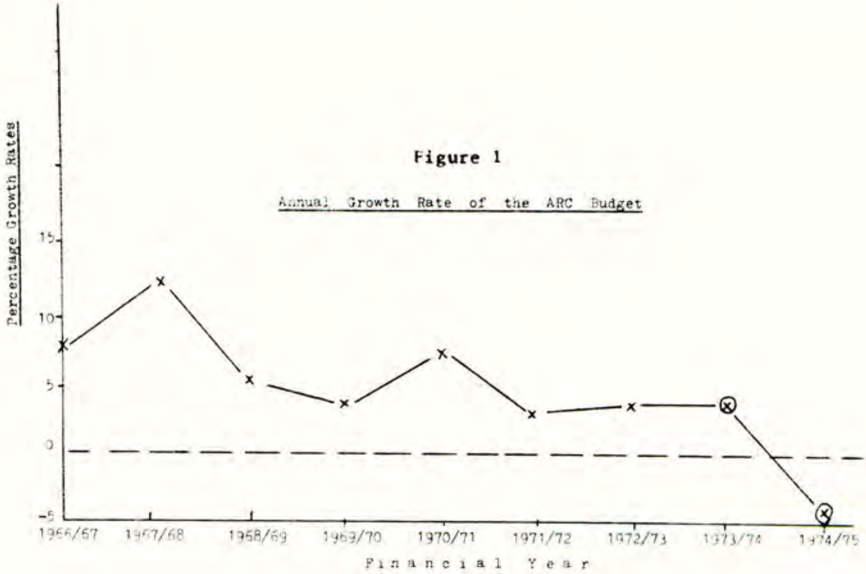

Figure 1

Annual Growth Rate of the ARC Budget

Figure 1 shows the annual growth rate of the ARC funds in real terms. The importance of matching the distribution of resources to the national need increases as the resources diminish, but the changes become more difficult.

There is no lubricant for change so effective as spare cash.

The selection of national priorities for R & D is not a matter for scientists only and an essential part of the reorganisation has been the creation of a national forum. The Joint Consultative Organisation (JCO) has been described in the agricultural and scientific press, so that I hope you will be familiar with the outline of our five national Boards on which farmers, processors, advisers and administrators, as well as research scientists debate the priorities with the help of specialist committees.

NATIONAL PRIORITIES

The JCO Boards met first in 1973, in circumstances of unhappy bewilderment for many British farmers. A doubling of the price of major inputs, due to a suddenly developed world shortage of cereals, of fishmeal and of soyabean meal, together with a sudden major increase in the price of oil supplies, was accompanied by a sharp check in the market for beef. Free adjustment by the play of market forces had long ago given way to a complex system of state subsidies and guarantees, which were in turn heavily affected by the equally complex EEC Regulations of the Common Agricultural Policy. It is particularly difficult under such rapidly changing circumstances to look ahead with confidence in order to select targets for research and development.

These targets must be concerned, not with the expediencies of the present, but with both the foreseeable needs of the future and the ability of the sciences to meet problems not yet foreseen. Some of the scientists and other members on the JCO

Boards have taken the view that it is for the Government to predict the future pattern of British agriculture which would be in the nation's best interests, for this would greatly simplify the problem of determining research priorities. I had, of course, discussed this possibility with the Minister and with senior colleagues; but Britain does not have a centrally-directed economy and unlike the Iron Curtain countries, has no Master Plan. I have been on some large collective farms and I am sure that the private enterprise alternative will long be found best suited to British conditions.

RESEARCH TARGETS

Nevertheless, we cannot give an effective weighting to the choice of research targets unless we have some mental picture of the British agriculture of some 5 to 10 years ahead in which the research results will be used. We must work not only for prosperous and efficient agriculture and food industries, but also, because these produce half of the nation's food supplies, we must work within the constraints imposed by national needs.

As scientists we must therefore look for any trends discernable in our boundary conditions.

The national policy of successive Governments towards their responsibilities for agriculture, fisheries and food, has been declared by Ministers to be the securing of a food supply which is reliable both in quantity and in quality. This must be at prices which are fair to both the farmer and the rest of the economy, affecting the whole of the population of which only some 3% are directly engaged in agricultural production. Objectives also include conservation and development of the quality of the environment, with special consideration for water supplies, since the agricultural industry occupies most of the reception surface for the rainfall which waters the nation as well as the crops.

Historically, we have grown to rely on the import of a substantial proportion of our food supplies from overseas. The severe maritime blockade of the Second World War however, accelerated development of the agricultural industry and since 1945 the national balance of payments problem has maintained the impetus to greater home production. Science and farming enterprise have in the interval increased our agricultural productivity, so that we now produce some 53% of our total food supplies and over 67% of those foods which can at present be grown in our climate - and despite having to feed a larger population and at a much higher standard of living.

All major political parties have now subscribed to policies of promoting maximum economic home production in British agriculture. The pendulum has thus swung in a century from the self-sufficiency before 1870 to the extreme reliance on imports of the 1930s and is now gaining momentum on the return swing towards greater self-sufficiency. Thus just at the time that agricultural science approaches the end of an era of generously funded expansion, the agricultural industry is being called on to accelerate production.

THE CLOSE OF AN ERA IN WORLD FOOD SUPPLIES

For a century Britain has drawn freely on world food surpluses for what we needed. Our views of the future have been coloured, over the past two decades, by living in a countryside abounding with evidence of the power of science, when applied to agricultural development, to increase food output. Overseas, the application of science to tropical agriculture by the great American Foundations of Rockefeller and Ford had produced the beginnings of a "Green Revolution" which extended optimism to the wider issues of world food supply. Those who called attention to the worsening position of the "third world" were dismissed as "prophets of doom". The World Food Congress, which ended a few days ago in Rome, has at least achieved a greater acknowledgement of the uncomfortable facts, and of their tragic consequences overseas.

Thus we must now accept that at least the younger half of the members of this Conference will experience a world in which there are two human beings for every one living today. In view of the tens of thousands now starving, this vast increase, considered in terms of daily food needs, is awe inspiring. The belated attempts at population policies, for which the World Conference at Bucharest offered little enough encouragement, will not affect our R & D decisions materially, since the structure of existing populations, with some 40% under 15 years of age in the tropics and subtropics, already ensures the next 25 years of population surge. Until the recent World Food Conference there has been a tendency in UN pronouncements on these problems to emphasise that world food supplies have increased almost as fast as world population, but not to emphasise that the imbalances of distribution have also increased.

A critical aspect of this world situation has, I believe, escaped sufficient attention in British estimates of future world food supplies. This is that only one out of seven of the vast increase in world population will be born in the more developed countries of the temperate zone. The other six will be born in areas already massively dependent on subsistence agriculture, in climates of the monsoon and inter-tropical convergence zone types. We do not need elaborate and highly speculative forecasts of world weather trends to estimate the effects on the availability of world food supplies. We already know that the well established patterns of the climates of the tropics and subtropics have, as a basic feature, an instability which guarantees drought and flood incidence and has caused a long history of regional disasters. Having worked for many years in a group of developing countries and visited many others, I had, 5 years ago, an opportunity to make a tour of 19 countries to study the way in which their changing patterns of land use were affecting their soil and water supplies. The overall picture was that the growing populations in the tropical and subtropical countries were being maintained, not by improvements in agricultural methods, but by a relentless expansion of subsistence agriculture. This inevitably is moving into drier, steeper, stonier and less fertile land, while the better land is cropped even more intensively. Much of this steeper, drier land can be cultivated safely only with the skilled layout of good soil conservation engineering. The present cultivation methods of primitive subsistence agriculture lead inevitably to destruction of soil and water resources. The extraordinary resistance of the human race to the lessons of our environment is brought home sharply by the following quotation from Plato (Criteas, about 400 B.C.).

> "There are mountains in Attica which can now keep nothing more than bees, but which were clothed not so very long ago with fine trees, producing timber suitable for roofing the largest buildings; the roofs hewn from this timber are still in existence. There were also many lofty cultivated trees, while the country produced bountiful pastures for cattle. The annual supply of rainfall was not then lost, as it is at present, through being allowed to flow over a denuded surface to the sea. It was received by the country in all its abundance, stored in impervious potter's earth, and so was able to discharge the drainage of the hills into the hollows in the form of springs or rivers with an abundant volume and a wide distribution. The shrines that survive to the present day on the sites of extinct water supplies are evidence for the correctness of my present hypothesis."

Those of you who are familiar with the Mediterranean coastal ranges of Greece and Turkey will know how accurate was Plato's analysis of his observations. Government re-afforestation schemes are restoring some water control but the damage is on a vast scale.

On the flatter lands of better soils, continuous cropping without fertilisers has reduced productivity sadly. In Ethiopia I saw farmers sitting down to harvest barley with a hand-sickle, because in spite of good rains it was only 4 inches high.

FAO demonstration plots of fertiliser application stood out like block diagrams and there were roads enough to reach a substantial part of the farmlands, but the political and economic willpower was missing. Only 15% of the world's fertilisers are used in the crop areas on which 70% of the world's population depends. I am convinced therefore, that the timelag between the rise in the human population and the application of existing knowledge will cause an increase in the number of world food emergencies in the next two decades.

To meet emergencies the reserve is now only some 25 million tons, while the trade shipments to developing countries have reached some 60 million tons, but already the population increase requires 25 million tons more cereals every year and this increase itself is growing, so that looking only 15 years ahead, the annual increase in grain consumption will be 40 million tons. The grain producing countries of the western world have not profited from the biblical example of Joseph's grain storage operations. Over-year storage has been planned only to hold what could not profitably be sold. Since storage is an expensive business, the countries of the New World have actually reduced their government granary commitments in the last two or three years.

I therefore conclude that the research and development policy in British agriculture must be based on the assumption that the world market on which Britain at present relies for half of her food supplies will become an increasingly unreliable source. We shall be unable to avoid competition, for cereals and for protein meals, with countries whose populations are in desperate need. The more cynical opinion, that developing countries will not have the foreign exchange to compete, is not borne out by recent experience; the international agencies charged with purchasing relief grain must go to the only surplus available and we shall rightly support them to pay what is necessary to save life.

The EEC and the Common Agricultural Policy in which we now participate, might indicate that we should look to Europe instead of the world for our food supplies, but Europe is very much part of the world market as we have seen recently in the case of both oil and of soyabean meal. Monsieur Lardinois has already predicted that the EEC will need to purchase some 8 million tons of wheat and 11 million tons of soya in the coming year.

The further objection may be that the last three years of world weather distribution have been exceptionally unfortunate for food production and that a more kindly run of chances in the world's local climates could very quickly produce a more favourable picture. Prediction of climate is, of course, one of the most promising prospects in modern science and is being studied with good resources by the Meteorological Offices of the technically advanced countries and also by smaller groups in several universities. The reports are fascinating, but all that emerges with any consistency from my own reading of them, is that none of the clues to the future predict any improvement in the regularity of rainfall for world crop production. Forecasts at various levels of, shall we say, adventurous extrapolation, all tend towards descriptions of greater variability. This means more frequent and more extreme regional crop failures.

From all of the foregoing indications I believe that our British agricultural R & D policy should be based on the assumption that over the period of 5 to 15 years, in which research projects initiated now can be expected to bear fruit, we shall be able to place very much less reliance on the nation's ability to purchase every year 10 million tons of grains and protein meals from overseas. I believe that the general picture which I have tried to outline in the last few minutes also indicates the expectation that our own British agricultural production will be given in the near future a very much higher priority in our national life.

The last three years have produced such violent changes in the world's economic and food supply situation, that it might be more logical to adopt an R & D policy of wait and see, while holding all our options open in the hope that the world situation would revert to the familiar historical pattern. There is, however, one relentless limitation to research and development, which denied us this option. Time is essential to the study of the growing of crops and the improving of livestock and even with the fullest facilities there is very little that can be done in 10 years time to make up quickly the time lost now. We must indeed continue to pursue scientific improvements on a broad front, since food and agriculture are together too complex an industry to be treated simplistically. I believe however, that I have outlined a strong national case for the reinforcement of effort on some easily recognisable lines of research and development.

R & D PRIORITIES FOR BRITISH FOOD AND AGRICULTURAL INDUSTRIES

I have outlined for you earlier the national forum which is studying the problem of research priorities and the way in which the Ministry discusses with the ARC and DAFS what the overall decisions should be. Both the Joint Consultative Organisation and my own Chief Scientist's Group were assembled during 1973, and have been in operation for one year. This is too early for conclusions, but I will try to sketch out for you a personal view of the picture as it is emerging from these studies and discussions.

Wheat

Firstly, as I have been discussing world grain supplies we might start traditionally with our daily bread. The hard wheats of high protein quality needed by the bakers have traditionally been imported from warmer and drier climates. Outstandingly successful research by the Flour Millers and Bakers Research Association developed the Chorleywood process which permitted a substantial increase in the use of home-grown wheat. The baking industry took up the new process rapidly and the national grist is currently blended from 3 million tons of imported wheat and 2 million tons of home-grown wheat.

At first sight the priorities for plant breeding should therefore be to produce higher yielding high-protein wheats; this is a very difficult target at which plant breeders in several countries are aiming. However, the biggest obstacle to the use of more home-grown wheat in Britain, is its variability. This renders it unusable in modern mills which are designed to handle large shipments of uniform imported grain. The main reason for the variability is the susceptibility to diseases, which causes farmers to grow three or more different varieties on a single farm. Disease resistance, therefore appears, for Britain's circumstances, more immediately important than protein content. Luckily the two are not incompatible and usable wheats such as Maris Freeman and Maris Widgeon represent real progress in both requirements. Yields are not as high as for the feed wheats, but they are better than those of the great plains of Canada, USA, Argentina and Australia and they are very much nearer to the mills. The organisation and storage to grow larger quantities of more uniform wheats, must therefore be a high priority in development as well as in research. It is a development that has started late in an agriculture geared to grow cereals for stock feed.

Storage and waste

Storage of grain on a national scale is costly. I have seen a figure of £10 per ton per annum which is probably now exceeded. While there was a reliable world surplus, the storage of grain was therefore kept to a minimum. In the world picture which I have outlined, I now believe that the biblical Joseph will become increasingly recognised to have been a good consultant. There is a further research implication here. Throughout the world inefficient use of modern insecticides has built up many resistant races among the grain weevils and other storage pests. Insecticide used directly in a food supply must be strictly limited in amount and persistence and clearly, there is much work to be done in this field. Indeed, a high priority must be given to the prevention of waste of food in storage. With a food imports bill which has inflated 55% in the last two years to reach a staggering total of £3,500 million per annum, the estimate of several sampling surveys carried out by food scientists, shows that the nation as a whole wastes some 25% of the food supplied from both home-grown and imported sources. Here we must recognise a high priority for R & D, while realising that the subject of waste is complex and the relation of R to D is particularly difficult. In the field, pests, diseases and weeds are all sources of waste in production systems, and the agrochemical industry has firmly established routes to success in overcoming them.

Livestock feeds

World price rises in the last two years have made it clear beyond argument that the importing and feeding of highly expensive cereals and protein meals to animals in Britain is too extravagant. We grow 10 million tons of our feed grains and import 4 million tons of cereals and 2 million tons of protein meals. There is general agreement that for ruminants the solution is to grow, conserve and feed a very great deal more grasses and forages. Here much of the central research has been done and we all know that the first move is to apply a great deal more nitrogen. Nitrogen fertilisers are, however, temporarily in short supply on a world scale and will always be dependent on the supply of hydrogen and of energy from either oil or natural gas. While concentrating on the development side of the better use of available nitrogen fertilisers in the immediate future, we must, I believe, apply very determined priority to research for the improvement of legumes. Here Pirie's 25 years of research work on the extraction of leaf protein offers a better way to use legume forage and is now coming high on the list for development into practice. Already the ARC has pilot scale experience at two stations of separating lucerne juice as a useful pig feed leaving either first class silage or material for dried cobs, while at a farmers' cooperative enterprise the de-watering of lucerne before drying has already shown substantial fuel savings on a commercial scale. There are, I believe, real possibilities that given sufficient investment and concentration of R & D resources, we could replace a very high proportion of the present 2 million tons of imported protein meals. The JCO is working on this and I am looking forward to their recommendations.

The energy and fibre components of potential stock feed which disappear annually as we burn so much of our 3½ million tons of surplus straw, represent a different sort of challenge. Here the research is largely economic, since the technical processes for making straw digestible, or, alternately, for making it into paper pulp, are already developed by industry. Such economic studies are already in hand as well as studies of the engineering problems of compaction and transport of straw. This again will be a matter of not only research and development, but of commercial organisation and enterprise.

Minimum tillage

The plough, hoe and seed drill have been improved a very great deal since Jethro Tull's innovation, in 1730, of the idea of growing crops in rows, but these three implements are still used, on most farms, as three separate operations. The cost of oil now guarantees that the streamlining of these multiple-pass tractor operations will be given high priority and fortunately much R & D progress has already been made by the agrochemical industry, by the ARC laboratories and by ADAS. Since the main purpose of cultivations is weed control, innovation will depend critically on the progress of the science which we shall be discussing for the rest of this Conference. I have remarked earlier on the transformation of the British agricultural scene, which herbicides have already brought about, but, if we are to grow more of our own cereals, some of them will have to be grown in wetter country and this will pose challenging problems for the chemists and other weed control specialists. It will also rely heavily on the help of the plant pathologists and the drainage engineers.

Water resources and pollution

New Regional Water Authorities are beginning a determined attack on the pollution of the nation's water resources. Almost all of their problems are with industrial wastes and urban sewage, but there is some occasional evidence, on permeable strata, of nitrogen losses from agricultural operations. This is not the result of too much fertiliser, but is a basic outcome of the disturbance of soil and the growing of crops, which result in the mineralisation of organic matter. The ploughing-in of the residues of a good crop of clover or lucerne releases more nitrogen than any farmer would apply from the bag. This problem is basic to agriculture and cannot be avoided. The basic need is for the intensification of research into the recovery of nitrogen from water supplies. This is a very difficult problem indeed and presents a severe challenge to both chemists and microbiologists. The farmer is already conscious enough of the rising world prices of fertilisers and will need no urging to apply them with care and attention.

The pollution problems of the intensification of livestock holdings will be reduced as imported feeds are replaced by forages and stock are thereby related more directly to the fields which support them. When the livestock are divorced from fields on which slurry can be spread, there is not so much a research and development problem as the straightforward need for investment of capital in slurry disposal by known methods developed for urban sewage and verified by the recent intensive joint R & D programmes of ARC and ADAS.

The improvement of marginal land

In general, the last two decades have seen much progress in the application of science to the more advanced and highly developed sectors of the industry, based on the more favourable climates and soils of the lowlands. However, Britain must clearly make better use of the 16 million acres of marginal uplands. This is a major target for development, using the results of research which are already well established. I have seen marginal lands developed in many countries and I have the impression that capital resources used in fairly large scale units are the characteristics of success and also that seasonal movement of stock between marginal lands and areas of high fertility and more favourable climate is accepted as a basic principle. All such development of marginal lands may well throw up new problems of research, but at present it would seem to me that the priorities are for development and reorganisation based on the vigorous use of research which we have already done.

These are, I would stress, some of the priorities for R & D attention which I have seen emerging over the past year. Agriculture is too complex to reduce to a few points and there are many others of importance, still to come.

THE INTERNATIONAL INSTITUTES

I do not want to give the impression that we should abandon the developing countries and concentrate on feeding ourselves in a "fortress Britain" or even a "fortress Europe". I have proposed rather that we reduce our competition for scarce overseas supplies. The problem of the massive population increase in the developing world can be solved only by increasing their own food production. The very real success of the new highly productive strains of dwarf wheat and rice, produced initially by the Rockefeller and Ford Foundation Institutes, and adapted and developed locally by national plant breeders and agronomists, is contributing materially to the feeding of the third world. They are being followed up and extended by a substantial international effort. The Consultative Group of donor nations and foundations, based on the World Bank, the FAO and the United Nations Development Program now support eight international institutes. These are concentrating on crop improvement in wheat, maize, rice, sorghums, millets and a new triticale grain hybrid of wheat and rye; they are improving the main tropical legumes, soyabeans, field beans, cowpeas, pigeon peas, chick peas, and the starch crops potatoes and cassava. One international institute is working on beef in South America and two others in Nigeria and the Phillipines respectively are working on mixed crop systems for peasant agriculture. This is work in which Britain is helping, directly by subscription and also by the supply of staff experienced in tropical research and by the backing of university studies in Britain, especially of legumes and of nitrogen fixation.

While the bilateral aid programmes of all the developed countries are providing various degrees of assistance in agriculture, the chain of International Institutes is mounting a powerful scientific attack on the problems of increasing the world food supply in the developing countries. It represents, I believe, the main scientific hope of feeding the huge increase in tropical populations, which is already gathering momentum.

This lecture was prepared as a tribute to the memory of Sir Frederick Bawden and I was acutely aware as I was drafting it how much I would have valued his opinions on so many of the points raised. His comments would have been pungent but accurate and his deep concern for the future of British agricultural science and for the contributions we could make overseas to solving agricultural problems would have led to some forceful suggestions. It has been for me a great privilege to be able to speak in his honour.

BAWDEN MEMORIAL SCHOLARSHIPS

In addition to the annual lecture in memory of the late Sir Frederick Bawden, the British Crop Protection Council decided to offer a limited number of scholarships annually to enable young people to attend its main Conference, usually held in Brighton during November. The scholarships are awarded on the basis of an essay competition, open to students and employees under 30 years of age, of any nationality, studying or employed in the United Kingdom.

In 1974, one studentship was awarded and the winning essay on the topic 'The Role of Crop Protection in Agriculture and Horticulture' is presented on the following pages.

Proceedings 12th British Weed Control Conference (1974)

THE ROLE OF PLANT PROTECTION IN AGRICULTURE AND HORTICULTURE

B.V. Scarborough

St. Peters Cottage, Colston Bassett, Notts.

The basic role of plant protection has always been to eliminate or minimise competition from weeds, pests and disease and thus increase yield, facilitate ease of harvesting, and ensure a clean crop.

The first efforts in plant protection were probably the manual removal of weeds from various crops. From the eighteenth century onwards there was an increasing awareness that efficient weed control was essential for successful crop production. Crop protection depended on the removal of weeds by cultivation, removal of weed seed from crop seed and the rotation of crops. The practice of crop rotation denied any one weed species the opportunity to take advantage from a favourable environment and thereby gain dominance. Crops such as potatoes and turnips were included in the rotation since these crops, unlike cereals, could be weeded during their active growth. In addition to protecting crops by allowing the removal of weeds, rotation enhanced soil fertility and prevented the build-up of eelworms which attack crops such as potatoes, cereals and bulbs. Cultivation of the soil at certain times of the year exposes many soil-living insects, which are subject to predation by birds. Populations of leatherjackets and wireworms, which can seriously damage many crops, are thus reduced by birds following the plough in the spring and autumn.

The cleaning of crop seed by winnowing dates from ancient times and is still practised in the primitive agriculture of many tropical countries. Techniques for seed cleaning in the developed countries have now become extremely refined and legislation exists to control the levels of weed seed in crop seed. Increasing knowledge of farm management and hygiene and the use of healthy planting material has done much to prevent unnecessary losses due to insect pests and fungal diseases. Under glass, attention has been focussed on the maintenance of the crop in an environment unfavourable to insects and fungal disease. For example, inadequate ventilation may create an ideal environment for the rapid spread of fungal disease whilst the maintenance of a dry atmosphere favours attack from red spider mite. Glasshouse hygiene is of utmost importance. Previously steam was used for the sterilisation of soil. Waste plant material and weeds were removed from the glasshouse since they were sources of inoculum for the introduction of pests and diseases. These early methods of plant protection may be referred to as cultural control. Cultural techniques employed for cropping should always be those that give the crop the maximum opportunity for good growth. Attention to the sowing date of a crop will often ensure that plants are not in a susceptible stage when a particular pest is ready to lay eggs. Other factors, such as manuring, irrigation and drainage help to assist plants to grow strong and healthy and are still used to prevent undue damage resulting from pest attack.

One of the oldest and most successful methods of protecting plants from insects and related pests is by using their natural enemies to attack and destroy them. The deliberate use of natural enemies for pest control is known as biological control.

The first noteworthy demonstration of biological control came from California in 1888. Here the developing citrus industry was seriously threatened by the cotton scale insect and many growers were forced to abandon their plantations. This insect had become resistant to treatment with hydrogen cyanide and the ladybird beetle (Rodalia cardinalis), a natural predator of the scale insect, was introduced and soon gave completely satisfactory control. Since then, biological control has been conducted throughout the world with some success. More than 110 different pests in 60 countries have been controlled using parasites and predators. Bacterial and virus diseases and, in some cases harmless insects, have been introduced to control pests. Insects have also been used with success for the biological control of weeds. In 1925 prickly pear was a considerable problem in Australia and covered 60 million acres, but was controlled ten years later following the introduction of the Cactoblastis moth.

In the mid 1950's a practical means of controlling insects was established by sexual sterilisation or genetic control. In this technique insects are reared and sterilised using radiation, or alternatively chemicals may be used to induce sterility in the natural population. The sterilised insects mate with normal insects in the population, and as a result the population of the insect concerned falls and can be reduced to a low level.

Plants have also gained protection via legislative control. Plant health legislation is used to prevent the introduction and spread of important diseases and pests, and to control the levels of purity of crop seeds. For example, vigilance has been exercised in Britain for the Colorado beetle, a serious pest of the United States and Canada which spread into Europe in 1921. During the period 1941-1952 many breeding colonies of the beetle were found in Britain and destroyed and no subsequent infestations have been reported.

The concept of using chemical control for plant protection was probably first stimulated by the discovery by Millardet in 1885 of the fungicidal properties of Bordeaux mixture for the control of vine downy mildew, although the insecticide Paris Green, a mixture of acetate and arsenite was used as early as 1867 for this purpose. The interest created by these compounds led to a more logical examination of other inorganic chemicals for use as pesticides. As a result, copper sulphate, ferrous sulphate and sulphuric acid were used as herbicides and lime sulphur, mercury compounds and Bordeaux mixture were employed as fungicides. Plant products such as nicotine, pyrethrum and derris were used as insecticides. Over the last thirty years we have witnessed a change from the use of simple inorganic chemicals and natural plant products to the use of many synthetic pesticides produced by the chemical industry. The era of synthetic pesticides is often considered to have commenced with the recognition of the insecticidal properties of DDT around 1940 and with the discovery of the selective herbicidal properties of the synthetic phenoxyacetic acids shortly afterwards.

After the second World War the practice of strict crop rotations, previously necessary for weed control purposes, was changed considerably by the introduction of more cereal cropping. This was made possible by the use of selective herbicides in the cereal crops, so that the control of the weeds was carried out in the cereal and did not have to await a row crop in the rotation. Prior to the introduction of growth regulator herbicides, cereal crops were regarded as the 'dirty' crop of the rotation. Today cereals are considered to be 'cleaning' crops because a wide range of broad-leaf and grassy weeds can be controlled by spraying. This has reduced the threat of weed infestation to the subsequent crops of the rotation. Following the war there was a considerable expansion in agriculture and horticulture, and the cropping of large areas of land was made possible by using mechanical harvesters which have since become larger and more sophisticated. The cropping potential of the land has also become more fully realised by the sowing of higher yielding crop varieties made available by the work of the plant breeders. Plant breeders have also produced crop varieties which are resistant to fungal attack and short-strawed cereal varieties which are less prone to lodging and also facilitate more efficient mechanical harvesting. Dwarf cereals have placed increased reliance on the efficiency of herbicides for weed control, since they offer less crop competition with weed flora. In addition farmers have become increasingly aware of the nutrient requirements of individual crops and have been able to boost crop yields with the application of suitable chemical fertilisers.

This expansion of agriculture has stimulated the chemical industry to synthesise and screen new organic chemicals for use as pesticides. The products arising from this intensive research have afforded plants greater protection from weeds, pests and diseases than ever before. These pesticides can be divided into three main groups:- insecticides, fungicides and herbicides.

When an insecticide is applied to a plant, it may act as a fumigant and kill by entering the breathing pores of the insect e.g. nicotine. Insects ingesting insecticide whilst eating treated foliage can be susceptible to compounds which act as stomach poisons, whilst contact insecticides kill the insects by direct contact. It is now apparent that many insecticides can act in several ways.

Fungicides which prevent the germination of fungal spores are often used as 'protectants' and therefore must be applied prior to fungal infection. Eradication of existing fungal infection is very limited in practice and perhaps the best example of this type of action is exemplified by dodine against apple scab fungus. Seed dressing fungicides e.g. organomercurials, which are applied to crop seeds, particularly cereals, to kill fungi on the seed, are termed 'disinfectant' fungicides. A major achievement was accomplished in pesticide research with the discovery of fungicides and insecticides with systemic action. Systemic pesticides are translocated in the plant and ideally possess the ability to protect new growth. Some systemic fungicides are effective against vascular diseases of plants e.g. benomyl may be used to treat wilts of carnations and tomatoes: Prior to the systemic fungicides, no effective treatments were available. Chemical sterilants have replaced heat as a method of soil sterilisation in glasshouses, but are not economic for use in agriculture.

Herbicides are now available to control a broad-spectrum of weeds in most crops. They may be applied before planting the crop (pre-plant), after planting the crop but prior to its emergence (pre-emergence), or after emergence of the crop (post-emergence). The initial advances in chemical weed control were in the use of selective herbicides in cereal and pea crops. Selective herbicides for use in row crops were not developed until after 1960 and these crops then also became freer of the restrictions of labour scarcity and cost. The introduction of effective herbicides for use in vegetable crops has resulted in the extension of these crops to new areas often to act as break-crops from cereals. The use of herbicides in row crops has permitted closer plant spacings than those traditionally used to enable effective cultural weed control. However, micro-climatic conditions produced within such close-spaced crops increases the incidence of pest and pathogen attack, thus creating increased reliance on the fungicides and insecticides. The continual use of herbicides can cause changes in the weed flora, for example, the early use of MCPA in cereals virtually eliminated the problem of poppy and wild mustard, but cleavers, chickweed and polygonaceous weeds, which were not adequately controlled with MCPA, became a bigger problem in the absence of competition from MCPA susceptible weeds. The introduction of mecoprop in 1956 provided control of cleavers and chickweed and in 1961 dichlorprop became available for the control of the Polygonums. In recent years there has been an increased tendency to use herbicide mixtures to control a broader spectrum of broad-leaved weeds in cereals. In arable farming, there is evidence of changes in weed population as a consequence of using selective herbicides. This is particularly apparent where farmers have become specialised and more intensive due to the increased mechanisation caused by the cost and scarcity of labour. On farms growing intensive cereals there is a tendency for some weed species, especially annual and perennial grasses, to reach significant levels of infestation. Annual grasses such as blackgrass and wild oats, and the perennial couch grass are now the most important grass weed problems in cereals.

Insecticides have not only destroyed insect pests, but also many parasites and predators living within the area of application. When tar oil washes for fruit trees were first introduced, the red spider mite began to increase in number. After the introduction of DDT, the mite began to rapidly increase, and the red spider mite has changed from a relatively insignificant insect to one of the most troublesome pests for the fruit grower. The realisation that fungi and insects could acquire immunity to a chemical has made it desirable that alternative compounds should be available for the treatment of any one fungal disease or insect pest. Spraying two or more chemicals for any one problem minimises the development of tolerance since the organism then needs to acquire several different tolerance mechanisms in one particular strain. This is particularly important under glasshouse conditions where crops are grown intensively and tolerance is likely to develop more rapidly where individual chemicals are used continuously. Thus the role of plant protection has not only increased in magnitude, but also in character and the pesticide industry has modified its search for new products accordingly.

The development of synthetic pesticides proceeded with little or no regard for the possible adverse long-term effects. Detailed research eventually exposed the subtle ecological consequences of the widespread and incautious use of pesticides which were very persistent in the environment. The organochlorine insecticides, DDT, aldrin, dieldrin, were found to accummulate in food chains. Predatory birds were found dead, poisoned by organochlorine insecticides derived from seed eating birds, on which they had fed e.g. pigeons fed on wheat seed treated with aldrin for wheat bulb fly control. Many pigeon deaths resulted, but many others only acquired sub-lethal doses,indirectly causing the death of their predators such as the sparrowhawk. This was a striking example of the concentration of poisons in one part of a food chain resulting in death to animals at the end of the chain. The consequence of this and other findings was a partial or total ban on the organochlorine insecticides in many countries. After the organochlorine insecticides, the mercury fungicides attracted attention. In Sweden methylmercury compounds, thought to be derived from agricultural seed dressings, were found to be accummulating to damaging levels in predatory birds. The position in Sweden was complicated by the widespread use of mercury in industrial processes, but this finding caused other workers to look for similar results in case the use of seed dressings was more dangerous than had previously been realised. The pattern of pesticide usage has thus not only changed due to the development of more efficacious materials, but also due to chemicals, although effective, being abandoned due to their detrimental environmental effects.

The consideration of the environment now demands more research and development for new pesticides, thus increasing costs considerably. The extreme persistence of the organochlorine insecticides made them damaging to the environment, but this persistence was also responsible for the prolonged protection that plants were given by these compounds. Less persistent insecticides are desirable for the protection of the environment, but several applications of these may be necessary instead of one treatment with an organochlorine insecticide. It may thus be uneconomic to apply present compounds to some crops, and researchers will justifiably ignore screening for unimportant pests. Increasing costs will obviously lead to more discerning use of pesticides. The criteria today for an acceptable pesticide are much more difficult to define than 25 years ago when DDT was launched.

The pesticide industry still has an important role to play in plant protection, since chemicals are so valuable for the immediate control of weeds, pests and pathogens affecting crop production and thus eventually our health and welfare. New products are needed. Wild oats, blackgrass and perennial grasses are an increasing weed problem in cereals. No adequate replacement has been found to replace the organochlorine insecticides for use in vegetables, strawberries and bulbs. No concentrated effort seems to have been directed toward the development of locally systemic fungicides for post-harvest use. Post-harvest losses of perishable produce can total more than a quarter of the total harvest. The yields of new crop varieties often fall short of expectations due to soil-borne pests and diseases and a soil disinfectant, cheap enough for agricultural use, is required. The use of insect repellents in agriculture is largely unexplored and warrants much additional research. Developments in plant protection may arise from research on plant growth regulators - compounds which modify the growth of plants to some economic advantage, e.g. cycocel shortens wheat straw and thus prevents loss of yield due to lodging. Plant growth regulators which can confer drought or frost resistance to crop plants would be a great advance for agriculture and horticulture. These are but a few examples of the need for new pesticides.

The sterility technique will not be practical for controlling many insects, but it could play a prominent role in the control and possible eradication of some major insect pests. The success of biological control is directly related to the research effort expended and many more pests may be controlled when countries turn from excessive use of pesticides. Biological control should only be introduced after careful study of the pest community. Where it is possible to introduce biological control, the control is permanent, safe and economic. We must now pay more attention to traditional good agricultural husbandry and hygiene, since these practices have been neglected due to excessive reliance on pesticides. We must also ensure that new pesticides are more specific and do not interfere with natural biological control mechanisms or the environment. If these conditions are fulfilled we can foresee that pesticides will maintain their important role in plant protection.

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TRIALS WITH DIFENZOQUAT FOR THE CONTROL OF WILD OATS (AVENA SPP.) IN WHEAT AND BARLEY AND ON CROP TOLERANCE IN WHEAT

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Summary The results of field trials during 1973 and 1974 with difenzoquat* [1,2-dimethyl-3,5-diphenyl-1H-pyrazolium (cation) present as the methyl sulphate salt] are described. Trials compared the effectiveness of difenzoquat at 0.75 and 1.0 kg a.i./ha at different times of application for the control of *Avena* spp. in wheat and barley. Good control was obtained from both doses at a range of application dates, but the higher dose was more consistent. When applied before the appearance of the first node of the crop, 0.75 kg a.i./ha caused 79-99% reduction of *Avena* spikelets and 1.0 kg a.i./ha 86-100% reduction. Later applications were less effective.

Further trials tested the tolerance of two varieties of winter wheat to difenzoquat applied at 1.0 to 3.0 kg a.i./ha and two varieties of spring wheat at doses of 0.75 to 2.25 kg a.i./ha. It was found that, despite moderate levels of leaf scorch and noticeable reductions in the height of two varieties, grain yield was unaffected except in one variety of winter wheat where difenzoquat applied at 3.0 kg a.i./ha gave a 7% reduction in yield.

INTRODUCTION

Difenzoquat [1,2-dimethyl-3,5-diphenyl-1H-pyrazolium (cation) present as the methyl sulphate salt] coded AC 84,777 has been described by Shafer (1974). Preliminary results of field trials in England with difenzoquat for the control of *Avena* spp. in wheat and barley were described by Winfield and Caldicott (1974). The report presented here gives further results of trials during 1973 and 1974 which compared doses and times of application for control of *Avena* spp. and which tested the tolerance of spring and winter wheat to difenzoquat. Varietal screening trials during 1973 had indicated different degrees of tolerance in wheat varieties, measured by height and vigour reductions, where high doses of difenzoquat were applied. Varieties chosen for more detailed work described here were representative of the most tolerant and least tolerant varieties in screening trials.

* Proposed B.S.I. common name; approved by A.N.S.I. and Weed Science Society of America

METHOD AND MATERIALS

Dosage and timing trials which assessed control of Avena spp. were conducted during 1973 and 1974 in commercial crops of winter and spring sown wheat and barley. The sites were located in Eastern England where natural infestations of wild oats were present. Avena fatua was present at all twelve sites and A. ludoviciana in small quantity at two of these sites.

Tolerance trials which assessed the effects of difenzoquat on vigour and yield of spring and winter wheat were situated in crops which were not infested with Avena spp. The four varieties chosen for tolerance studies, winter wheat varieties Maris Ranger and Maris Nimrod and spring wheat varieties Kleiber and Maris Dove, were, from previous work, believed to differ in their tolerance of difenzoquat. Observations on crop vigour and height after treatment with difenzoquat at 2.0 kg a.i./ha had shown no effect on varieties Maris Ranger and Kleiber, but noticeable reductions in height on varieties Maris Nimrod and Maris Dove.

All trial areas received similar cultural treatment to the remainder of the fields including the use of herbicides for the control of broad-leaved weeds. These applications were timed to allow a minimum interval of 1 day before difenzoquat was applied.

Randomised block designs with three or four replicates were used in each trial and two or three plots were left untreated in each replicate.

In 1973 an aqueous solution of difenzoquat was used and a non-ionic wetting agent was added to spray mixtures at the rate of 0.5% v/v. In 1974 a formulation combining difenzoquat (25% a.i.) with a non-ionic wetting agent was used. Spray mixtures were applied at 200 l/ha and 2.8 kg/cm^2 spray pressure using an Oxford Precision Sprayer fitted with five Allman "00" nozzles 34 cm apart.

The stage of growth of crops and Avena spp. was recorded at each time of application. Details of dates of treatment and growth stages are given in Table 1 and Table 2.

In spring and winter wheat tolerance trials, leaf scorch (yellowing) was scored 7 days after application on a scale of 0 - 9 (0 = no effect, 9 = 100% leaf area discoloured). Crop height assessments were made during July.

Survival of Avena spp. was recorded during July when the majority of panicles were fully emerged. Spikelet numbers were assessed in each plot using the method described by Holroyd (1972).

At harvest, grain yield was assessed in a strip 1.25 m x 14 m cut through each plot with a small combine harvester, and yields were adjusted to 85% dry matter.

RESULTS

1. Dosage and timing trials

General Observations

There were no visible effects of treatments on Avena spp. until 10 to 14 days after application. At this time it usually became apparent that growth of the weed had ceased and there followed discolouration and ultimately death.

The crops treated with difenzoquat at 0.75 and 1.0 kg a.i./ha showed transient discolouration (yellowing) affecting 5 to 20% of the leaf surface, which disappeared after 10 to 14 days. At 1.0 kg a.i./ha difenzoquat had no effect on crop height of winter wheat or barley but small reductions in crop height (2 to 5 cm) were observed in the trial on spring wheat (var. Maris Dove) at site 7.

Control of *Avena* spp.

Mean percentage reduction of *Avena* spikelets by each treatment is presented in Tables 1 and 2 in winter and spring crops respectively.

Table 1

The effects of difenzoquat at two doses and at different growth stages for the control of *Avena* spp.

Crop	Site No. Variety	Time of application*	Growth stage at time of application: Crop**	Wild oats † (no. leaves)	Wild oat spikelets/ m^2 in untreated	% reduction in spikelets†† at two doses (kg ai/ha) 0.75	1.0	Sig. level by "F" test
winter wheat	1	12/4/73	3	2 to 5	4,710	87^{b}	86^{b}	
	Maris	+12	4	3 to 5			98^{a}	0.01
	Nimrod	+26	5	4 to 6		79^{b}	87^{b}	
	2	9/4/73	3	2 to 5	2,746		95^{b}	
	Cappelle	+15	4-5	4 to 5		97^{ab}	99^{a}	0.01
	Desprez	+29	5-6	4 to 5		96^{ab}	99^{a}	
	3	3/4/74	3-4	2 to 5	676	99^{ab}	100^{a}	
	Bouquet	+16	5	3 to 6		98^{bc}	98^{bc}	
		+29	7	4 to 6		76^{d}	94^{c}	0.001
		+30	7	4 to 6			99^{ab}	
	4	3/4/74	4	2 to 5	1,034	97^{ab}	98^{a}	
	Maris	+7	5	2 to 5		92^{abc}	94^{ab}	
	Ranger	+19	6	4 to 5		71^{cd}	68^{d}	0.001
		+30	7	4 to 5			90^{bc}	
	5	9/4/74	4	3 to 5	1,066		99^{a}	
	Maris	+9	4-5	3 to 5			99^{a}	
	Huntsman	+23	5-6	3 to 6			86^{b}	0.01
		+39	7	4 to 6			64^{b}	
winter barley	6	3/4/73	3	1 to 4	438	91^{c}	92^{bc}	
	Maris	+13	4	2 to 4		99^{a}	99^{a}	0.001
	Otter	+31	5-6	2 to 6		97^{ab}	99^{a}	

* date of earliest application and days to subsequent application.

** crop growth stage by Feekes-Large Scale (Large 1954).

† wild oat growth stage by no. leaves on main stem - tillers were also present at 4, 5 and 6 leaf stages.

†† within sites, means with common superscripts are not significantly different at p = 0.05 (Duncan's New Multiple Range Test).

In winter wheat at site 1, only the treatment of 1.0 kg a.i./ha applied at crop G.S.4 gave more than 95% control of wild oats whilst other treatments were significantly less effective. In contrast, at site 2 the five treatments at two doses and three times of application each gave 95% control or greater. At sites 3 and 4 (1974), control was best at the earliest times of application (crop G.S. 3-4 and G.S.4) diminished slightly at G.S.5 and at times of application later than G.S.5 the results were inconsistent at both sites. At the fifth site in winter wheat, applications of difenzoquat at 1.0 kg a.i./ha clearly became less effective after crop G.S. 4-5. In winter barley at site 6 there was a significant improvement in the efficacy of difenzoquat at crop G.S.4 and G.S.5-6 over the earliest applications at G.S.3.

Table 2

The effects of difenzoquat applied at two doses and at different growth stages for the control of **Avena** spp.

Crop	Site No. Variety	Time of application*	Growth stage at time of application: Crop**	Wild oats † (no. leaves)	Wild oat spikelets/ m^2 in untreated	% reduction in spikelets†† at two doses (kg ai/ha): 0.75	1.0	Sig. level by "F" test
spring wheat	7 Maris Dove	3/5/73	3-4	1 to 4	1,243	99	99	N.S.
		+10	4-5	2 to 5		99	100	
		+28	7	4 to 6		98	99	
	8 Sappo	17/5/74	3-4	3 to 4	562	84^{b}		0.01
		+12	5	2 to 5		97^{ab}		
		+18	7	4 to 5		94^{ab}		
spring barley	9 Berac	24/4/73	2	1 to 4	587	94^{b}	92^{bc}	0.001
		+15	4	2 to 5		99^{a}	100^{a}	
		+24	5	3 to 5		86^{c}	93^{b}	
	10 Tern	11/5/73	4	2 to 4	846	99	99	N.S.
		+11	5	2 to 5		98	98	
	11 Julia	30/4/74	2-3	1 to 3	1,098	94	97	N.S.
		+28	5-6	2 to 5		85	90	
	12 Tern	14/5/74	2-3	1 to 4	2,027	92^{abc}	96^{a}	0.01
		+16	5	3 to 5		86^{bc}	95^{ab}	
		+21	7	4 to 6		84^{c}	91^{abc}	

* date of earliest application and days to subsequent application.
** crop growth stage by Feekes-Large Scale (Large 1954).
† wild oat growth stage by no. leaves on main stem - tillers were also present at 4, 5 and 6 leaf stages.
†† within sites, means with common superscripts are not significantly different at p = 0.05 (Duncan's New Multiple Range Test).

Table 3

The effects of difenzoquat on four varieties of wheat not infected with *Avena* spp.

Crop/year:	Winter wheat/1974					Winter wheat/1974				Spring wheat/1974					Spring wheat/1974				
Variety:	Maris Ranger					Maris Nimrod				Maris Dove					Kleiber				
Dose (kg a.i./ha:	G.S.	0	1.0	2.0	3.0	G.S.	0	1.0	2.0	G.S.	0	0.75	1.5	2.25	G.S.	0	0.75	1.5	2.25
Growth stage* at appl^{n}.																			
LEAF SCORCH ** †																			
	3-4	0^{a}	1.3^{b}	2.0^{cd}	3.1^{e}					4	0^{a}	1.0^{b}	2.3^{d}	3.0^{e}		not recorded			
	4-5	0^{a}	0.3^{a}	0.6^{a}	1.5^{bc}	5-6	0^{a}	0.6^{b}	1.7^{c}										
	6	0^{a}	0.6^{a}	1.3^{b}	2.5^{de}					7	0^{a}	1.5^{c}	3.0^{e}	3.5^{e}					
CROP HEIGHT REDUCTION (cm) †																			
	3-4	none present								4	0^{a}	0^{a}	3.3^{b}	5.5^{c}	4	none present			
	4-5					5-6	0^{a}	0.8^{a}	6.7^{b}										
	6									7	0^{a}	2.3^{b}	5.5^{c}	7.5^{d}	6				
GRAIN YIELD (% of untreated) †																			
	3-4	100	98	98	90					4	100	97	102	103	4	100	103	98	100
	4-5	100	95	102	96 (NS)	5-6	100	101	100(NS)					(NS)					(NS)
	6	100	100	97	93					7	100	98	96	95	6	100	103	98	103
	mean	100^{a}	97^{ab}	99^{a}	93^{b}														

* growth stage by Feekes-Large Scale (Large 1954).

** discolouration (yellowing) and tip necrosis on 0-9 scale where 0 = no effect, 9 = whole plant affected.

† within sites, means with common superscripts are not significantly different at p = 0.05.
N.S. = no significant differences.

Treatments in spring wheat at site 7 (1973) gave excellent control (98%-100%) at each of the two doses and three times of application (Table 2). At spring wheat site 8 (1974) only the higher rate of application gave similarly excellent results. In spring barley at site 9 wild oat control was clearly greater following application at crop G.S.4 than at G.S.2 and G.S.5. At site 10 excellent control was maintained between G.S.4 and G.S.5, whilst at site 11 application at G.S.5-6 was less effective than at G.S.2-3. There was no clear indication of optimum time of application at site 12; there being small reductions in control from G.S.2-3 to G.S.5 and from G.S.5 to G.S.7. Comparisons between doses in spring barley showed a strong tendency for greater control from the higher dose at sites 11 and 12 in 1974, but in 1973 at sites 9 and 10 the results were similar in four of the five comparisons.

2. Wheat tolerance trials

Trials in winter wheat

Mean scores for leaf scorch up to 3.1 were recorded where difenzoquat was applied at 3.0 kg a.i./ha to variety Maris Ranger (Table 3), and up to 1.7 at the dose of 2.0 kg a.i./ha in Maris Nimrod. Difenzoquat had no effect on the vigour and height of Maris Ranger but mean reductions in height and vigour of 0.8 cm and 6.7 cm resulted from the two treatments in Maris Nimrod.

There was a statistically significant mean reduction of 7% in the yield of Maris Ranger following doses of 3.0 kg a.i./ha but lower doses had no significant effect on the yield of either variety of winter wheat.

Trials in spring wheat

Leaf scorch in Maris Dove was recorded at scores up to 3.5 for the highest dose of 2.25 kg a.i./ha. Reductions in crop height of up to 7.5 cm were recorded for this variety and were greater following applications at G.S.7 than at G.S.4. No reductions in height were observed in variety Kleiber.

Difenzoquat had no significant effect on the grain yield of either Maris Dove or Kleiber.

DISCUSSION

Dose and timing trials during 1973 and 1974 confirmed the very high efficacy of difenzoquat for the post emergence control of *Avena* spp. in wheat and barley.

The lower application dose of 0.75 kg a.i./ha, whilst giving excellent results from approximately 50% of applications, was not as consistently effective in all crops as 1.0 kg a.i./ha. Particularly in spring wheat and spring barley, it was noticeable that the two doses were approximately equally effective in 1973 but the higher dose gave rather greater control in 1974 irrespective of time of application.

There was no clearly defined optimum time of application of difenzoquat for the control of *Avena* spp. in either of the four crops and results generally demonstrated a high degree of flexibility in time of application. The germination and emergence of *Avena* spp. in the U.K. usually extends into late spring when wheat and barley crops are at "jointing" (G.S.6) or post "jointing" stages, possibly up to G.S.9. In the majority of infested crops the optimum time of application of a foliar acting herbicide is after the growth of the crop has advanced sufficiently to eliminate *Avena* seedlings emerging after application, but before the weed infestation has become so competitive with the crop as to result in yield loss. This optimum time is best defined by crop growth stage, which experience suggests will, in the majority of cases, be between crop G.S.3 and G.S.5. The trials described here indicate that difenzoquat gives excellent control of Avena spp. over this range in both winter and spring crops, and is sufficiently flexible to give similar results with slightly less reliability at later times of application up to G.S.7.

It was not possible in these trials to make applications of difenzoquat earlier than 1st April. Such applications may be appropriate especially in heavily infested winter crops, and it is desirable that applications of difenzoquat in late autumn and early spring should be evaluated.

The tolerance trials in winter and spring wheat demonstrated that, despite appreciable levels of leaf scorch and noticeable reductions in crop height, difenzoquat had little or no effect on grain yield of the four varieties tested. The varieties Maris Ranger and Kleiber were apparently unaffected in vigour and height by the higher rates of application (Table 3), whereas the varieties Maris Nimrod and Maris Dove were noticeably affected, especially after application at the later stage of growth in Maris Dove. Thus there were clear differences between the visible reactions of the four varieties, which were not substantiated by data on yields. Only Maris Ranger, which was quite severely scorched at the higher doses but apparently unaffected in height and vigour, suffered a small but statistically significant reduction in grain yield.

The yield of the three other varieties was unaffected at doses up to 2.0 and 2.25 kg a.i./ha despite leaf scorch and height reduction in two of the three.

Acknowledgements

The author wishes to thank all co-operators who allowed him to carry out these experiments on their crops.

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THE CONTROL OF WILD-OATS IN BARLEY WITH FLAMPROP-ISOPROPYL UNDER A WIDE RANGE OF WEST EUROPEAN AGRONOMIC CONDITIONS

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Summary In 1973/1974 256 field trials were carried out with flamprop-isopropyl (BARNON*) on 32 varieties of spring and winter sown barley in 10 countries of West Europe.

Results from trials on spring barley show that good wild-oat control was achieved when flamprop-isopropyl was applied at 1.0 kg a.i./ha to vigorously growing crops from the end of tillering to just after first node formation. Under conditions normally recommended for application a mean reduction in the total number of wild-oat panicles of 80% was obtained in the Mediterranean countries of Spain, Portugal and Greece. An 87% reduction was obtained in the mid-European countries of Austria and Southern Germany and an 83% reduction in the N. Maritime countries of U.K., Benelux, N. Germany, N. France and Denmark.

A comparison of total panicle counts with spikelet counts was made in the U.K. and Spain. In the U.K. trials a 75% reduction in total panicle counts equated with an 86% reduction in total spikelets. In Spain a 75% reduction in total panicles equated with a 97% reduction in spikelets.

Trials on winter sown barley in the U.K. showed that the best performance (a mean 89% reduction in total wild-oat panicles) was achieved when the application of 1 kg a.i./ha of flamprop-isopropyl was made to vigorously growing crops at or near to the first node stage.

Crop selectivity was good. Only the French cultivar Bettina exhibited straw shortening, but yield increases resulting from wild-oat control were still obtained.

Yield response was dependent on the level of wild-oat infestation. In trials where the infestation of wild-oats was low, yield increases of 5-10% over the untreated control were usual. Where infestations were high, increases of 20-80% were obtained.

*Shell registered trade mark

Résumé 256 essais ont été entrepris, en 10 pays d'Europe occidental, avec le flamprop-isopropyl (BARNON*) sur 32 variétés d'orge.

En ce qui concerne les essais sur l'orge, une bonne efficacité sur la folle-avoine est obtenue a la dose de 1.0 kg m.a./ha du flamprop-isopropyl quand le produit est utilisé, en conditions poussantes, à partir du fin tallage jusqu'a la formation du premier noeud. Avec des conditions normales d'emploi, les réductions moyennes en nombre total d'epis de la folle-avoine durent de 80% dans les pays meridionals - l'Espagne, le Portugal et la Grèce, de 87% en Autriche et dans le sud d'Allemagne, et de 83% dans les pays nord-martimes - la Grande-Bretagne, les pays Bénélux, le Danemark et dans le nord d'Allemagne et de la France.

En Grande-Bretagne et en Espagne une comparaison entre des comptages des epis de la folle-avoine et des spicules fut entreprise. En ce qui concerne les essais brittaniques, on trouve qu'une réduction de 78% en epis correspond a une reduction de 89% en spicules. Pour les résultats espagnols cette correspondance montre une reduction en spicules de 97% avec une réduction en epis de 75%.

Suivant les essais sur orge d'hiver entrepris en Grande-Bretagne, le meilleure performance (89% réduction en epis de la folle-avoine) est obtenu avec une application de 1.0 kg m.a./ha du flamprop-isopropyl au stade du premier noeud, toujours en conditions poussantes.

Vis-à-vis de la plupart des varietés, la selectivité du flamprop-isopropyl est bonne. Bien qu'on note un raccourcissement de la paille de la variété francaise Bettina, en presence d'une infestation de la folle-avoine, une augmentation du rendement fut encore obtenue.

L'augmentation de rendement par rapport aux temoins non traites est liee au niveau d'infestation en folle-avoine. Avec une infestation basse, les augmentations de 5-10% ont ete obtenues mais dans le cas de forte infestation on a noté les augmentations de 20-80%.

*Marque déposé du Groupe Shell

INTRODUCTION

Following the discovery of flamprop-isopropyl en early 1972 an extensive programme of field trials has been carried out in countries of West Europe to define as fully as possible its activity against Avena spp. in the barley crop.

The mode of action of the compound, its chemical and physical properties and initial studies in the glasshouse and field have already been described by Jeffcoat (1974) and Haddock et al (1974). The results of the early field studies indicated that flamprop-isopropyl gives good control of wild-oats in spring barley at a dose of 1.0 kg a.i./ha, when applications are made to an actively growing crop during the period from the end of tillering until just after the first node formation (stages G to I/J after Keller and Baggiolini (1954)). During this period the crop competition complements the severe growth inhibition produced by the action of the flamprop-isopropyl on the treated wild-oat.

In 1973 and 1974 the field trial programme was expanded to investigate the performance of flamprop-isopropyl under a wide variety of conditions and 256 trials were carried out in 10 European countries. The trials were established to study a number of factors including dose rate, timing of application, formulation and compatibility with other herbicides.

This paper summarises the results obtained with the 1.0 kg a.i./ha dose rate of the commercially available 20% w/v e.c. formulation in all the trials.

METHODS AND MATERIALS

Trials details

The trials were laid down on commercial crops of spring and winter sown barley. Field plots measured 2-3 metres by 10-15 metres and were usually sprayed across the rows to minimise variability caused by drilling or fertiliser applications. Four replicates per treatment were randomised in blocks with at least one untreated control plot per block.

Applications were made using a hand precision sprayer giving a spray volume of 250-500 l/ha at a pressure of 2-4 kg/cm^2. In a few trials a Landrover mounted sprayer was used and in these trials the plot length was increased to 20m-30m.

Assessments

1. Wild-oat counts

Wild-oats were assessed in all the trials by means of panicle counts in two to six 0.5m x 0.5m quadrats located at random in the central two thirds of each plot. The actual number of quadrats counted depended on the level of infestation, six quadrats being used when there was a low population of wild-oats (<50 panicles/m^2 in the control plots).

In some of the trials in the U.K. and Spain a more detailed assessment of wild-oats was made by classifying the panicles into one of three size categories:- 1) small panicles with less than 11 spikelets, 2) medium panicles with 11-30 spikelets and 3) large panicles with more than 30 spikelets (Holroyd 1972).

2. Crop health

Observations on crop health were made about one month after treatment and again just before harvest.

3. Yield

Yield data were obtained where facilities for harvesting were available. The area harvested varied between 12.5m^2 - 40m^2 per plot depending on the size of the treated plots and the type of equipment being used.

Regions

The trials can be conveniently grouped into three broad 'regions', those within each group being carried out under basically similar agronomic conditions. A total of 33 trials were carried out in Mediterranean countries, Iberia and Greece, 23 in the mid-European area of Southern Germany and Austria, and 180 trials in the Northern maritime countries of N. France, Belgium, Holland, N. Germany, Denmark and the U.K. An attempt has been made to describe the more important agronomic and climatic conditions prevailing in the regions (Table 1).

In the Northern Maritime region the trials on winter and spring sown barley are considered separately.

Table 1

Growing conditions for barley in Western Europe

Region	Sowing to harvest (days)	Row width (cm)	Period of active stem elongation	Average yields t/ha	Main wild-oats species	Typical weather during growing season
Mediterranean	200	20	April - early May	2.5	A.ludoviciana A.sterilis	Cool/moist then hot/dry
Mid-Europe	180	12	Late May - early June	3.4	A.fatua	Cool/wet then hot/dry
N. Maritime spring barley	120-200	12	May - early June	4	A.fatua	Cool/moist then warm/moist
N. Maritime winter barley	up to 300	12	April - May	5	A.fatua A.ludoviciana	Cold/wet then warm/moist

RESULTS

The results are summarised in three categories for each region: a) the mean percentage reduction of total wild-oat panicles and the range of results included in the mean are given for all of the trials, b) results from trials where the applications were made between the end of tillering and just after the formation of the first node and c) results from trials where the activity of the flamprop-isopropyl was not adversely affected by applications of hormone weedkiller, rain at or close to the time of application, the treatment of abnormally thin crops or by very poor growing conditions that reduced crop competition.

1. Mediterranean Region - Table 2

In 1973, 14 of the 17 trials received applications within the crop growth period G - I/J. The mean reduction of total panicles in these 14 trials was 62% compared with the untreated controls. One trial result was discounted because of rainfall during application and two because of treatment of very poor crops with low plant densities. A mean 73% reduction in total panicles was achieved in the remaining 11 trials which had infestation levels of 10-115 panicles/m^2.

In the 1974 trials, 15 applications at crop growth stages G - I/J gave a mean 70% reduction in total panicles. In 6 trials carried out in normal crop densities a mean 87% reduction was achieved in infestation levels of 10-130 panicles/m^2.

Yield increases of 8% to 55% were obtained from the treatment of crops with low to high levels of wild-oat infestations respectively.

Table 2

Wild-oat control with 1.0 kg/ha of flamprop-isopropyl in the Mediterranean region (Iberia, Greece)

			1973	1974
A.	All trials	No. of trials	17	16
		% reduction of total panicles	53	69
		Range of control (% reduction)	(0-100)	(18-100)
B.	Applications correctly timed	No. of trials	14	15
		% reduction of total panicles	62	70
		Range of control (% reduction)	(43-100)	(18-100)
C.	Applications complying with normal use recommendations	No. of trials	11	6
		% reduction of total panicles	73	87
		Range of control (% reduction)	(61-100)	(72-100)

Varieties treated: Pallas, Union, Hatif de Grignon, Ager, Beca, Hassan.

2. Mid-Europe - Table 3

In 1973, 7 out of the 11 trials had applications within the crop growth period G - I/J and the mean reduction achieved in these 7 trials was 78%. One trial was carried out in an extremely thin crop and one trial was treated with hormone weedkiller 4 days before the wild-oat treatment. Because of the lack of crop competition in the one trial and the known interaction with hormone weedkiller applications made close to flamprop-isopropyl, the results of these 2 trials were discounted. A mean 88% reduction of total panicles was achieved in the remaining 5 trials.

In 1974, the 7 trials treated at the correct crop growth stages gave a mean percentage reduction of 81. The lowest percentage reduction (50%) was the result of a trial in which the crop was suffering severe moisture stress at the time of application.

No yield data were available from these trials.

Table 3

Wild-oat control with 1 kg a.i./ha of flamprop-isopropyl in mid-Europe (Austria/S. Germany)

			1974	1974
A.	All trials	No. of trials	11	12
		% reduction in total panicles	65	67
		Range of control (% reduction)	(3-99)	(25-96)

contd.

Table 3 (contd.)

Wild-oat control with 1 kg a.i./ha of flamprop-isopropyl in mid-Europe (Austria/S. Germany)

			1973	1974
B.	Applications correctly timed	No. of trials	7	7
		% reduction in total panicles	78	81
		Range of control (% reduction)	(46-99)	(50-96)
C.	Applications complying with normal use recommendations	No. of trials	5	6
		% reduction in total panicles	88	86
		Range of control (% reduction)	(62-99)	(71-96)

3. N. Maritime Europe (spring barley) - Table 4

The majority of the trials were carried out in this region.

In 1973, 101 trials were sprayed within the crop growth period from early tillering until formation of the flag leaf (E-L). On the basis of the total number of trials a 74% reduction of total panicles was achieved. A mean 86% reduction of total panicles was obtained from 54 trials in which applications were made between crop stages G - I/J. One of the 54 applications was made shortly before rainfall and 4 others were made close (within 10 days) to applications of a hormone broadleaved weedkiller. When the results of these 5 applications were discounted the mean percentage reduction in the remaining trials was 88.

Wild-oat infestations varied from 14-206 panicles per m^2 in crops yielding from 1.73 - 4.48 t/ha. Yields were measured in 38 of the trials and the mean increase over control was 8%. In the higher infestation levels of over 100 panicles/m^2 the yield increases were 20-50%.

In 1974, 52 of the total 79 treatments were applied within the crop growth stages G - I/J and these gave a mean 61% reduction in the total number of wild-oat panicles. 5 trials were treated with a hormone weedkiller within 10 days of application, 3 trials included the sensitive French cultivar Bettina and 19 trials were in poor crops suffering severe moisture stress. The remaining 25 applications gave a mean 78% reduction in the total number of panicles.

Table 4

Wild-oat control with 1 kg a.i./ha of flamprop-isopropyl in spring barley in N. Maritime Europe

			1973	1974
A.	All trials	No. of trials	101	79
		% reduction in total panicles	74	58
		Range of control (% reduction)	(0-100)	(0-100)

contd.

Table 4 (contd.)

Wild-oat control with 1 kg a.i./ha of flamprop-isopropyl in spring barley in N. Maritime Europe

			1973	1974
B.	Applications correctly timed	No. of trials	54	52
		% reduction in total panicles	86	61
		Range of control (% reduction)	(9-100)	(0-97)
C.	Applications complying with normal use recommendations	No. of trials	49	25
		% reduction in total panicles	88	78
		Range of control (% reduction)	(45-100)	(54-97)

Varieties treated: Senta, Julia, Proctor, Imber, Vada, Zephyr, Lofa Abed, Berac, Mazurka, Ingrid, Wing, Clermont, G. Promise, Hauters, Columba, Villa, Rika, Delissa, Carmen, Trait d'Union.

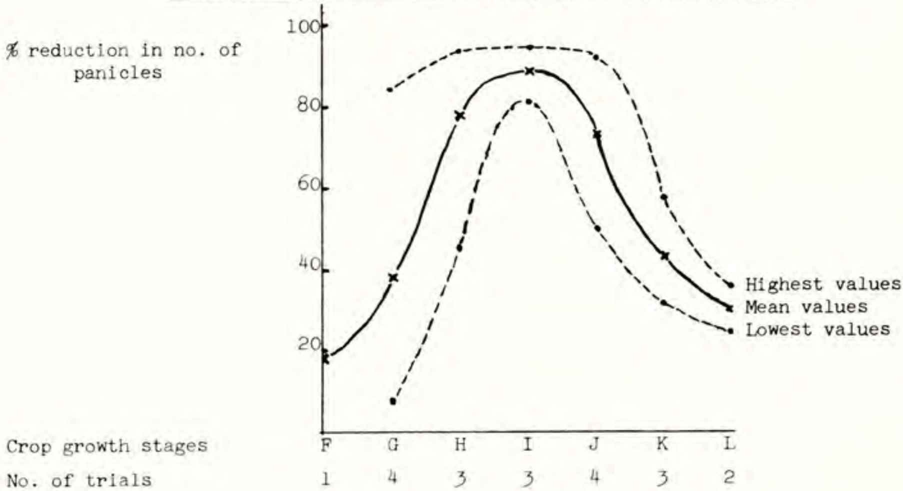
4. N. Maritime Europe (winter barley) - Fig. 1

During the period 1972-1974, 24 trials were carried out in the U.K. on crops of winter barley. In 4 trials there was interaction with hormone weedkillers. The results of these 4 trials have been discounted and the results of the remaining 20 trials are given in Fig. 1.

Yield responses were usually in the range of 20-80%.

Fig. 1

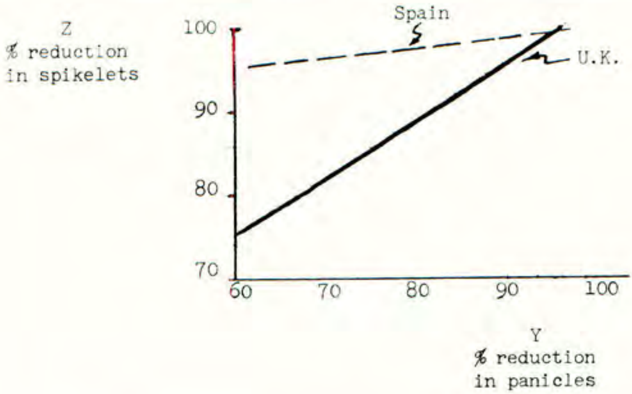
The control of wild-oats with 1.0 kg/ha of flamprop-isopropyl applied to winter barley in the United Kingdom



Assessment methods

Fig. 2

Regression of spikelet assessments (Z) on panicle counts (Y) for 75 pairs of observations in the U.K. and 35 in Spain



A comparison of percentage reduction of total panicles with the estimated percentage reduction in spikelets was based on the U.K. trials in which panicles were classified into three size categories. Within the range of results 60-99% reduction in panicles, the comparison showed a relationship of:-

% reduction spikelets = 33.03 + 0.7063 (% reduction of panicles) (Fig. 2)
The correlation coefficient is 0.89

In 35 observations from trials in Spain the relationship was different, as all results gave greater than 90% reduction in spikelets. A 75% reduction in total panicles equated with a 97% reduction in spikelet numbers.

DISCUSSION

A study of the results shows that the range of performance within a region is similar to that between regions and that all species of wild-oat treated are equally susceptible. It is clear that for good performance with flamprop-isopropyl, application must be made to an actively growing crop and that this is as important a factor as the actual crop stage. This gives a period of 7-20 days for successful application from the end of crop tillering to just after the formation of the first node (crop stages G - I/J).

In the Mediterranean region, mean reductions of total wild-oat panicles resulting from applications to healthy crops during the correct growth period was lower in 1973 (73%) than in 1974 (87%). The difference was primarily due to the survival of a larger number of stunted panicles in the base of the crop in 1973 as a result of poor crop competition caused by wet, cold weather at the time of application. In spite of the lower level of total panicles control in 1973, the mean estimated reduction in total spikelet production in the 8 trials was 97%, showing in fact, a very high degree of wild-oat control.

The trials in Austria and Southern Germany have been dealt with separately since these crops were grown in conditions of low fertility to produce good malting barley. The crop density in these conditions tends to be low with lighter crop canopies and yields. However, provided application was not made to crops suffering severe moisture stress or to crops that had received hormone weedkillers within 10 days of treatment, a high level of total panicle reduction was achieved in both years (mean 88% and 86%).

The data from the large number of trials carried out in North Maritime Europe reflect a change in objectives of the trials in 1973-1974, and the different growing conditions in the two years.

A major objective of the 1973 programme was to define the optimum period for application. In 1974, although most treatments were made during this period, weed control was generally less than expected. This was due to the unusual weather conditions which made the 1974 season totally different to those in the preceding years. Throughout Holland, Belgium, N. Germany, N. France, Denmark and the Eastern part of the U.K. the growth of many spring sown crops including barley, was seriously retarded. When trials were laid down under these conditions reduced crop competition resulted in poorer wild-oat control.

The performance of flamprop-isopropyl on winter barley appeared to be less good than on spring barley in the U.K. until a more detailed study of the data was made. This study revealed that since application was made on a crop growth basis many treatments were made at the G-H stage which occurs earlier in the spring than with the spring sown cultivars. This invariably meant that growth conditions were poor with little crop competition to aid chemical action on the wild oat. The results showed clearly that for good performance it is better to restrict the application to crops at or near to the first node stage, when good growing conditions generally prevail.

Holroyd (1972) pointed out that the objectives of weed control include both the reduction of competition from the weed and the prevention of viable seed being returned to the soil. Clearly the second objective is important in the longer term and should be considered when evaluating the performance of a wild-oat herbicide. Comparison of assessments based on total panicles with total spikelets from trials in the U.K. and Spain confirmed that assessments based on total spikelets gives a more sensitive measure of the control obtained. It is clear therefore that the use of total panicle counts to assess the activity of flamprop-isopropyl in the entire series of trials has underestimated the true performance of the compound.

Yield responses on both spring and winter barley varied with the level of wild-oat infestation. Treatment of light infestations (5-50 panicles/m^2) gave increases up to 10% over control, medium infestations (50-100 panicles/m^2) gave increases of 10-20% and in heavy infestations (100-300 panicles/m^2) substantial increases of 20-80% were achieved.

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THE EFFECT OF REPEATED ANNUAL APPLICATION OF BENZOYLPROP-ETHYL ON POPULATIONS OF AVENA FATUA AND AVENA LUDOVICIANA IN WINTER WHEAT

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Summary Application of benzoylprop-ethyl to the same area of winter wheat each year for three years in the U.K. has reduced the numbers of panicles of *Avena fatua* by 22% in 1972, 95% in 1973 and 87% in 1974. In consequence of this, and of the lower numbers of spikelets present on existing panicles, calculated seed production diminished by 85%, 99% and 88% in each year respectively.
In France, panicle formation in *Avena ludoviciana* has been reduced by 91%, 99% and 97%, resulting in a suppression of seed production of the order of 99% in 1972, 100% in 1973 and 99% in 1974.

Resume L'application de benzoylprop-ethyl chaque année pendant trois ans sur la même parcelle de terrain ensemencée en blé d'hiver au Royaume-Uni a fait diminuer les nombres de panicules d'*Avena fatua* de 22% en 1972, de 95% en 1973 et de 87% en 1974. Par suite de cela, ainsi qu'aux nombres plus petits d'épillets étant présents sur les panicules actuelles, la production de graine s'est réduite de 85%, de 99% et de 88% respectivement chaque année.
En France, la formation de panicules dans l'*Avena ludoviciana* s'est réduite de 91%, de 99% et de 97% donnant une suppression de la production de graine de l'ordre de 99% en 1972, de 100% en 1973 et de 99% en 1974.

INTRODUCTION

A great deal of information has been accumulated on the efficiency of benzoylprop-ethyl as a herbicide for the control of *A. fatua* and *A. ludoviciana* when applied in a single year. Seeds of the weed may remain dormant for long periods and germinate some years after control measures have been taken. Two long-term trials have therefore been carried out to investigate the effect of benzoylprop-ethyl in reducing the population, in winter wheat, of *A. fatua* in England and *A. ludoviciana* in France, by treatment of the same area each year.

The results of the first three year's work are presented and discussed.

METHODS AND MATERIALS

Site 1 was located near Huntingdon on a sandy clay-loam soil infested with Avena fatua. Site 2 was at a location near Toulouse on a silty clay-loam carrying an infestation of A. ludoviciana.

Both sites have been sown with winter wheat continuously since the initiation of the trials in 1972.

Site 1 carried a uniform wheat crop initially, but, in early 1972, waterlogging occurred which resulted in some stunted growth in Spring. There was, in addition, a rather variable A. fatua population, as may be seen from pre-treatment plant counts. An appreciable and increasing infestation of A. myosuroides developed at this site. By May 1974 there were 95 plants/m2.

Site 2 did not suffer waterlogging at any time, and the infestation of A. ludoviciana was quite uniform.

Dicotyledonous weeds were controlled by annual applications of appropriate herbicides.

Experimental design consisted of two single plots, each 12m x 36m in size. One plot remained untreated, the other received applications of benzyolprop-ethyl each year. A central strip of five sub-plots, each 5m x 4m, was used for all assessments in each main plot.

Following the manufacturer's recommendation, the dose used in England was 1.12 kg/ha.a.i. and, in France, 1.25 kg/ha. a.i.

Application was made at crop stage H-J (Feeke's Scale). The basic plant populations of A. fatua and A. ludoviciana were recorded by quadrat counts just prior to treatment. Two to three weeks before harvest all the panicles were counted in 50 x 0.09 square metre quadrats per plot. These panicles were classed as follows :

A. Above crop or level with crop. (Tall)

B. Approximately half crop height. (Medium)

C. Severely stunted. (Stunted)

In 1973, early crop lodging on the untreated plot at Huntingdon resulted in production of panicles on short, late tillers. These panicles are described as ' small ' in the tables of results.

The number of seeds produced each year was estimated as the product of panicles by spikelet numbers x 2 seeds per spikelet. At no time were more than two seeds per spikelet found, either at Huntingdon or Toulouse.

RESULTS

Mean results from treated areas were compared to those from untreated areas by a T-Test. The results of this analysis were confirmed by performing Wilcoxon's Test.

Significance levels are quoted in the table dealing with numbers of panicles per square metre.

TABLE 1

Pre-treatment plant counts
(No. per m^2)

	Huntingdon		Toulouse	
	Control	Benzoylprop-ethyl	Control	Benzoylprop-ethyl
1972	86	108	35	51
1973	192	82	Not available	
1974	169	12	42.5	3

These counts were made normally on the day of treatment, and show fluctuations in the number of plants growing on control areas. The reasons for these variations may include climatic conditions, the period elapsing between harvest and re-drilling and other factors, such as the effectiveness of stubble cleaning and the timing of cultivations.

A major influence may be a build-up in infestation by Alopecurus myosuroides exerting a competitive effect on the A. fatua population at the Huntingdon site.

The extent to which the A. fatua population has diminished due to treatment is also apparent.

TABLE 2

Mean panicle numbers per m^2 at harvest

HUNTINGDON

Panicle Height	Untreated control: Tall	Medium	Small	Total panicles	Treated with benzoylprop-ethyl: Tall	Medium	Stunted	Total panicles
1972	117.1	35.5	-	152.6	25.0	61.3	33.4	119.7
1973	190.0	57.2	10.3*	257.5	0.2	0.7	11.8	12.7
1974	92.3	35.0	-	127.3	7.3	7.5	1.3	16.1

* Panicles formed on late tillers following crop lodging.

TOULOUSE

Panicle Height	Untreated control: Tall	Medium	Small	Total panicles	Treated with benzoylprop-ethyl: Tall	Medium	Stunted	Total panicles
1972	97.9	4.7	-	102.6	0.9	6.0	2.6	9.5
1973	47.1	31.2	-	78.3	0.0	0.4	0.6	1.0
1974	106.3	13.8	-	120.1	0.0	3.2	0.0	3.2

All differences, for tall, medium and stunted panicle numbers, between untreated and treated areas are statistically significant at the 0.1% level except in the case of medium-class panicles at Toulouse in 1972, which were not significantly different.

TABLE 3

Mean spikelet numbers per panicle at harvest

HUNTINGDON

	Untreated control			Treated with benzoylprop-ethyl		
Panicle height	Tall	Medium	Small	Tall	Medium	Stunted
1972	65.6	9.4	-	20.8	9.4	4.2
1973	42.0	12.8	4.6	14.0	7.3	4.1
1974	15.3	6.4	-	18.9	7.1	4.3

TOULOUSE

	Untreated control			Treated with benzoylprop-ethyl		
Panicle height	Tall	Medium	Small	Tall	Medium	Stunted
1972	69.7	30.3	-	8.7	7.3	2.7
1973	47.7	14.4	-	*	6.1	3.1
1974	41.2	12.6	-	*	10.3	*

* No panicles present.

It is of interest to note that there has been a steady decrease, over three years, in the numbers of spikelets per panicle, classed as tall, in untreated areas, both on *A. fatua*, and *A. ludoviciana*. At Huntingdon a possible explanation is the presence of an increasing population of *A. myosuroides*. Quadrat counts in May 1974 showed the number to be 95/m2. This may have subjected the *A. fatua* infestation to inter-species competition, resulting in less vigorous plants producing fewer spikelets.

TABLE 4

Calculated numbers of seeds produced per m^2

HUNTINGDON

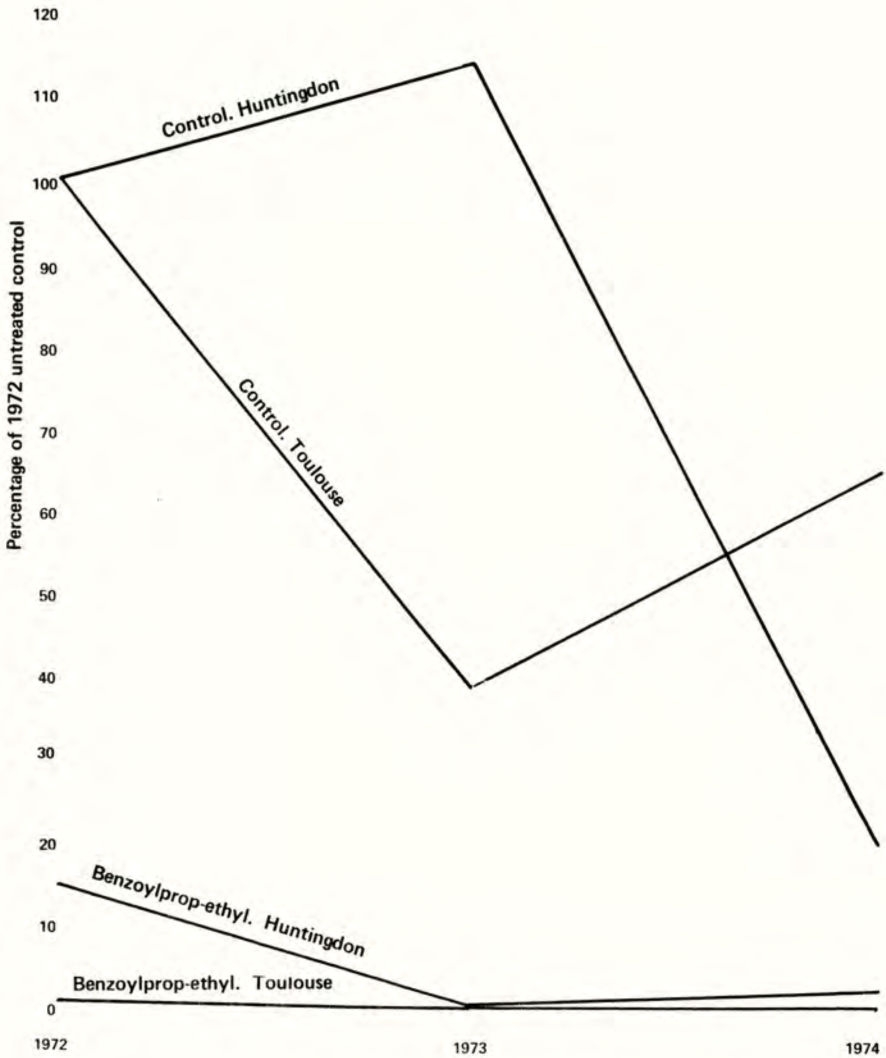
Panicle height	Untreated control: Tall	Medium	Small	Total seeds	Treated with benzoylprop-ethyl: Tall	Medium	Stunted	Total seeds
1972	15,500	670	-	16,170	1,040	1,150	280	2,472
1973	15,960	1,460	950	18,370	6	10	97	113
1974	2,825	448	-	3,273	277	108	11	396

TOULOUSE

Panicle height	Untreated control: Tall	Medium	Small	Total seeds	Treated with benzoylprop-ethyl: Tall	Medium	Stunted	Total seeds
1972	13,650	285	-	13,935	30	82	14	126
1973	4,496	900	-	5,396	0	5	4	9
1974	4,760	348	-	9,108	0	66	0	66

Figure 1

Total seed production as % of 1972 untreated control



DISCUSSION

Panicles formed above crop level or at the same level as the crop always produce the largest numbers of viable seeds, which are largely responsible for carry-over of the infestation, whilst panicles on suppressed or stunted plants contribute much smaller numbers.

It is the total production of viable seeds which is the important parameter to consider in terms of the eradication of the weed.

At Huntingdon, the 1972 application of benzoylprop-ethyl gave relatively poor control of panicle numbers, due, it was thought, to early waterlogging which reduced crop vigour and, therefore, competitiveness. However, total seed production was appreciably reduced, as shown in Table 4 and Figure 1.

The reason for the large reduction of seed numbers in 1972 was due to the good control of the large and highly productive panicles, classed as tall. However, this was insufficient to prevent a relatively high plant count in 1973, indicating that seed numbers had not been reduced very effectively. The degree of control of A. fatua panicles by the more successful 1973 treatment reduced the calculated seed production to a very low level, which resulted in much smaller numbers of plants being present prior to treatment in 1974. The control so achieved suggests the possibility of final eradication by hand-rogueing in the following year, without chemical treatment.

However, there remains the probability that there is a residual ' seed bank ' in the Huntingdon treated area which may result in a continuation of germination over a period of some years.

The dormancy period of A. ludoviciana can be considerably shorter than that of A. fatua, (Thurston 1962) and therefore it is likely that, in the light of the excellent results obtained at Toulouse, very few dormant seeds remain.

In order to confirm these conclusions it will be necessary to extract seeds from the soil and to carry out tests to assess the numbers of non-dormant and dormant viable seeds and dead seeds present.

The trials will continue for at least a further two years in order to gain more information on these aspects and to allow observations to be made on any effects occurring on soil organisms and changes in the broad-leaved weed spectrum.

Reference

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Proceedings 12th British Weed Control Conference (1974)

CONTROL OF WILD OAT WITH NEW CHEMICALS IN WHEAT AND BARLEY

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Summary A number of chemicals were compared against wild oat and other cereal weeds from a total of seven trials during the years 1972-73 and 1973-4 in Greece. Difenzoquat, benzoylprop-ethyl, WL 26624, and flamprop-methyl (WL 29761) at the end of tillering application, flamprop-isopropyl at mid-tillering and perfluidone at early tillering gave the highest and most consistent control of Avena spp. 5-chloro-4-methyl-2-propion (TO-2), ipuron/dinoterb (Exp. 3154), chlortoluron/mecoprop (Printan 22L), 2,4,6-trichlorophenyl-4-nitrophenyl ether/neburon (SIP 3340) and SIP 3425 gave less satisfactory control, but in general an economic yield response was obtained in cases of heavy weed infestation. Difenzoquat, Printan 22L, Exp.3154, and both SIP formulations caused some temporary chlorosis or necrotic spots on the cereal plants. Perfluidone, Exp. 3154, and Printan 22L also controlled Lolium spp., Phalaris spp. and some broadleaf weeds, and resulted in higher yields than herbicides controlling only Avena spp. in cases of mixed infestation. Data for seeds of Avena spp./m^2 showed that some chemicals, in addition to increasing yield, prevented the return of viable weed seed to the soil.

INTRODUCTION

Wild oats (Avena spp.) as well as Lolium spp. and other grass weeds have increased in importance as weeds in wheat and barley in Greece recently, although selective chemical control has been a possibility for a number of years. The results from earlier work gave sufficient information about the use of herbicides against wild oat and indicated that it could be controlled (Skorda, 1972).

However, the introduction of new chemicals and the appearance of new grass weeds in cereals after wild oat control made it necessary to conduct further trial work against these weeds. In a series of trials at P.B.I. Thessaloniki,Greece, the biological efficiency, crop tolerance and application criteria were investigated for eleven other herbicides against wild oat and other grass weeds as well as broad leaved weeds. The trials were carried out in 1973 and 1974.

This report describes the results of these trials, and discusses the weed control problems of cereals in Greece.

METHODS AND MATERIALS

Experiments of two types were designed: the first to compare the effectiveness of eleven chemicals at different rates and stages of application against Avena spp., Lolium spp. etc, and the second to determine the reaction of the commonly grown wheat and barley varieties to herbicides. Three series of experiments were set up on recent alluvial soil as follows:

Series I. Experiments with heavy wild oat competition:(a) cv.Generoso (bread wheat) with good stand (1974), (b) cv. Capeiti with good stand (1973), (c) cv. Capeiti (durum wheat) with poor stand (1974), (d) cv. Zephyr with good stand (1973).

Series II. Experiments with mixed weed flora in an area in which wild oat control was undertaken in previous years and the wild oat infestation was light, while Lolium spp. population and broad leaved weeds were heavier: (a) cv. Generoso, good stand (1973), (b) cv. Generoso, good stand (1974).

Series III. An experiment on crop tolerance of herbicides with the most important seven wheat varieties and also one 2/rowed and one 4/rowed barley variety in a field with a moderate infestation of wild oat and other weeds (1974).

During the season trials received the usual cultural treatments including the application of herbicides for the control of broad leaved weeds in experiments I(a), (b) on plots treated with herbicides controlling only wild oat.

The main wild oat species was A. sterilis ssp. ludoviciana, which has two germinating peaks, in the autumn and spring, so it could germinate over a very long period. For the first type of experiments randomized block designs with either four or six replicates were used, the plot sizes varying from 10 to 30 m^2, while for the second a split plot design with four replicates was used and a plot size 5.5 m^2.

All doses are expressed in kg a.i./ha. The herbicides used and their formulations were as follows:

1. benzoylprop-ethyl 20% w/v, e.c.
2. WL 26624 12.5% a.i., w/v, e.c.
3. flamprop-methyl (WL 29761) 20% w/v, e.c.
4. Printan 22L (200 g chlortoluron + 200 g mecoprop/l) e.c.
5. perfluidone 50% w.p.
6. SIP 3340 (2,4,6-trichlorophenyl-4'-nitrophenylether 30% + neburon 37%) w.p.
7. SIP 3425 (unknown)
8. TO-2 (5-chloro-4-methyl-2-propion) 50% w.p.
9. Exp. 3154 (240 g ipuron + 200 g dinoterb/l) e.c.
10. flamprop-isopropyl 20% a.i., w/v, e.c.
11. difenzoquat 40% a.i., w/v + 0.5% Triton X100, e.c.

All treatments were applied with an Azo propane knapsack sprayer with cone nozzles 34 cm apart producing a fine spray. Hoeing was done by conventional means and supplemented by hand-weeding where necessary, at the mid-tillering stage. Most of the weather conditions were favourable for the growing season and the crop cover was quite thick when later treatments were applied in March.

A.sterilis populations were measured in all plots by counting in rectangular quadrats at both ends of the plots, just before seed shedding began. Rectangle size was 2 m^2 and included a two metre length of the middle 4 rows of wheat or barley. This was used as measure of the plant population per plot. The wild oat panicles were counted in two categories: panicles above the wheat plants and panicles below them. From each plot 10 panicles of each category were collected, dried, weighed and the spikelets and seeds per panicle were measured. From the same area the whole mass of weeds was collected, dried and weighed.

Grain was harvested from a central strip 1.25 m down each plot using a Hege mini plot harvester and yield recorded in kg/ha (kg/10 m^2 plot).

RESULTS

The results of experiments in which eleven herbicides were compared in bread and durum wheat and barley varieties are presented in Tables 1,2,3,4. In the Tables the dose and stage at application for each herbicide are described.

Crop phytotoxicity

The emerging wheat and barley treated pre-em. with SIP 3340 and SIP 3425 showed a little growth suppression, some yellowing of the leaves, and some small necrotic spots. All these symptoms, more intensive in durum wheat and barley, were temporary and disappeared in some days. Similar symptoms observed in wheat and barley treated post-em. with Exp.3154 were also temporary.

Difenzoquat and Printan 22L caused temporary slight to moderate stand reduction in wheat and some yellowing of the leaves. Wheat was more tolerant of difenzoquat at the 4-7 leaf stage than at the 2 leaf stage. After some days, wheat and barley treated with perfluidone showed dark green colouring and reduced height, similar to the effect of Cycocel treatment. The height difference had disappeared by the heading stage. Some yellowing of the tip of the barley and durum wheat leaves was caused by perfluidone, but only at the late application growth stage.

Wheat was tolerant to TO-2, but in 2 and 4 rowed barleys caused some temporary chlorosis. The chemicals benzoylprop-ethyl, flamprop-isopropyl, WL 26624 and flamprop-methyl caused some chlorosis only in the cases of poor crop stand and heavy infestation of wild oat. Application of flamprop-isopropyl made after the end of tillering gave rise to slight risk of phytotoxicity. Slight and temporary leaf chlorosis was observed in some varieties, but this had no discernible effect on the final yield.

Wild oat control

Application of difenzoquat,benzoylprop-ethyl, flamprop-methyl, flamprop-isopropyl and WL 26624 at the end of tillering gave the best wild oat control. Difenzoquat at early post growth stage was less effective. Early post-em. applications of perfluidone gave wild oat control approaching that obtained with the foregoing chemicals, but lower rates and later applications gave lower wild oat control when measured in terms of total population. However, most of the surviving panicles were short and with few spikelets. Printan 22L gave the same wild oat control with both rates and times of application. Similar control was obtained with Exp. 3154 at the rate of 5.0 kg/ha, followed by SIP 3425 and TO-2. Finally, SIP 3340 gave the poorest control of wild oat, even though the conditions for this chemical were very favourable, as the soil had the necessary humidity at the time of application. The mean number of plants surviving to produce large panicles was noticeably less with benzoylprop-ethyl, difenzoquat, perfluidone, flamprop-isopropyl, flamprop-methyl, and WL 26624 than for other chemicals, especially for the best rate and application time.

Table 1

Effects of herbicides on wild oat density and wheat grain yield as percent of control (1972-1973)

Treatment	Rate kg a.i. / ha	Stage of Wheat at application	Wild oat panicles/m^2			Wild oat height cm			Wheat grain yield kg/ha		
			II(a)	I(b)	I(d)	II(a)	I(b)	I(d)	II(a)	I(b)	I(d)
Control			100 (54)	100 (86)	100 (49)	100 (134)	100 (146)	100 (143)	100 (2930)	100 (2632)	100 (3537)
Hoeing				39cde	86ab		91abcd	92ab		120ab	100cde
benzoylprop-ethyl	1.50	end tillering	20cde	30de		57de	62f		124abc	114abc	
WL 26624	0.60	end tillering		7f			47g			114abc	
flamprop-methyl	0.60	end tillering	15de	3f		64d	44g		117bcd	109abc	
flamprop-isopropyl	1.0	mid tillering			20fg			56d			131a
	2.0	mid tillering			11g			46d			130a
	1.0	end tillering			34defg			68c			112bcd
	2.0	end tillering			30cdefg			52d			122ab
difenzoquat	0.5	4-5 leaves	54b	52bcd	64abcde	86abc	87cde	87b	116bcd	121a	120ab
	0.8	4-5 leaves	41b	39cde	39cdef	90abc	88bcd	85b	121abc	126a	119ab
	1.0	4-5 leaves	28bcd		61abcde	78c		86b	120abc		115abcd
	0.5	7-8 leaves	46b	45bcde		95ab	91abcd		110cde	111abc	
	0.8	7-8 leaves	56b	29e		83bc	82de		120abc	121a	
	1.0	7-8 leaves		27e			86de			112abc	
	0.8	end tillering	10cde			63d			118bcd		
	1.0	end tillering	3e			47e			112cde		
TO-2	2.0	4-5 leaves	51b	46cde	74abcde	90abc	90abcd	86b	130ab	117ab	120ab
perfluidone	3.0	5-7 leaves	39bc	71ab	70abcd	78c	78e	73c	134a	111abc	118abc

Means followed by the same letter are not different at the 5% level of significance for varietal comparisons only

Table 2

Effect of herbicides on grain yield, wild oat density, seeds/m², and total weed dry matter as % of control (1973-74)

Treatment	Rate kg a.i./ha	Stage of Wheat at application	Grain yield kg/ha I(a)	Grain yield kg/ha II(a)	Grain yield kg/ha I(c)	Wild oat panicles/m² I(a)	Wild oat panicles/m² II(a)	Wild oat panicles/m² I(c)	Total weed dry matter g/m² I(a)	Total weed dry matter g/m² II(a)	Total weed dry matter g/m² I(c)	Wild oat seeds/m² mean
Control			100 (1450)	100 (3308)	100 (1067)	100 (86)	100 (38)	100 (85)	100 (335)	100 (639)	100 (425)	100 (1415)
Hoeing			161b	115de	195cde	39de	72ab	37def	30c	43cde	-	45
benzoylprop-ethyl	1.5	end tillering	196ab	-	167fg	18f	-	45def	28c	-	68bc	25
flamprop-methyl	1.5	end tillering	-	-	175def	-	-	1g	-	-	72b	1
difenzoquat	1.0	3-leaves	166ab	-	-	65bc	-	-	51bc	-	-	46
	0.8	mid-tillering	-	-	145g	-	-	37ef	-	-	70bc	33
	0.8	end tillering	-	105e	160fg	-	6fg	8g	-	92d	69bc	4
	1.0	end tillering	198a	117cde	-	14f	3g	-	34c	77ab	-	5
perfluidone	2.0	early tillering	-	131abcd	199cd	-	58bc	80abc	-	37cde	53bcd	40
	3.0	early tillering	-	133abcd	249a	-	26de	53cde	-	19de	30de	25
	4.0	early tillering	-	144a	220bc	-	15ef	27f	-	12e	5e	12
	2.0	5-7 leaves	189ab	129abcd	179def	65bc	78ab	81abc	46c	48bcd	49bcd	50
	3.0	5-7 leaves	199a	128abcd	172ef	38e	54bc	84ab	33c	36cde	49bcd	40
SIP 3340	4.0	pre-emergence	132c	-	227ab	87ab	-	60bcd	78ab	-	40cd	75
SIP 3425	2.5	pre-emergence	186ab	-	242ab	53cde	-	53bcde	51bc	-	47bcd	48
Printan 22L	4.0	3-leaves	164ab	-	-	42cde	-	-	37c	-	-	38
	4.8	3-leaves	190ab	-	-	41de	-	-	34c	-	-	38
	4.8	early tillering	170ab	-	-	44cde	-	-	41c	-	-	39
TO-2	2.0	3-leaves	171ab	-	-	62cd	-	-	53bc	-	-	43
Exp 3154	2.2	mid-tillering	-	131abcd	-	-	74ab	-	-	39cde	-	70
	3.3	mid-tillering	-	135abc	-	-	51bc	-	-	22de	-	46
	4.4	mid-tillering	-	141ab	-	-	44cd	-	-	12e	-	40

Control of other weeds

All herbicides tested except difenzoquat, benzoylprop-ethyl, WL 26624, flamprop-methyl, and flamprop-isopropyl controlled some other grass and broad leaved weeds. In the trial in which the wild oat population was not so heavy, the collected total weed dry matter was higher in the plots of the first herbicides (Table 3).

Table 3

Populations of principal weed species per square metre after use of benzoylprop-ethyl, Printan 22L, perfluidone, SIP 3425, TO-2, Exp.3154, difenzoquat

Weed species	Weed population/m² after treatment *							
	Control	1	4	5	7	8	9	11
Alopecurus myosuroides	56	30	12	30	34	21	-	50
Convolvulus arvensis	2	1	2	1	2	2	3	2
Delfinum consol.	7	7	1	2	0	0	3	8
Lolium spp.	34	26	2	1	6	6	1	28
Papaver spp.	7	7	0	4	0	2	0	15
Phalaris spp.	22	16	5	0	11	7	1	14
Polygonum aviculare	5	5	1	1	0	1	1	4
Veronica spp.	32	47	1	1	0	0	0	37
Vicia villosa	3	1	0	1	1	0	1	8

* Code for treatments from Methods and Materials section

Wild oat seeds per m²

The average reduction of wild oat seeds/m² expressed as a % of the control plots was very high for benzoylprop-ethyl, flamprop-methyl, flamprop-isopropyl, difenzoquat and perfluidone at the most effective rate and time of application (75%, 99%, 54-99%, and 50-99%, respectively). Reduction for SIP 3425 was 52%, for Exp.3154 30-70% and for TO-2 57%.

Grain yield

Almost all herbicides gave significant increases in wheat yields as compared with control plots, though some of them caused substantial stand reductions.

In the series I trials with heavy wild oat competition, the herbicides which only control this weed benzoylprop-ethyl and difenzoquat increased the yield at the rate and time of application as Printan 22L, TO-2, SIP 3425, and perfluidone, which also control other weeds.

The same is not true for the series II trials with mixed weed flora, or in series I with high infection and poor stand. In these trials the herbicide perfluidone gave the highest increase in wheat yield, followed by Exp. 3154, SIP 3340, SIP 3425, which control Lolium spp. and other broad leaved weeds as well. Chemicals benzoylprop-ethyl, flamprop-methyl, and difenzoquat all gave lower yields.

Compared with the untreated control, the highest yields were obtained where difenzoquat was applied at 1.0 kg a.i./ha, at the end of tillering stage(198%). There were no appreciable differences in mean yield as between the two treatments at 1.0 and 1.2 kg a.i./ha at the 3-leaf stage, but differences were always found between the mean effects of the two timings. When applied at the 3-leaf stage Printan 22L gave the highest yield when applied at 4.8 kg/ha, but the control of wild oat was the same in all treatments with Printan 22L.

The highest yields, 220% and 249% compared with the untreated control, were obtained where perfluidone was applied at 3.0 and 4.0 kg a.i./ha at the early tillering stage. Applications at later stages and at 2.0 kg a.i./ha also gave high yield increases, although the wild oat control was not as good as with other chemicals. Probably perfluidone caused growth stimulation and yield increase. This was confirmed with a trial free of wild oat and other weeds, and in the series III trials in which perfluidone resulted in yield increases in most of the wheat and barley varieties tested (see Table 4). The darker colour and reduced height of plants after treatment with this chemical, also indicated some evidence of growth stimulation. The deepest green colouration of plants was observed in wheat varieties which gave the highest yields. The optimum results with flamprop-isopropyl were obtained when applications were made at mid-tillering stage at the rate of 1.0 kg/ha. No differences in yield increase were found comparing results obtained with the ipuron/dinoterb mixture when applied at three different rates.

Treatment with these eleven herbicides did not affect the height, Hl-weight, protein content or 1000 kernel weight of the cereals.

Selectivity

Most of the commonly grown wheat and barley varieties from the major cereal growing areas of Greece have been sprayed at normal or higher dosages with small yield reductions resulting for some of them when in fields with a medium wild oat infestation. Perfluidone treatment resulted in higher yields compared with the untreated controls in all the wheat and barley varieties tested. These yield increases varied from variety to variety but in all cases were higher than those obtained from cereals treated with any of the other chemicals. This fact, when added to the observed deep green colour and reduction in height of the plants up to the heading stage,gives further evidence of growth stimulation properties of this chemical.

Chemicals Exp. 3154 and TO-2 had no adverse affect on the yield of any wheat and barley varieties tested when used at the recommended rate. Chemicals Printan 22L and difenzoquat, when applied at normally used or 10% higher rates, caused yield reductions in some wheat varieties.

DISCUSSION

In this series of trials, good control of wild oat was obtained with chemicals benzoylprop-ethyl, WL 26624, flamprop-methyl, difenzoquat and perfluidone. However, the increases in grain yield, which were observed on all treatments, show a correlation with the levels of wild oat control obtained only in trial with heavy wild oat infestation and good density of crop, but not in medium infection or poor stand. In the latter cases the poor competition of wild oat and the crop plants permitted the development of other weeds, grass or broad leaved, and the yield increases are correlated with the effectiveness of the herbicides against the other weeds. It follows therefore that, in the first case, the best chemicals are those controlling the wild oat only; and, in the second, those controlling a broader spectrum of weeds. The control of wild oat for 2-3 years creates a new weed problem, i.e. other grass and broad leaved weeds.

Table 4

Effect of herbicides on yields of wheat and barley as percentage of yields in untreated plots

Crop and variety	Yield after specified treatments ***				
	Printan 22L (4.8)	perfluidone (3.0)	TO-2 (4.2)	Exp.3154 (4.0)	difenzoquat (1.2)
Wheat					
Amyntas	96	123	100	110	95
Generoso	98	157 **	126 *	158 **	118
Niki	136 *	136 *	174 **	123	120
Strampelli	103	167 **	122	114	131 *
G-02763	110	141 *	119	130 *	101
G-84865	89	127 *	117	127 *	85
G-84909	89	135 *	95	122 *	107
mean	103	141	122	126	108
Barley					
Beka	96	121 *	129 *	99	134 *
Elasson	137 *	137 *	134 *	138 *	131 *
mean	116	129	131	118	132

* significantly different from control at P = 0.05
** significantly different from control at P = 0.01
*** treatment with herbicides at rates (kg/ha) specified in parentheses

The regressions of yield on wild oat control were significantly negative in the trials with high wild oat infestation, but the trials with low infestations showed that the regressions of yield on the density of wild oat population were not significant. In all types of trial, the regressions of yield on total weed dry matter/m^2, collected shortly before harvesting, were significantly negative (Table 2). These results indicate the close relationship between wild oat infestation and total dry weed matter. In low wild oat infection no relationship was found between it and wheat yield, which has been affected by other weed species.

It was found that correct timing of the application of the chemicals difenzoquat, flamprop-isopropyl and perfluidone was the most important factor in obtaining optimum wild oat control and high yield increases.

The application of chemicals SIP 3340 and SIP 3425 was unsatisfactory so far as control of wild oat was concerned, but because of early application (pre-em.) and the control of other weeds, they resulted in high yields. However, pre-em. application in Greece is questioned, because both winter and spring wheat and barley are always sown in the autumn and pre-em. application is very difficult, if not impossible, as the sowing time is very short and adverse weather conditions can prevent not only herbicide application but occasionally sowing also.

Perfluidone gave the best result when applied at the rate of 3-4 kg a.i./ha and at early tillering stage, when the highest grain yield increases were obtained.

It is of interest to note that perfluidone also gave remarkably good control of Lolium spp. and Phalaris spp. compared with the other materials which were active against these weeds.

The measurement of wild oat height, size of panicles and number of spikelets or seeds per m^2 has shown that this type of assessment is particularly important when comparing a herbicide such as perfluidone which tends to reduce the size of the wild oat plants as well as the panicles and number of seeds. Therefore, for some herbicides, such as perfluidone, simple counts of Avena panicles seriously under-estimate the degree of control which has been obtained (Holroyd, 1972). It is clear also, that with the best herbicides, following the correct application procedures, not only are valuable yield increases obtained but also the return of viable weed seeds to the soil is prevented.

Finally, in choosing a herbicide to control wild oat, its ability to give some control of Lolium spp., Apera spica-venti and other grass as well as annual broad leaved weeds is a major asset, as these weed species occur frequently together and, after Avena spp. control, increase rapidly.

Acknowledgements

I would like to thank my colleagues and especially Mr. G. Korpetis, who have all contributed to these experiments.

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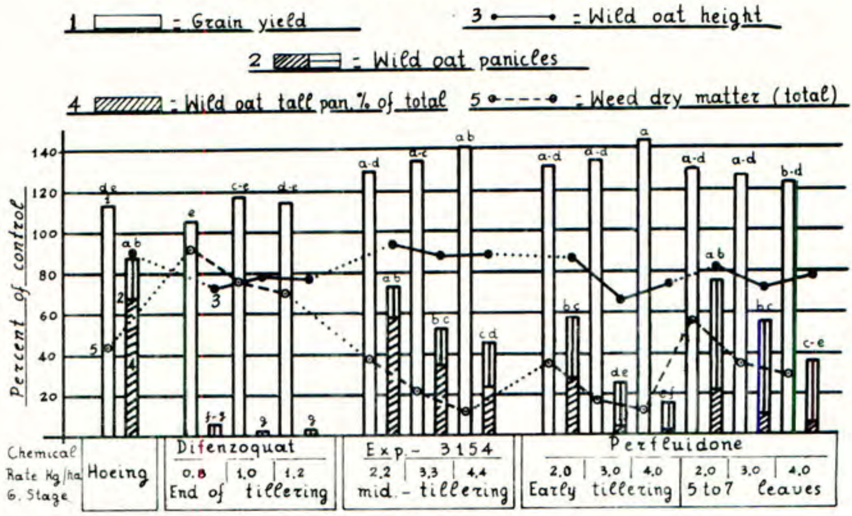
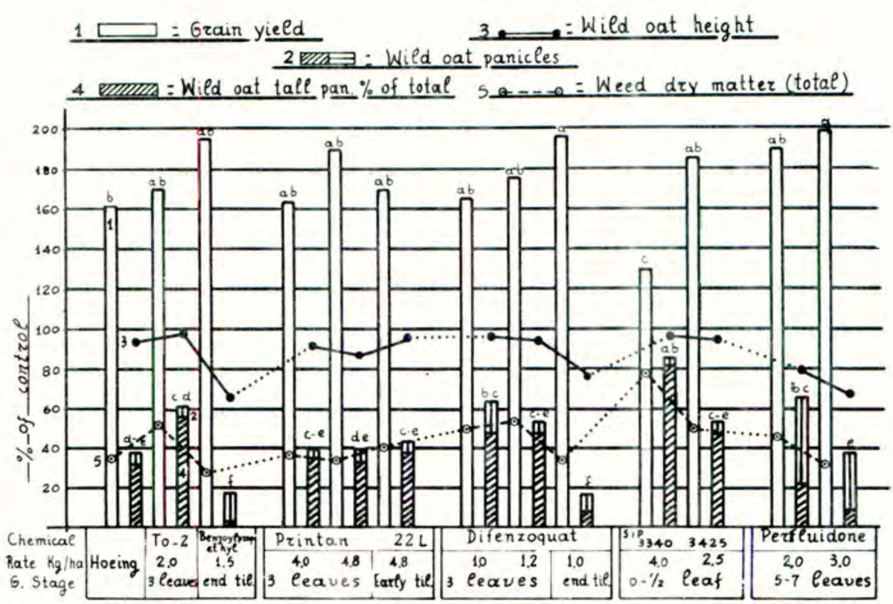
Fig. I(a)

Effect of herbicides on wild oat density, height of tall panicles, total weed dry matter and grain yield.



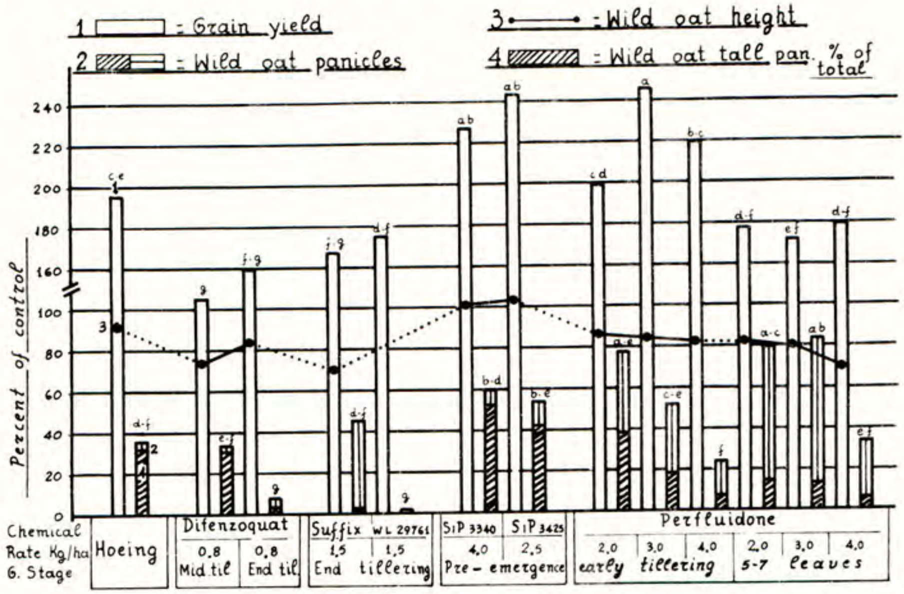
a. Light wild oat infestation. Bread wheat



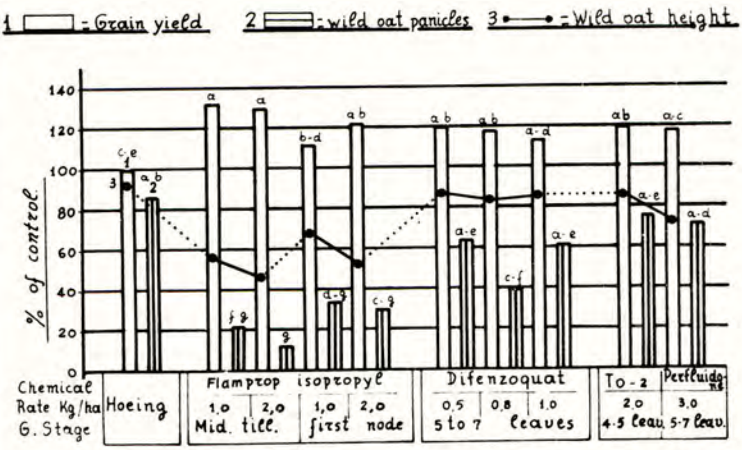
b. Heavy wild oat infestation. Bread wheat

Fig. I(b)

Effect of herbicides on wild oat density, height of tall panicles, total weed dry matter and grain yield.



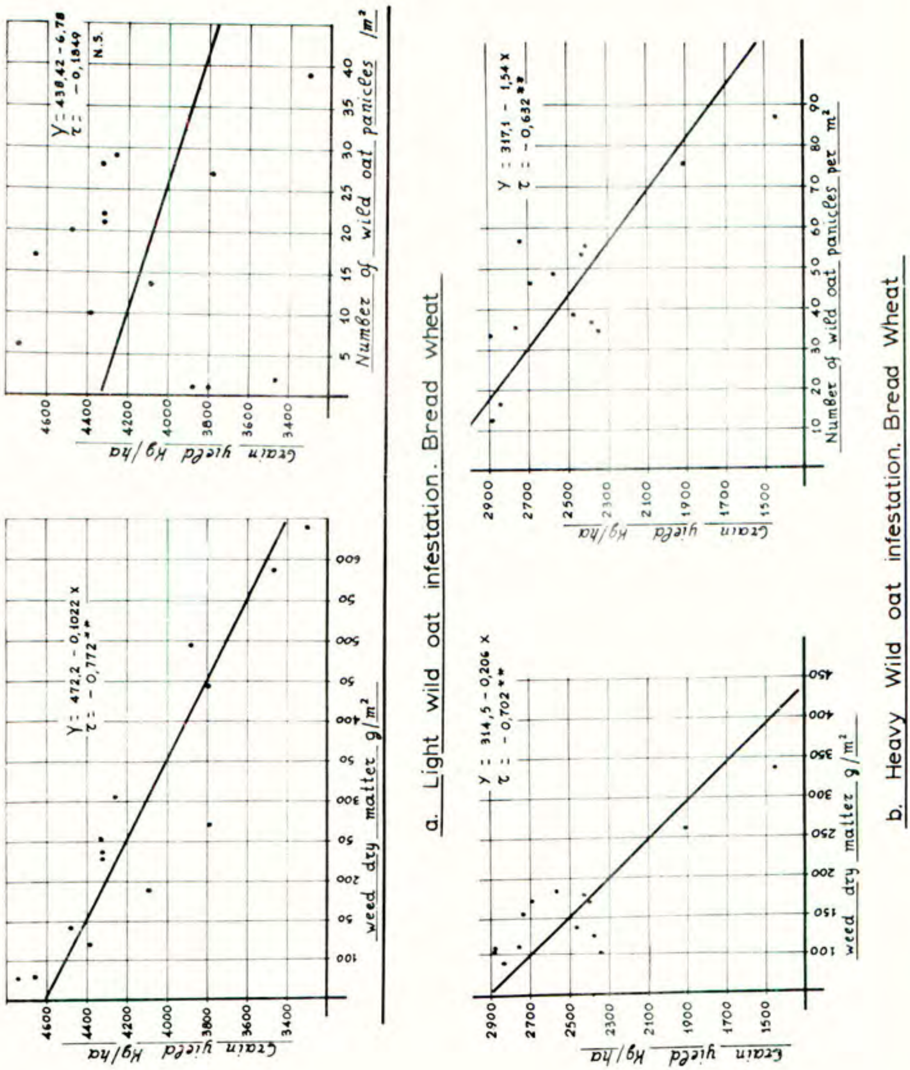
c. Poor stant. Durum Wheat. Heavy infestation Wild oat



d. Barley. Moderately heavy infestation Wild Oat

Fig. 2

Regressions of yield on total weed dry matter g/m^2 and wild oat panicles/m^2.



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THE RESPONSIBILITIES OF THOSE WHO USE HERBICIDES

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In the preparation of my talk, I read again the two papers given at your last meeting in November 1972 on the respective roles of government and industry in relation to herbicides (Tschirley, 1972 and Glasser, 1972). I have been asked today to consider the responsibilities of those who use herbicides.

As you will hear, I did not find it altogether easy to separate the responsibilities of the users from others involved with herbicides, in particular those in industry and government. Nevertheless, as the users of herbicides must form by far the largest proportion of all the people directly associated with herbicides, it is appropriate that we should examine in some detail their particular role.

The users of pesticides are not only numerous, they are also very varied. Some act on their own behalf, others on behalf of a single employer with whom they have close and regular contact, while yet others are employed by large companies and so perhaps are more governed by general rules of employment than by personal supervision related to the use of pesticides. These large concerns may be private, a government agency such as the Forestry Commission or a nationalized industry like British Rail.

The user ranges from those, like farmers, who regularly apply relatively large amounts of herbicides, to the small-scale user such as the suburban householder with his back garden and the research worker in his laboratory testing a new substance. A user may benefit directly from the effectiveness of the herbicide (in the case of a farmer his very livelihood may depend on it), or he may be the employee of an operating company who is paid to apply a herbicide whose effect he may never witness. Their experience and training also varies from very little to the extensive. Some may be highly trained in some other function e.g. in flying in the case of a pilot spraying crops from the air, but may still be almost totally ignorant of the cargo they are carrying or of its effects.

It is probably true to say that the most uniform character that typifies the users of herbicides is their lack of specialist knowledge about the chemistry of the compounds they use, their mode of action and their possible undesirable effect on the environment. We are in the position where society has entrusted a large number of widely differing non-specialist members with the extensive use of what are often highly complex poisons and it expects these people to act in such a way that the remainder of the population is not poisoned and the environment is not harmed. This is a formidable responsibility that has been given to the user and if today, without the benefit of the experience of the last twenty years, we were asked to make a decision as to whether or not we could take this risk, we could be forgiven for having doubts.

It is because of his lack of expert knowledge, that the user is so dependent on specialists. He relies on scientific, medical and agricultural experts for guidance over the choice of herbicides and the techniques to be employed for their application. He receives guidance from other specialists, such as ecologists and water engineers, to advise him over special precautions to be taken to protect the environment. This last consideration is made more difficult however when we consider the countryside generally and its wildlife, for in addition to expert opinion a value judgement is also involved. Society today expects an attractive countryside containing wildlife. This expectation is frequently and at times loudly proclaimed by specialist interest groups and in the media. An indication of the Government's attitude can be gained from the legislation where in sections 11 and 49 (4) of the Countryside Act, 1968 it states:

11 "In the exercise of their functions relating to land under any enactment every Minister, government department and public body shall have regard to the desirability of conserving the natural beauty and amenity of the countryside."

49 "References in this Act to the conservation of the natural beauty of an area shall be construed as including references to the conservation of its flora, fauna and geological and physiographical features."

But what constitutes attractive countryside and a satisfactory number and distribution of wild plants and animals is very much a matter for debate.

Our session this morning is concerned with the environment (this I will take to mean the natural environment minus man himself), so let us now consider the possible unacceptable effects of herbicides on the environment for which the user has a direct or special responsibility (I will not go into any great detail as Dr Way who is talking after me will be considering this aspect in detail).

If we accept the definition of pollution as the wrong thing, in the wrong place at the wrong time (wrong in the sense that it is to the detriment of Man's interests) herbicides can result in pollution of the air, water and the terrestrial environment. Air pollution can be caused by spray drift, water pollution as a result of run-off or rapid drainage from the land and from carelessness or accident when obtaining water or while washing-out equipment. It can also result from a misuse of aquatic herbicides, as can terrestrial pollution as a result of incorrect use of herbicides on the land. Both aquatic and terrestrial pollution can result from careless disposal. Pollution is generally undesirable and should always be reduced by the best practicable means. If it is the result of carelessness it is unacceptable. It can be fairly claimed that prevention of pollution resulting from herbicide use is the foremost responsibility of the user. Most of it results from carelessness. Spray drift need not occur if spraying is confined to suitable weather conditions, as can most instances of run-off of excess herbicide from the land into waterways. The escape of herbicides to waterways from accidents can be readily avoided by careful and disciplined working. Excess of aquatic herbicides in waterways will only occur if instructions are not followed, likewise terrestrial pollution is the result of the wrong pesticide being used in the wrong place or at the wrong time.

To fulfil his responsibilities the user must undertake his practical operations in the field in a thorough and efficient manner carefully following the instructions and advice available to him. All his efforts will be to little avail however if the background research and development by experts, and the translation of these into clear instructions, have not also been carried out thoroughly and efficiently. The user has the responsibility for studying and abiding by the instructions, but if the manufacturer or adviser gives wrong or inadequate instructions the responsibility passes to them. Users should refuse to handle a compound if they cannot fully understand the instructions and manufacturers should constantly take the users views of the effectiveness of their forms of communications with them.

As members of an interdependent society the user, even if he himself has no particular interest in the countryside and its wildlife, should respect the wishes of others to preserve aspects of the countryside. This applies even if it is difficult to decide what it is the conservationists are trying to achieve and their aims do involve value judgements. Such considerations do not release the user from his responsibilities.

Only exceptionally have herbicides been associated with the serious poisoning of animals. An outstanding, and now well documented case, is the teratogenic effects following the use of certain batches of 2,4,5-T. For problems with serious implications of this kind the responsibility could not be said to lie with the user. In Britain the official Advisory Committee on Pesticides and Other Toxic Substances, which includes as part of its responsibilities the effects of pesticides on wildlife, would be expected to take the necessary decisions to cover such a situation.

The main undesirable effects of herbicides on the countryside result from the direct destruction of rare and attractive flowering plants and the changes produced in habitats by the killing of certain of the component species, leading to a diminution of the interest of the habitat itself and of the fauna it supports. In such instances the user can be said to have a direct responsibility for avoiding unnecessary despoliation of this kind in the countryside.

To a considerable extent plain common sense and a bit of personal initiative by the farmer, highway engineer, railway worker or water authority official and all oth other users can play an important part. However there are certain areas of the countryside that have outstanding qualities and to fulfil his responsibilities towards these the user can reasonably expect to be given guidance as to their location and importance and also encouragement for any special efforts he makes to safeguard them.

On the official side the Nature Conservancy Council, which came into existence in November 1973 has the main responsibility. The new Council, which has taken over the work of the old Nature Conservancy, has in addition in the Act been specifically charged with a statutory responsibility to provide advice for the Secretary of State or any other Minister, on the development and implementation of policies for or affecting nature conservation in Great Britain, and in all its functions it must take into account actual or possible ecological changes. By its advice and action therefore it will expect to help users fulfil their responsibilities to nature conservation. Many of the outstanding areas of Britain are now included in National Nature Reserves, the present total is 137. This provides the Nature Conservancy Council with control over their management. The notification to the Planning Authorities of other habitats and areas of outstanding zoological and botanical interest as Sites of Special Scientific Interest (SSSIs) also serves as an important means of identifying areas requiring special care. In the case of SSSIs however the conservation of their scientific interest depends on the co-operation of the owners and occupiers. This is essential if spraying is not to be undertaken.

On the voluntary side the County Naturalists' Trusts are now fully operative and well organised on a Great Britain basis. They have a steadily growing membership. In addition to running their own reserves and helping to advise on their local SSSIs; as members of local communities they have a vital part to play in helping the user when he is planning his herbicide treatments. Members of the Trusts have an intimate knowledge about their very local sites that the Nature Conservancy Council officials with their national role cannot possibly possess. It is an important part of the Trusts' functions that they should readily provide help and advice to herbicide users. Equally one can hope that the users accept as another of their responsibilities that they should contact their local conservationists. Herbicide users understandably are irritated at ill-conceived attacks that are sometimes directed towards them, but in turn they should accept as one of their responsibilities that they have an obligation to make contact with conservationists and to explain to the public what they are doing and why.

I said at the beginning that it had proved difficult to distinguish with any precision the responsibilities of the user. What my review has in fact confirmed is that the user is extremely reliant on others associated with herbicides and that success depends very largely on co-operation. We have had in Britain a remarkable degree of co-operation and success between all those connected with herbicides and conservationists. Conditions are however continually changing, so it is up to all of us, including the large numbers of users scattered throughout the country, to be on our guard against complacency. With this continued co-operation however there is no reason to suppose that effective production of food cannot be continued at the same time as conservation needs are met.

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THE ENVIRONMENTAL IMPACT OF THE USE OF HERBICIDES

THE NEED FOR HERBICIDES

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Summary Herbicides have a minor impact on the environment in comparison with Man's other activities but they play a vital role in the protection of Man's food supply. Assessing the environmental impact is an expensive and lengthy task which should not be complicated by change or unnecessary requirements that can increase costs of research and development to a level where the benefits of new products may no longer be available to provide Man's food supplies. It is suggested that the system of registration adopted in the United Kingdom as a result of close co-operation between industry and the Government should be considered as a model for other countries.

Résumé Les Herbicides causent un choc secondaire aux entourages comparé aux autres activitées de l'homme, mais ils jouent un role très important pour la protection des resources de nourriture humaine. Coter le choc des environs est une tâche couteuse et longue qui ne devrait pas être compliquée par des changements ou par des besoins inutiles, qui pourraient augmenter les frais de recherches et de development à un niveau ou les profits de nouveaux produits ne seraient peut-être plus disponible pour les resources de nourriture de l'homme. On a suggéré que le systeme d'inscription utilisé par le Royaume Uni, étant le resultat d'étroite co-operation entre le Gouvernement et l'industrie, devrait être considéré comme exemple pour tout autre pays.

The environment which we now enjoy has been created by Man to suit his convenience, albeit unconsciously, and has often stemmed from fear - fear of attack by animals or his fellow men, fear of starvation, fear of climate and, perhaps today, fear of status.

The environment certainly cannot be termed "natural", having in many parts of the United Kingdom, for example, been created by the destruction of natural forest cover for the provision of defence, be it ships, fortresses or otherwise. Equally, the environment has been affected by the self-interest of minority groups involved in such activities as land enclosure, not only for agriculture but for hunting and similar activities. The impact of these more recent happenings is far greater than any efforts of primitive Man in removing forest to provide land for cropping. However, all of these activities pale into insignificance compared with Man's impact on his environment today. The demands for roads, minerals, generally higher standards of food and shelter, has a daily, indeed almost hourly, affect on the landscape as we know it. The environment is always changing but the impact of

Man upon it by his multifarious activities creates a dynamic situation in which different activities have the most significant affect on environmental change at any time. However, no matter how viewed, the use of herbicides can be no more than a miniscule drop in the vast ocean of Man's other activities as far as the environment is concerned.

Although Man may not have consciously thought of the effect of his efforts on the environment in the past, today we like to believe that we do contemplate the effect of our actions on the environment now and in the future. This applies whether it be the creation of a new motorway or the use of a herbicide. In considering the impact on the environment of our actions, particularly in the developed countries, we frequently tend to overlook our basic responsibility to our fellow Man, namely, to feed the multitude. The nature of Man's immediate environment is frequently related to his own wellbeing and, more particularly, the state of his nutrition. This applies whether it be the slums of the United Kingdom or in the villages of some of the developing countries. Where poverty exists low levels of nutrition and generally unacceptable environmental circumstances tend to go together. We cannot disassociate wellbeing from environment, nor can we disassociate environment from political considerations and all are closely linked to Man's nutrition.

Thus, in considering the need for herbicides and their impact on the environment, the first requirement is that we should remind ourselves of the world population and food problem which exists today. 460 million people suffer from malnutrition and by 1985 34 countries with a population of 800 million are likely to be suffering from a deficiency of between 100 - 200 million tons of cereals to provide the basic energy necessary for their existence.

In the recent World Food Conference Dr. Kissinger referred to the need to improve world food supplies and indicated a five point programme. Within this herbicides have a clear role in improving and protecting the supply of food.

In any country the combination of land, water, seed will provide a basic potential of food yield. This can be enhanced by the utilisation of fertilizers but the potential is then subject to the deprevations of insect, weed and disease both during growing, storage and processing (GIFAP 1974).

In this paper the concern lies with herbicides, which have the prime objective of enabling the potential of the basic input in terms of land, water, seed and fertilizer to be realised. Traditionally as an industry we measure the effect of herbicides in terms of yield increase but in reality the herbicide prevents loss due to weed competition. In principle it cannot and does not increase yields per se. Examples of the affect of the removal of weeds in enabling the full potential of the crop to be achieved are numerous and at any one of these conferences a range of examples can be obtained. In general the removal of weed competition by herbicide use leads to a crop yield increase. The work of Proctor and Livingstone (1972) in the United Kingdom on grass weed control in winter wheat is typical of the situation. In their case yields of 35 cwts. per acre were obtained from treated areas compared with 26 cwts. in the untreated areas. In other words, the weed competition reduced the potential yield by 9 cwts. This is the equivalent of sufficient grain to feed one man for half a year at Western standards.

It is frequently indicated that this sort of value from herbicides cannot be obtained in the developing countries but experience in the United Kingdom and many other areas indicates that the greatest loss of yield can be prevented by the use of herbicides in the poorer crop situations; the greater the vigour of the crop the more its own ability to compete with weeds. Thus, in areas of sparse cropping the potential improvement due to removal of weeds is likely to be greater than in the vigorous crop; a situation which is perhaps not always recognised in the developing countries in relation to resolution of their food problems.

There can be only one answer to the question "Are herbicides required?", for without them yields would drop to a level where continuous famine would be the lot of Man in the developing countries and perhaps even some of the developed countries. The alternative to the use of herbicides in cropped situations, namely, the removal of weeds by manual means, in many cases is not practical. Generally there is insufficient labour available and frequently the removal of weeds by hand is much less effective than by herbicides. Equally in areas of low nutrition the starving man cannot even hoe his crops.

It is perhaps not out of place to remind ourselves of the development in production over the past years, particularly in so-called sophisticated agricultural areas. In the United States the picture is as follows:

1750 - 17 farmers fed themselves and 1 person;
1850 - 1 farmer fed himself and 4 people;
1900 - 1 farmer fed himself and 7 people;
1940 - 1 farmer fed himself and 11 people;
1970 - 1 farmer fed himself and 46 people;
1974 - 1 farmer feeds himself and 55 people.

In just over two centuries production has increased by 850% in the United States and, according to Dr. Kissinger, there seems no doubt that the United States could produce yet more food to mitigate world cereal deficiencies if it was given the opportunity. It is perhaps significant that the United States has a high technology input in agriculture, in which herbicides are regarded as an important part of maintenance of yields. It is equally of interest to note that the territories showing the greatest yield increase in crops over the past decade are those where the utilisation of herbicides is high.

There is, then, no doubt about the benefit of herbicides but these benefits have to be balanced against the potential problems which can arise from their use. Herbicides, like anything else, can be subject to misuse. Atomic power is a useful source of energy but it can take the form of a nuclear warhead. Herbicides can ensure crop yields but they can be used for defoliation in war situations. We have in this industry, as in any other, to balance the total benefits to Man against the actual and potential risks. It is generally the latter which create concern and cause the emotional outbreaks against this or that particular chemical. But it is perhaps significant that such outbreaks almost inevitably stem from the developed countries and from those who can only be described as "having a full belly". One wonders if the ethics of which they are so fond would be the same if they had to concern themselves with where their next meal would come from.

Turning from the agricultural to the more general use of herbicides, the problems of benefit as against risk, particularly in terms of environmental situations, are much more complex. Herbicides can be used as a tool that can be used in environmental management. Not infrequently Man wishes to change the flora or fauna of an area to suit his needs, for example, the creation of a weed-free lawn. It is perhaps in this context that the use of herbicides and their impact on the environment are most relevant.

Accepting that use in the agricultural sense of removal of weeds from a cropped area is a desirable environmental result, in terms of food production, is it equally desirable in terms of affect on wild life? Recent work has shown that removal of weeds could affect the partridge population in this country but have we in fact tried to create too high a population for the land to sustain? Vesey-Fitzgerald (1968) suggested that a pair of partridge require 10 acres on which to forage, with some emphasis on the need for hedgerows. In a farm location with which the author is reasonably familiar, 100 acres appears to support almost as many partridge. There is no under-usage of herbicides on this farm, nor are there many hedgerows. It is probable that we are trying to carry too many game birds. Surely it is for us to establish our priorities. What type of food do we want? There can be no objective answer for tastes differ but the standards which may apply to an East Anglian farm are hardly those which should be translated to those in a country where starvation is rife.

Turning towards other sectors in which herbicides can be used to manage the environment, three sectors have been selected as a basis for discussion.

1. Industrial Locations

Unwanted vegetation on factory sites creates hazards in terms of fire, corrosion, hiding places for rodents, particularly in food preparation areas, as such, this is clearly undesirable. Herbicides can be used to remove the vegetation and create what is in effect a sterile area. This may well be desirable, for example, in timber yards, railway tracks etc., but there is an alternative in factory areas, namely, to consider the use of herbicides to permit landscaping using shrubs and eliminating hand labour by choice of shrubs to suit the available herbicides. This approach to convert what can be a somewhat unsightly area into an area of attractive appearance without heavy cost is surely something which should be explored further by those concerned with factory and municipal developments. This must surely be regarded as an environmentally desirable use of herbicides.

2. Forest Areas

There can be no doubt that the establishment and maintenance of good forests is an essential requirement in the United Kingdom economy. In many areas accessibility is difficult, weed control, especially during the establishment of the crop, is labour dependent and labour is often not available due to the location of the forest area. By careful choice and use of herbicides forest establishment can be achieved economically utilising available labour.

Equally, in forest areas the creation of recreational sites is now an accepted feature and use of herbicides to control unwanted species, for example nettles (urtica) will permit the maintenance of the areas at acceptable levels with minimal labour input. Such areas, preferably of grass and shrubs, are surely better created and managed through the use of herbicides than the alternative of slabs of concrete in the countryside. Again, correct choice of material can provide an environmentally acceptable use of herbicides.

3. Waterways

Water is one of Man's most vital requirements, not only in terms of survival but in its use as an industrial medium and as a leisure and recreational facility. The need for provision of weed-free, or at least weed-controlled, situations in waterways is clearly recognised. This may be for the purpose of providing easy movement of boats or the creation of the right conditions for angling. One of the more fundamental requirements is to control weeds in such a way as to enable waterways to serve their true function of free passage of water to prevent flooding and to provide clean water that can be handled by pumps without any risk of mechanical damage or blockage. The treatment of water with herbicides demonstrates one of the strongest dilemmas between benefit and risk. Technological information which is now available on materials that can be used in water is such that there can be no case for not using them to create the advantages that are available. It has, however, to be recognised that these are potential contaminants and, as such, a means of determining benefit as against risk needs to be established. Whilst it is inevitable that this area must be subject to emotional and subjective views, attempts must be made to establish an objective approach to such situations.

To provide herbicides which can be used as tools of management within the environment necessitates that they meet a specification which is both specific and yet at the same time general. The herbicides must kill specific weeds in specific circumstances and yet should not affect the environment even when applied without particular care. This challenge has been met by industry who have been ably assisted by the many governmental organisations throughout the world. Assessing the acceptability of a material in relation to its activities outside its direct herbicidal usage is extremely complex. What are the potential side effects? What are we looking for and how do we assess these potential risks and the impact on Man and his environment?

Check lists have been provided on many occasions and, indeed, feature in the protocols for registration in many countries. Edson (1973) and Kradel (1973) have made valuable contributions to this science. The present position can be summarised as one in which herbicidal products should meet the current toxicologically acceptable standards in regard to Man's safety and their affect on his environment.

Current toxicological standards have to be established and recognised but once agreed they should not be continuously changed either within or between countries, merely because new analytical techniques provide means of finding something that we were unaware of at the time of setting the standard. In this connection Mrak (1973) commented: "In summary, today we find ourselves in a position of being well aware of many problems. We find well meaning people with great concern exerting great pressures on those in position to make judgements with the result that unwise decisions and judgements are made too often. This, I presume, is bound to be the situation as long as there is an absence of sufficient and reliable information. We must become more heavily involved in research and the development of methods to use in testing for safety and monitoring and the development of protocols to follow in monitoring. We must develop an understanding of when, where and how to monitor. This applies clear across the board. Until this is done, I am afraid we will continue to have chaos, but fortunately, as a philosopher once said - order comes out of chaos. I must say, we have the chaos so I am looking forward to the time when we will have order."

Certainly Mrak's view cannot be challenged but we may query the concept that change automatically brings order. Any change without due regard to the prime necessity of providing sufficient food is more likely to bring continuing chaos. It is essential that we realise what change may mean within the already time-consuming and costly developments of pesticides. Indeed, we must examine closely the desirability of providing on the one hand specific pesticides for developed countries and, on the other, recognising the need for introduction of even the most elementary use of pesticides in developing countries. These two requirements do not necessarily conflict but they require an acceptance that in some territories development of the older materials may yield greater benefits than concentration on the more recent inventions. The use of new material merely because it is new can rarely be justified.

Untastenhofer (1970) indicated that the cost of developing a pesticide was in the order of £3 - £4 million for a period of 6 - 8 years. Knüsli (1974) suggested \$5 - \$10 million and the following table provides some idea of the scope and volume of the work involved.

INCREASE OF THE MINIMUM REGISTRATION REQUIREMENTS

	1950	1960	1970
Toxicology	Acute toxicity: 30-90 day, rat	Acute toxicity: 90 day, rat 90 day, dog 2 year, rat 1 year, dog	Acute toxicity: 90 day, rat 90 day, dog 2 year, rat 2 year, dog Reproduction, 3 gen., rat Teratogenesis, rodent Fish, shellfish, etc. Birds.
Metabolism		Animal (Min.)	Rodent, and/or dog Plant
Analytical	Food Crops, 1 ppm[a]	Food Crops, 0.1 ppm[b] Meat 0.1 ppm Milk 0.1 ppm	Food crops 0.01-0.05 ppm[b] Meat 0.1 ppm Milk 0.005- 0.05 ppm
Ecology			Environmental Stability Movement Spectrum[c] Accumulation

a = Pesticide only
b = Pesticide plus toxic metabolite (s).
c = Number of species affected - specific or broad range of toxicity.

Source: Johnson J.E. and Blair E.H. (1972) Cost, time and pesticide safety. Chem. techn. November 1972 p. 666.

This requirement for extensive and expensive tests has to be viewed against the relatively short patent life that applies under today's legislation. With 8 years to develop a material only 8 years remain in which to recover the investment in the compound and provide the cash flow for continuing developments. In addition we have to recognise that the security of the original inventor is often diminished by the ready access to registration authority files, which permit the early and rapid marketing of material on which the original work was carried out. The originator has really little to justify his continuing work in this field.

That industry should continue to operate in such a high risk business where the demands for additional information are constantly changing is perhaps a reflection of the concern of the majority of companies with the world food problem.

Not all have found it acceptable to remain in the pesticide business and some have opted out of basic research and there must be many who are re-considering their investment in this area.

Kradel has suggested that there is scope for industry/Government links to provide a means of developing materials with a reduced risk to the originator and perhaps even a greater security to Man and, more especially, the environmental impact of products. Certainly there is scope for some exploration of this area but it would be unrealistic to suggest that anything other than an entrepreneurial approach will provide a continuing availability of herbicides which is so vital to Man's wellbeing and indeed survival.

In this paper a very brief look at some aspects of the role of herbicides in Man's food production and the impact on the environment has been made. No attempt has been made to enter the ethical debate on the investment of industrial concerns in an area which is fraught with both political, economic and emotional problems. Our task must surely be to feed the multitude. We cannot rely on fast or magic to overcome the famine which stares us in the face. It is to be hoped that the good sense of all those concerned with the environment in the broadest sense will never create a situation in which the undoubted benefits to Man in ensuring his wellbeing and survival are sacrificed at the altar of preservation, conservation or emotional considerations related to either that are not linked to a factual situation. Here in the United Kingdom we have arrived at a registration system which has provided the ideal balance between production and risk. Surely we must look to this conference as ensuring that not only does this continue in the United Kingdom but it is also seriously considered by our colleagues in Europe and perhaps other places.

Acknowledgements

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THE ENVIRONMENTAL CONSEQUENCES OF HERBICIDE USE

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We have heard about the need for herbicides and about the regulations and provisions that are made for their safe use. The question that now arises is 'What are the environmental consequences of their use in practice?'. Where they have effects beyond the confines of the weed infestation that they are applied to control, are these effects universally acceptable, debatable or arguably unacceptable? For example, the environmental consequences arising from herbicide use in agriculture as an integral part of crop production are acceptable; the widescale uses of herbicides for aquatic weed control may have environmental consequences that are debatable, largely because we know so little about them; the widescale spraying of selective weedkillers on established roadside verges is not acceptable because the environmental consequences go beyond the need for which the herbicides are applied.

There is not time here to say more than a few words about a number of topics that I think may be of particular interest. In order to set the scene for these, however, I should say, that, considering the potential hazards of using biologically active chemicals to kill plants on a very wide scale throughout the country, the record of safety and of responsible use of modern herbicides has been very high. Problems of animal toxicity have scarcely arisen from terrestrial applications and where they have, they have been confined to local incidents. They have been insignificant when compared to the tonnage of materials used and there have not been any suggestions of accumulative or environmentally unacceptable long term effects from commercial applications. A distinction is drawn here between these and military applications. Field applications of herbicides in agriculture, horticulture and fruit growing have led to changes in weed floras and the population densities of weeds (Fryer & Chancellor, 1970) that pose agronomic but not, at this point in time, widespread environmental problems if the aim in agriculture is clean crops. There have, of course, been changes in insect and other animal populations associated with the changes in the weed flora, but in my view there is no environmental argument against the use of herbicides in crop production that is not entirely outweighed by the benefits to agriculture. Likewise, industrial applications of weedkillers for total weed control have not to my knowledge produced any environmental problems, although there may have been local incidents of trees, and bushes, for example, being damaged when their roots are present inside treated areas even though the plants themselves are outside. The application of total herbicides to rail tracks and cesses is the next largest use of herbicides after agriculture, but I have not seen any recorded side effects from this use.

You may then be wondering what there is to say about environmental consequences. The nub of the matter is that, although modern herbicides have proved very safe in use to man and animals (except for dinoseb and paraquat), they are extremely poisonous to plants. In addition the use of selective herbicides can cause shifts in plant communities in unfavourable as well as in favourable directions, and, because of their ease of application, herbicides can affect plant communities and vegetation generally on a vastly wider scale than was ever possible before their introduction. We are concerned therefore with the environmental consequences of toxicity to plants, with selectivity and with problems of scale of use, in non-agricultural and quasi-agricultural situations. I shall take as my stand the premise that any herbicide use that unnecessarily damages the wild flora, and especially where the economic advantages of application are suspect, constitutes an undesirable environmental consequence that should be avoided.

APPLICATION

Official reports of spray drift remain at about the same level each year and concern economic damage to neighbouring crops and gardens, but it is my observation that there is likely to be much greater damage done to the flora of hedge bottoms and field margins around the arable fields themselves, than are likely ever to be reported or recorded. I would guess that most arable field boundaries receive a good dose of herbicide each year with consequent effects on the native wild plants. I know that in some cases deliberate applications are made to them and I shall discuss this later on. What I am commenting on here is the unintentional application, much of it from drift.

Likewise drift occurs from aerial applications and in my view aerial application of herbicides in small-scale hedged landscapes will always be fraught with hazards. I should have more to say about these if very recent regulations of the Civil Aviation Authority (CAA, 1974) had not severely restricted the application of auxin herbicides from aircraft. Nevertheless some 28 herbicidal compounds or mixtures are listed as being approved in the regulations for application from the air, and it is not correct to say that aerial spraying of herbicides has been banned.

QUASI-AGRICULTURAL

I have argued elsewhere on agronomic grounds (Way, 1972) the case against the use of herbicide sprays, and especially paraquat, to hedge bottoms and around field margins in the absence of subsequent cultivation. Applications to cultivated headlands are a different matter, and are likely to succeed in the control of annual weeds and creeping perennials (such as couch and thistle), where applications to uncultivated areas will almost certainly fail. Not only fail but probably encourage just those aggressive weedy plants that one is trying to control. Apart from the general pointlessness of applications of herbicides to hedge bottoms and marginal land from an agricultural point of view, one is also concerned about the effects of needless habitat destruction on wildlife. A number of other non-crop uses on farms are certainly debatable so far as the achievement of any clear objective can be judged, but are generally unlikely to have environmental consequences.

FORESTRY

The uses of herbicides in forest nurseries, transplant lines and for tree release seem quite unexceptional and are often a necessary part of good tree husbandry. Similarly application of herbicides to clear the ground, and for scrub control, have legitimate commercial advantages that outweigh any effects on habitats. Forest managers are entitled to manage their forests in the way that they feel best and the use of aerial applications of 2,4,5-T/2,4-D to Forestry Commission established conifer woodlands, to remove hardwoods, cannot in this regard be a misapplication, especially as the spraying itself was generally carried out very carefully. Nevertheless the policy of hardwood removal by aerial spraying in the 1960's is a good example of the environmental consequences that can arise from scale of use of herbicides. In half an hour's flying it was possible to kill all the hardwoods in a 100 acre plantation and several plantations could be treated in a week; an exercise that would have been impracticable by hand labour. This would not be important if the policy itself had not been subsequently changed and the presence of a certain proportion of hardwoods in conifers found to be acceptable. It is possible that the policy of removal would never have evolved if the technology had not been available. The problem is that any policy maker can be wrong or can change his mind, but the effects of decisions to apply herbicides to large areas of country will often outlast the life of a particular policy and sometimes the policy maker. These remarks do not apply only to foresters (to whom I apologise for having used their experience to make my point), but equally to many other extensive land managers including the Property Services Agency of DoE, Local Authorities, Airfield Operators, River Authorities, British Rail and others.

FUNCTIONAL AREAS

These are areas associated with a primary land use but whose management, providing it satisfies the needs of that use, can be for other purposes. Roadside verges and railway embankments are particular examples. The largest areas of land in this category are the responsibility of central and local government departments. The widescale (and indeed some small scale) use of weedkillers in management have very serious consequences for the environment in terms of wildlife conservation. I do not think that they necessarily achieve anything for the land manager himself, economically or culturally. Nevertheless there is a temptation to use herbicides and growth retarders and sometimes pressures are applied, particularly to local authorities and often in terms of their wrongly supposed statutory obligations under the Weeds Act, 1959.

There is a school of thought that functional areas represent a great new opportunity for uses of herbicides. There are friends of mine in different places who feel that they have a duty to develop uses of herbicides wherever there is vegetation to be managed. This seems to me to be unwise. I do not see that there is any possibility of large scale uses in functional areas being acceptable economically, or in response to any need so far stated. Although there may well be a need for local applications of materials to solve particular problems, I do not see support for herbicides as a form of management for functional areas in general.

WATER

The increasing interest and use of herbicides in water has been foreseen for some years and is economically justifiable in those instances where there is a real need for control of aquatic vegetation. What are the environmental consequences and are these any different from those that would be produced by hand or mechanical means of vegetation control? The fact of the matter is that we scarcely know. There is very little work on the <u>ecological</u> effects of aquatic herbicides and very few published papers to draw on. There are plenty of reports on the efficacy of various treatments to higher plants and on the problems of direct toxicity to fish; there are fewer reports on effects on other aquatic animals, there are even fewer on the effects of herbicides on the fundamental algal and planktonic components. The number of papers attempting an ecological synthesis of all these strongly interacting factors are not enough to be counted on the fingers of two hands. Thus it is not possible for me to say what the environmental consequences are, and I doubt if anyone can. Here I draw a distinction between envisaging what <u>might</u> occur and being able to say what <u>actually</u> occurs. Considering the widely foreseen increase in the use of aquatic herbicides, and the recognized hazards (the Code of Practice was first produced in 1967), the lack of <u>support</u> for ecological investigations into the environmental consequences of aquatic herbicide usage by user organisations and others having responsibility, verges on the irresponsible.

Uses of aquatic herbicides are open to problems of scale of use, as already mentioned above, and to the vagaries of policy makers. Nobody knows what length of a water course or a river can be treated without environmental consequences occurring

- nor at what level we should start to measure these consequences. In static water, whilst the matter is not predictable, it is known that the most serious effects can be avoided by treating part of the area only at any one time (Newman & Way, 1966). This question of the scale of use is an important one, and is one with which River Boards might well like to concern themselves before evolving policies that could mean the application of herbicides (particularly from the air) to many consecutive miles of waterway during any one season.

CONCLUSION

I should like to conclude by re-emphasising what I see as the main points of this paper. These are the very great benefits of herbicides as an essential part of crop husbandry, and their very good record of safety and lack of unacceptable environmental consequences in agriculture. The usefulness and safety of herbicides used for total weed control by British Rail and by other industries on their premises. The usefulness of herbicides in some other non- or quasi-agricultural situations, including forestry and water. The need to remember that herbicides are not "quite safe" to wildlife but only (and so far as we know) to animals. They are very poisonous to plants and very few plants are weeds. Herbicides have a good reputation for those applications where there are clearly identified and economic needs for their use, and these are widely recognised and supported. This support might be affected by, and there would certainly be opposition to, the invention and development of techniques of herbicide use where there is no economic justification or clearly defined need. Lastly there is the question of scale of use. What may be perfectly safely applied to a small area, might have damaging consequences when applied to a larger one. Policy makers need to be aware that their are additional problems to do with scale, and that whilst policies can easily be reversed, ecological damage arising from bad policies may be more lasting.

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