Introductory Remarks

by

PROF. H. G. SANDERS

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We live in exciting times, exciting agriculturally, because we are seeing a great acceleration in the former very slow process of replacing the old sort of husbandry by the science of growing, and I think exciting because science advances step by step whereas husbandry, something built up over the centuries, is of course an integrated whole which one of these scientific advances could throw off balance. Just for a few years when the combine was introduced it did appear that the farming system might, in fact, be seriously upset. Husbandry in relation to that case was a well-informed aspect and strong enough to absorb that new weapon, the combine harvester, and did not upset the balance.

The advances in the control of weeds have been stupendous, no doubt due to the prowess of the chemists and the biologists and almost surely to the fact that the weed after all is unmitigatingly bad, and control of it must have no adverse side-effects. After all, this whole Conference is based on the idea that a weed is a bad thing and many think that the effect of weed control should be followed up. This is a waste of time since, apart from the obvious things, it depends on the weed and the crop and there are many imponderables if the weed is removed—the gain in ease of harvest and the long-term effect of having the land cleaner than in the past—things that cannot be followed, although chemical weed control in the last ten years or so has changed the face of this country.

That leads one to the thought as to what sort of standard we should aim for in weed control, because these weeds very soon regenerate. Prof. Wain defines a weed as 'a plant which when you pull it up, grows again'. That is a reasonably exact definition and we want to stop it growing again if possible. Treatment of every acre every year, as is done with manuring, is not practicable, partly because it would be very expensive and also because in our uncertain climate the weather is not always suitable.

We want to make a good job of weed control. A 50 or 60% kill is not good enough, and we must get much nearer 100% so that weeds like the dock or that terrible scourge, wild oat, can be so reduced in numbers to make it easily possible to hand-pull a few odd ones left per acre. Other methods of keeping land clean have still a part to play. For instance, take kale. Now we can control fly we can grow several crops of weeds before we sow and then sow on reasonably clean land, and then, spray or pre-emergence treatment might be the complete answer. The only trouble is we don't know what spray should be used and I am very glad to see that we are to hear more on this subject in the course of this Conference.

Those of us who are ignorant on this subject, rather sigh for a pause in this weed control advance; we should like to absorb all we have already got. There are, of course, still many challenges to those who are advancing this important science. Practically all weeds can now be dealt with, but we have had rather resistant weeds, chickweed, for instance, was a difficult problem which has been solved.

The question is whether weed species will develop resistance. Things like the chafer bugs and so on, all seem to develop resistance to chemicals. Of course, the weed has a long tenure. It has taken a long time to develop resistance but it may do it as the years go on and so I wonder whether the answer is mixing herbicides by rotation.

A SURVEY OF INTERNATIONAL PROGRESS IN CHEMICAL WEED CONTROL

by

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Introduction

At the last two Conferences we have had surveys concerning progress in chemical weed control. In 1954 the speakers dealt with Great Britain and the U.S.A., separately, while in 1956 Sir John Russell gave us a charming account of the development of our subject from the time of the first neolithic invaders of our shores, 4000 years ago, to the present day.

My experience of this subject is limited to the last ten years and I propose to talk of progress and some of the factors that influence progress, particularly in this country. The first part of my paper is concerned with estimates of general progress, while the second part relates to some of the more specific advances in chemical weed control during the last two years. I shall be dealing with these problems from the viewpoint of one who is interested in the organisation of applied research and development, rather than in the basic principles underlying the technology of our subject. I shall have in mind particularly the relationships that exist between State and Industry and between those taking part in education, advisory and regulatory activities, as well as those engaged in research and development work.

State and Industry

It is not necessary to state that progress in chemical weed control is dependent on the activities of the chemical industry just as much as it is on the work of the official research organisation, and collaboration between Industry and the State is hence of paramount importance. The nature of this collaboration in different parts of the world varies with the government of the country and with its agricultural chemical manufacturing capacity, if any. On the one hand we have the U.S.S.R. where 'collaboration' is complete and where it has been laid down that more time will be devoted to research on herbicides,[1] and the 1957 production of 600 tons of 2,4-D is to be increased to the calculated requirements of 10,000 tons.[2] On the other hand there are the democratic countries, ranging from those that produce large amounts of herbicide, such as our own, to those that have to import all their requirements. Where large chemical industries exist, the problems of collaboration assume the greatest importance. In countries that import their herbicides, the State has the opportunity of assuming most of the responsibility for testing them in the field and for advising the growers about their use. This is the situation in the Scandinavian countries, but in other parts of the world, where agriculture is not so highly developed, such as British Africa, the State may delegate many of these responsibilities to commercial interests.

Comparisons of the relationships that exist between the State and Industry in the U.S.A. and the U.K. are interesting. In the U.S.A. Industry expects the State to carry out most of the field evaluation of its new chemicals and in consequence to be in a position to give advice concerning their use. In return the State assumes the right to lay down strict laws relating to the application of herbicides, and expects Industry to carry out very detailed research on residues and toxicology. Such provisions have been incorporated into the Miller Amendment (Public Law 518 of the 83rd Congress) and this is probably the most important development in herbicides that has taken place in the U.S.A. during the last few years. Some would not agree that it was progress. In Great Britain, in contrast, Industry sets up its own field research organisations and does most of its own development work on new products. In return, the State lays down the minimum of rules and regulations concerning the sale and use of herbicides, runs a voluntary approvals scheme for proprietary products and allows Industry to sell anything so long as it complies with the Poisonous Substances Act. Manufacturers who operate on both sides of the Atlantic are in a better position than I to judge the relative merits of these two different approaches to the same problem. The progress that results from freedom for Industry must be weighed against the restrictions that are required for the protection of the public.

The Pest Control Products Act of Canada contains sense and moderation. One day, I think that we too will have to require that the quantity and nature of the active ingredients in every proprietary weedkiller will have to be declared before it is offered for sale to the public. Similarly it will be necessary to tighten up on restrictions concerning some of the methods of applying herbicides. It has been found necessary in other countries to restrict or ban the application of 2,4-D and similar herbicides from the air and to insist that aerial spraying operators obtain permission from, or notify local authorities before they are allowed to operate. The British Weed Control Council has already issued warnings concerning the application of growth-regulating herbicides from the air and, if I judge the situation aright, both aerial spraying contractors and chemical manufacturers are hoping for some lead from the State in these matters which would protect them, and the public, from the haphazard use of these chemicals by the over-adventurous.

The rapid progress that has taken place in chemical weed control during the last ten years has been due in no small part to the cordial co-operation that has existed between the official and the commercial people engaged in the practical application of this new technology. Anything that tends to detract from this partnership would be undesirable. The British Weed Control Council is unique in British agriculture and can play an important part in helping to ensure that a happy balance is maintained between the sometimes divergent interests of the State and commercial enterprise.

The assessment of progress

Progress in chemical weed control can be measured in many different ways. The types of statistics used to indicate progress depend upon the interests of the observer. An industrial representative might think in terms of the value of herbicides sold, a teacher or advisory officer in terms of the amount of information transmitted and a research worker in terms of the increase in knowledge. Ultimately, however, the real criterion of progress must be measured in terms of the increased efficiency of crop production made possible by improved techniques of weed control. Such an assessment is extremely difficult to make, even on a single farm, and would be impossible on a country or world basis. This is because weeds are so much a part of the whole problem of crop production that any study of the economics of their control inevitably becomes concerned with the economics of most of the aspects of crop production. For this discussion I will, therefore, confine my observations to progress as measured by:

(*a*) the quantities of herbicides used;
(*b*) the nature and extent of teaching and advisory work on chemical weed control;
(*c*) the research and development work accomplished.

Herbicides used

Figures for the quantities of herbicides imported and exported from different countries of the world are published, and there are, for some countries, fairly accurate estimates of the amounts of herbicide employed for different purposes. Data from the F.A.O. Year Book of Food and Agricultural Statistics[3] show that between 1953 and 1956 the most rapid increase in the consumption of 2,4-D and related herbicides occurred in Austria and Italy. Large increases must also have taken place in other European countries not mentioned, such as Yugoslavia, and in tropical and semi-tropical countries. Frankton[4] in his address at the last British Weed Control Conference gave us some very interesting figures for Canada. He told us, for instance, of the rapid acceptance of 2,4-D by the prairie farmer and how the acreage sprayed had increased from 500,000 in 1947 to 13,000,000 three years later, when 20–30% of the total cereal crop was being sprayed. Warren Shaw[5] gave us similarly startling figures for the expansion in the use of herbicides in the U.S.A., but, as far as I am aware, such detailed data for other countries of the world are not obtainable, although they must be available, in differing degree, to all the large chemical manufacturing firms.

This lack of official statistics, on either the sale or use of herbicides, is particularly apparent in the U.K. Detailed surveys of fertiliser usage are carried out annually and in 1954, '55 and '56 a few questions on herbicides were included in this survey, but nothing has been done since, and Boyd's paper given at the last Conference[6] is still the only published information.

Now that chemicals have become so important on the farm it would seem very necessary that we should know who is using them, how much is being used and how correctly. This information is necessary, not only for the advisory officer, but also for those who are concerned with agricultural policy and with the direction of agricultural research. Nowadays when so much information is collected about the crops that farmers grow and the types of machinery they possess, surely it would not be very difficult to ascertain, if and where herbicides are being applied.

Education and advisory work

Progress in practical weed control relies on teaching in schools, colleges and universities and ultimately on the dissemination of knowledge gained. Most countries have now accepted the fact that chemical weed control is a separate subject that needs its own specialists and its own courses at universities and agricultural colleges. Text books on weed control have been published in Denmark,[7] Holland,[8] Norway,[9] Germany,[10] U.S.A.,[11] U.S.S.R.,[12] Czechoslovakia,[13] and in the U.K. we have our Weed Control Handbook.[14]

In many countries there has been an increase in the number of people engaged in the advisory and regulatory aspects of weed control. In the U.K. chemical weed control is often a very small item in the curriculum of agricultural colleges and university departments of agriculture. I particularly noticed this shortcoming in our agricultural education on my recent visit to East and Central Africa, where time and again I met agricultural graduates from British colleges and universities who had no idea of the principles underlying the different types of herbicidal action and not much idea of how the different herbicides should be used. Unless agronomists responsible for the testing of these new herbicides have some basic training in the mode of action of phytotoxic chemicals, unless they understand, in a general way, how the different herbicides work, how they enter plants, move within plants, and persist both in plant and soil they will never be able to appreciate the ways in which climatic conditions, soil types and formulations are likely to influence their results and it is unlikely that they will make a good job of evaluating the potentialities of the new chemicals.

There is a need for more teaching of both the theory and practice of modern methods of chemical weed control. A lot is said and written about increasing technological training, but technology is invariably limited to the applied aspects of the physical sciences, and applied biology is forgotten. Surely there is also a need for expansion in the teaching of applied biology and in particular the biology of phytotoxic chemicals. There is, as far as I am aware, no college in this country where citizens can take a full-time course in the technology of chemical weed control. Nevertheless, Colombo Plan trainees coming from abroad and desiring to learn about the control of pests and weeds are given special courses, not at a state college, but at a school run by an industrial firm. I have always thought it strange that the State should delegate such responsibilities and that similar courses are not available for our own trainees. The activities of the Agricultural and Horticultural Chemicals Committee of the National Association of Corn and Agricultural Merchants and the Institute of Corn and Agricultural Merchants in organising courses in weed control are a welcome step in the right direction.

Educating the advisor and specialist in weed control must be comparatively easy compared with educating the user of these chemicals. Progress means more and more chemicals and as the number of chemicals increases so each tends to become more specific and limited in its application, for safety is dependent on specificity and specificity is inversely proportional to demand. Eventually the stage will be reached when the average farmer and grower is no longer able to decide for himself which is the correct herbicide for his requirements. In the U.K. we have already reached this stage and, in this respect, are definitely leading the world. Our intensive mechanised agriculture, combined with the ingenuity of our chemists, has resulted in the position that the cereal grower now has ten different chemical types and more than 80 approved herbicides from which to choose.

At present the farmer relies mainly on the advice of technical representatives of manufacturing firms, but this is not always sufficient; he often needs advice from impartial consultants. This could be given by the N.A.A.S., independent consultants, or the specialist advisory services of agricultural merchants. It would be right, I think, for the State to assume

more responsibility in this matter, but this cannot be done unless the advisory service has its own specialists and there are stricter laws concerning the declaration of active ingredients in proprietary products. The responsibility for giving impartial advice seems to be devolving more and more on the merchant who dispenses these materials, but whether he can afford the personal field inspection, often so essential for correct judgment, seems doubtful. It has been suggested that the swing will be back again to the specialist contractor, but this seems unlikely.

Research and development

Progress as measured by the amount of research and development work that is taking place in different parts of the world is not easy to assess accurately. Lists of official research workers engaged on weed control are not very informative, many of the people spend only a part of their time on weed control and, in any case, are often outnumbered by their commercial colleagues. Detailed figures are available, however, for the U.S.A. The number of full-time professional officers employed in the U.S. Dept. of Agriculture on weed control has increased from 17 in 1951 to 60 in 1958 and expenditure at the Agricultural Experiment Stations and in the Agricultural Research Service has risen from approximately $800,000 to $2,300,000 during the same period. Similar figures for European countries, particularly the U.K., would show that the increases in manpower and expenditure have been very much lower, or non-existent.

Another way of obtaining an indication of the amount of research work being done in the different countries is to count the number of scientific papers on weed control that each publish. Obviously there are many sources of error in such a method of assessment and in order to carry it out properly it would be necessary to obtain a complete coverage of the literature and to classify the papers. The amount of work undertaken by scientists is certainly not directly proportional to the number of words they write, in fact, if there is any correlation at all it is probably negative.

However, it is very easy for our Unit at Oxford to carry out such an assessment, as we abstract and index the world literature for our monthly publication *Weed Abstracts*. I therefore asked my colleague Kasasian to prepare a statement, based on the last two years' abstracts, of the numbers and types of papers that had been published on weed control in the different countries of the world. His figures showed extremely good agreement for the two years and were quite revealing. Of the 2000 papers abstracted each year, by far the most came, as might be expected, from the U.S.A. The percentages to the nearest whole numbers were as follows:

		%
(1)	U.S.A.	37
(2)	U.K.	13
(3)	Germany	6
	U.S.S.R.	6
(4)	Canada	4
	France	4
(5)	New Zealand	3
	Australia	3
	Holland	3
	Japan	3

(6) Italy, Yugoslavia, South America, India, Sweden, 1% each.

(7) Denmark, Belgium, Hungary, Austria, Norway, Switzerland. Israel and South Africa, 0·5–1% each.

We also tried to classify the papers originating from the different countries, but the errors involved in this subjective analysis were too high to allow me to present any results. The sort of conclusion we were coming to, for instance, was that the U.K. wrote the most reviews, but that with the U.S.S.R. we shared the honour of publishing the highest proportion of papers that were not worth abstracting. This obviously had little bearing on the amount of research and development work being done in the different countries, and Kasasian gave me his personal assessment, based on the literature, of the amount of work on weed control that is being undertaken in Eastern Europe and the Soviet Union at the present time, as follows:

'Without visiting the area, it is difficult to estimate the extent and calibre of the work for two reasons: (1) we are only just becoming aware of what they are doing; journals have only recently been obtainable and their Biological Abstracts[15] did not appear until 1954/5, and (2) the abbreviated method of presentation, even in their most reputable journals. My general impression is that in Eastern Europe outside the Soviet Union there is very little work indeed being done with herbicides and not much more on weed ecology or cultural methods of control. In the Soviet Union itself, it would appear that most of their work is on the application of existing herbicides. It is estimated that in 1957 approximately 1 million hectares were treated with 2,4-D and MCPA.[16] Much more of their literature is concerned with cultural methods of control than is the situation in the West and the nature of the articles in the purely agricultural and horticultural journals issued by their Ministry of Agriculture suggests that most of their farmers and growers have not heard of herbicides, or, if they have, have only the vaguest awareness of what they can do. However, the first Soviet Weed Control Conference was held last year.'

Weed control conferences

The numbers and distribution of weed control conferences are a good indication of progress. In a subject moving as fast as chemical weed control it is essential to provide a forum where all those co-operating in its progress can get together. Weed control conferences provide the answer and have become an essential part of the development of our subject.

Canada can probably lay claim to being the first country to set up a special organisation to consider weeds. Her Associate Committee on Weed Control was formed in 1924, but it was not until the rapid development of herbicides after the last war that most of the American weed control conferences were started. Willard and Alban[17] record that in those days new techniques meant millions of dollars to those that could use them and that 'manufacturers, dealers and farm papers waited in line to grab the most recent recommendations'. Times have changed, but there is still a need to guard against the hasty adoption of unsubstantiated methods and the pirating of new chemicals. After the American conferences others were started in many parts of the world (see Table I).

Table I

Weed control conferences

Country	Year first conference	Frequency	Country	Year first conference	Frequency
U.S.A.			New Zealand	1948	Annual
Western	1938	Annual	South Africa	1950	One
North Central	1944	,,	Great Britain	1953	Biennial
North Eastern	1947	,,	Germany	1955	First
Southern	1948	,,	France	1956	,,
California	1949	,,	Yugoslavia	1956	,,
Weed Society of America	1956	Biennial	East Africa	1957	,,
Australia	1954	First	U.S.S.R.	1957	,,
			Italy	1958	,,
			East, Central and South Africa	1958	,,

Six countries have held conferences for the first time since our last conference in 1956. This must represent a very large increase in the amount of time and effort that is being devoted to weed control in these countries.

The standard of work presented at weed control conferences varies considerably and organisers always have to decide how best to compromise between the need to present up-to-date interim reports and the necessity to guard against cluttering up proceedings with visual observations on unreplicated plots. Our own conferences have, I think, reached a happy compromise, but this is not the situation in some other parts of the world where the interim reports that are published do not always include descriptions of the way in which the experiments were carried out or give any indication of the accuracy of the results obtained. Such reports can be misleading, particularly to readers in other countries, and clog up an abstracting service.

Particular aspects of progress

It is often more instructive and interesting to consider the outstanding individual developments that have taken place, rather than to review over-all progress. The awakening of interest in herbicides in Europe, Asia and Africa has been accompanied by an increase in research on new chemicals.

New chemicals

During the two years since our last Conference many new herbicides have been discovered and tested. Some are already on sale to the public.

Perhaps the most outstanding group of chemicals that have been tested during this period are the substituted triazines. The herbicidal properties of a few of these chemicals were given by Dr. Gysin in a paper at our last Conference,[18] but other derivatives have since shown many different types of activity, ranging from an immediate contact effect to a slow systemic action, as well as many types of selectivity. We are looking forward to hearing the next instalment in this fascinating story from the man who first discovered their herbicidal activity.

Next in order of interest I would place the discovery of the herbicidal properties of ethylene-di-2,2′-pyridylium dibromide,[19] a completely new type of phytotoxic molecule, with a very rapid action that seems to be dependent on a mechanism of toxicity that is operative only in the above-ground parts of the plant. Again we are very fortunate in having Mr. Stubbs here to tell us more about the herbicidal properties of this chemical.

Another important development in new herbicides has been the introduction of chemicals that are partly volatile and can therefore be used for the control of weed seeds after they imbibe water and before they have fully germinated. Herbicides in this class are, dithiocarbamates such as sodium methyldithiocarbamate and the thiadiazine, 3,5-dimethyltetrahydro-1,3,5-2H-thiadiazine-2-thione, as well as 1,2,4,5-tetrachlorobenzene. We are also to hear of the outstanding aquatic weedkilling properties of another volatile and simple molecule from Mr. Barnsley later in this Conference.

In addition we have the thiolcarbamate EPTC (ethyl *NN*-di-*n*-propylthiolcarbamate) and new variations on old themes such as fluoro-substituted phenoxyacetic acids,[20] phenoxythioacetic acids,[21] 2,3-di- and 2,3,6-tri-chlorophenylacetic acids[22] and variously substituted benzoic acids. We will, I hope, be hearing something of the capabilities of some of these new herbicides from Dr. Beatty in his talk tomorrow.

In the U.K. the most important progress has been concerned with the widespread acceptance of mecoprop (CMPP) for the control of cleavers, chickweed and other weeds of cereals. The properties of this chemical were made public for the first time at our last Weed Control Conference.[23] More recently a mixture of 2,3,6-trichlorobenzoic acid and MCPA has been marketed for the control of weeds in cereals resistant to 2,4-D and MCPA. These are both big steps forward in cereal weed control. In addition dalapon has become more generally available and its place as a grass killer both in temperate and tropical countries is established. Here the Unit of Experimental Agronomy has been responsible for much of the development work and Fryer will be reporting on his experiments with perennial grasses and bracken.

Mixtures of herbicides

The further we progress in chemical weed control the more specific do the new herbicides become and in consequence the more important the mixing of herbicides. During the last few years there has been an increase in the interest in mixtures and this trend is bound to continue.

The advantages of a mixture of herbicides to deal with a mixed infestation of weeds is obvious. Many such mixtures are formulated for sale, e.g. mixtures of 2,4-D and 2,4,5-T for woody weed control, MCPB and MCPA for the control of MCPB-resistant weeds in cereals, MCPA and DNOC for weed control in flax. Sometimes the user can make the mixture himself. For instance, 2,4-D and dalapon can be mixed on the farm for the control of mixed grass and broad-leaved weeds on waste ground. Usually, however, special advantages are claimed for the mixtures and it is stated that there is a beneficial interaction between the components. Sometimes this interaction can be explained, as in mixtures of borate and 2,4-D for soil treatment where the borate prevents the microbiological breakdown of 2,4-D in the soil, but more

often it is not understood. Synergism has been claimed for several proprietary herbicidal mixtures, but there is a lack of detailed data. Much of the work on this very interesting and important aspect of herbicidal development is misdirected and visible progress is slow.

Formulation and application methods

The formulation of herbicidal chemicals can play a very big part in determining their toxic and selectively toxic effects. Progress in this sphere has been pioneered by the U.S.A. and in particular by Dr. Beatty and his company. Developments during the last few years have been many; perhaps the most important of which are granulated formulations, low-volatile ester and acid formulations, and invert emulsions.

Application methods have changed little. The aeroplane and helicopter are becoming more widely used in many European countries and we now have the European Aviation Centre[24] at The Hague. The technique of logarithmic spraying has been tested extensively and has been found to be an invaluable tool for the preliminary field evaluation of new herbicides.[25]

New techniques

In the past, most new herbicides have been developed for application by conventional machinery, to crops that are grown in the normal way. In other words, they have been used as pesticides to remove the pest when it became troublesome, in the same way as insecticides and fungicides are employed to control infestations of insects and fungi.

But there are important differences between herbicides and pesticides which are at last beginning to be appreciated by agronomists and horticulturists as well as by farmers and growers. Weeds, unlike insects and fungi, are always present and can be removed by cultivation. They are in consequence a major factor in crop production. It is not surprising, therefore, that many of the traditional methods of crop husbandry are based on weed control. Herbicides can, in consequence, have a profound effect on methods of crop production, for they give the farmer and the grower a freedom of cropping that has never before been possible. This aspect of progress was considered by Slade at our last Conference.[26] Since then there has been further progress in the introduction of new cultural methods based on the use of herbicidal chemicals.

A series of papers on the advantages of herbicides for killing grass sward prior to reseeding is to be given by Mr. Elliot. This work, which has been pioneered in the U.K. by our Unit, is just the beginning of this wider approach to the use of herbicides. Chemicals will in future be employed to replace many cultivation operations that are now considered essential, and completely new methods of crop production will be developed. For example, a really good selective pre-emergence weedkiller for sugarbeet would revolutionise the mechanisation of this crop; a selective weedkiller for *Agrostis* spp. and *Festuca* spp., the main weeds of grassland, might completely change the existing systems of grassland management, and the laborious cultivations sometimes considered necessary for the preparation of a seedbed might be replaceable, wholly or partly, by use of herbicides.

Such progress, which is concerned with the incorporation of either old or new herbicides into cropping systems in order to develop new cultural techniques, is a task much more for the State than Industry and is an aspect of research with which we in the A.R.C. and the N.A.A.S. are going to be particularly concerned.

In the past, crop production methods were based on the assumption that we had to live with weeds, in the same way as we thought we had to live with many diseases that have now been eliminated. In the future, weeds too will be eliminated, and as we approach this ideal for one crop after another, all who are concerned with crop production will have to devote more and more of their time to re-thinking their subject in terms of weed-free growing conditions. These are indications that this is happening already, e.g. the remarkable selectivity of simazin to maize. If simazin can keep maize weed-free, why shouldn't other chemicals be found that would keep sugarbeet, blackcurrants, raspberries and many other crops weed-free? There is, as far as I can see, no reason why these should not be found, and if the screening of new chemicals proceeds at the rate it has during the last few years, it should not be too long before some are available.

Conclusions

In this paper I have considered, in the first part, some of the general ways in which progress can be assessed, the nature of the essential co-operation between the State and Industry, the quantity of herbicides used, the advisory and educational work, and research and development. In the second part, I have mentioned some of the more outstanding developments that have taken place in the discovery of new chemicals and in their incorporation into old or new crop production systems.

I have been concerned with the more practical side of our subject because this is the primary object of weed control conferences, but it would be wrong to close without drawing attention to the obvious fact that all technologies must be based on scientific principles if they are to progress. So far, our technology seems to have gained comparatively little from basic research. Much of the time of research workers in the laboratories has been devoted to trying to explain why the practical man obtains results, and few principles for his future guidance have emerged. But it is worthwhile remembering that at any time a handsome prize may emerge from basic research. In the meantime, we should make sure that those concerned with the applied side make full use of the increasing knowledge that is accumulating on the mode of action of different herbicides, the factors controlling their entry, movement and persistence in both plant and soil as well as the nature of their biochemical effects at the site of physiological action within the plant, for it is when there is real co-operation between the basic and the applied worker that most progress is made. This co-operation must, however, be a two-way system. In this country it is too often assumed that progress is dependent on a flow of ideas from the laboratory to the field. I have found that those working in the laboratory can often learn as much from the field agronomist as the agronomist can from the laboratory.

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Discussion

In opening the discussion, *the Chairman* (Dr. E. Holmes) thanked Dr. Woodford for his excellent lecture. It was clear that the final arbiter of the value of herbicides was the farmer and not the chemical manufacturer or the advisor.

Dr. William Davies (Grassland Research Inst.).—Weed control by chemicals as well as biological and mechanical means, is now possible. The subject of chemical control is new and as yet not fully charted; mechanical control by ploughing and other cultivations is age old. Many aspects of biological control of weeds such as in some of our grazing systems are also traditional. We must always remember that in dealing with agricultural systems we are in fact dealing with ecology where the weather, soil, crop and animal (including man) all have their place within the ecological environment. If this environment is upset by, say, chemical control of weeds, a whole chain reaction may be triggered off which in some cases at least may need the formulation of new techniques and the discarding of some traditional concepts. Is the plough a necessary tool of the future? It may well prove to be obsolete because basically the plough functions as a mechanical weed controller and current evidence based on critical research suggests strongly that the place of the plough as a *fertility builder* may well be negligible. Improving soil fertility *as such* is clearly not the prime function of the plough and the cultivator, and so we may soon have to regard ploughing and cultivations as obsolete in farming.

Can Dr. Woodford tell me how to control by chemical means ground elder?

Dr. Woodford.—Apart from total herbicides, I would suggest the use of black plastic.

Dr. F. P. Coyne (Plant Protection Ltd.).—It seems to me that Dr. Woodford can hardly sustain his claim that weeds should not be regarded as pests, for that would mean that the British Weed Control Council has obtained the collaboration of the Pesticides Group of the Society of Chemical Industry under false pretences! I prefer to agree with Prof. Sanders that they are pests without any redeeming feature.

I could not, however, even find it easy to agree that the field of weed control is essentially different, in that it does not result in the throwing up of other problems as soon as one is solved. The prominence given to cleavers in cereals following the successful removal of other obnoxious weeds, appears to be a close parallel to the incidence of Johne's disease in cattle becoming more obvious as tuberculosis declined because of successful control.

Mr. A. W. Bennett (Plant Protection Ltd.).—I would like to point out that many commercial firms (including my own) maintain a highly trained field technical service who often appear to be more concerned with giving fine unbiased advice on the use of herbicides as opposed to the sales of any specific products of their own firm.

Dr. Woodford.—The technical service provided by large industrial firms has been and is very good indeed. Nevertheless limitations of the range of that particular firm's chemicals must have some effect on their recommendations to the farmer. My thesis is that commercially available herbicides must also be evaluated by an official body so that true and unbiased recommendations can be made to farmers on a national basis.

Mr. A. L. Abel (Fison's Pest Control Ltd.).—I was interested in Dr. Woodford's remarks on the need for a consideration of chemical weed control as an integral part of crop husbandry and the possibility of other crop rotations being possible through the use of weedkillers instead of normal cultural methods of weed control. As the potato crop is one which has yet to feel the impact of selective herbicides and about which there is some difference of opinion regarding the necessity for cultivations, would Dr. Woodford like to expand his views in relation to this particular crop.

Dr. Woodford.—To answer that question it is necessary to consider the early terms of reference of the A.R.C. Unit. Originally such a programme of work was strongly discouraged because it was considered to be bad husbandry. More recently, this view had been revised and experiments are now in hand.

Dr. R. E. Slade.—Speaking as a farmer, I ask could we be spared the multiplicity of names for products containing the same active ingredient? I see from the excellent *Weed Control Handbook* on sale here, that there are no less than 24 different names for approved products containing MCPA!