OPENING ADDRESS

The Rt.Hon.The Lord Netherthorpe
Chairman,Fisons Limited,95 Wigmore Street,London,W.l.

I am sensible of the honour you do me in inviting me to open this Seventh British Weed Control Conference.

My first happy duty is to extend a warm welcome to all of you here today, in particular the vast representation of overseas countries whose presence is especially welcome.

No country has a monopoly in the battle against weeds and we surely can, and must, learn from one another. For after all we have a common purpose in seeking to free the world from hunger and want.

Adequately feeding and clothing the world's populace is of critical importance if hunger and want are not to unleash the militance of the impoverished and hungry against those more fortunately situated. To horrifically magnify therefore the attendant risks of chemical aids and thereby prejudice their progressive development in improving production can only lead to a slowing down of the challenging task of expanding the economic production of food and fibre for everyone, but particularly the hungry and ill-clad.

My second task is to paint the back cloth to this conference, and here may I congratulate the Programme Committee on the extensive coverage of the papers to be presented.

Whether or not it is accepted that the advent of weeds in man's affairs is a direct consequence of the fall from grace in the Garden of Eden, there is no doubt that over the centuries weeds have been a major preoccupation of cultivators, and since man took to growing crops much of his energy has been devoted to the supression of weeds, and the protection of his crops against competition from undesirable plants.

One of the most exciting agricultural developments in our generation has been the discovery and exploitation of chemical weedkillers, first as a supplement, and progressively as a substitute for the man with the hoe, the draught animal, and mechanically powered cultivating equipment.

At one time the use of chemicals was regarded as a new fangled and rather a mysterious business which should be looked upon with suspicion by right minded farmers. Today the use of chemical weedkillers is an integral part of British and other advanced agricultures, and with a few exceptions we all recognise and welcome the fact that weed science is now proven and here to stay.

To understand the impact on agriculture of chemical weed control it is necessary to understand the significance of weeds in agriculture generally. Native vegetation is not an efficient or economic source of food, and while historically it may have provided a living for a limited population, as population has increased so native vegetation has had to be replaced by purposeful production through the development of new and improved varieties of plants and better techniques of husbandry.

In a country such as ours where the demands on our limited land resources are increasing, and much land is being taken for building houses, factories, roads and other public works, it is becoming increasingly necessary to secure the maximum output by improving production from the diminishing area of agricultural land. During the postwar years the production of British agriculture has risen by getting on to 100 per cent, and while it is not right to imply that this is due solely to the use of chemical weedkillers, there can be no doubt that the efforts of plant breeders, of machinery designers, of fertilizer specialists and of the other technologists concerned with crop husbandry would have been to a large extent frustrated if reliable weedkillers had not been available.

There are some who claim that traditional methods of weed control by the use of cultivations are preferable to the use of chemicals, which admittedly have some inherent defects. Labour and energy are expensive commodities, however, and it would be short-sighted to pretend that under present day conditions there is any reasonable alternative to chemical weed control in many of the crops that we grow on our farms, if these crops are to be produced at all economically. Our labour force on the land is progressively declining in numbers, and even if it were economic and we wished to persevere, it is understandably no longer possible to persuade workers to devote the greater part of their lives to the unremitting toil of hand work. Just as mechanical power has replaced man-power and horse-power, so now chemicals are progressively replacing mechanical energy in the fight against weeds.

Many of us will remember the days when yields of cereal and other crops were reduced by 50 per cent, or maybe more, as a consequence of the presence of weeds which could not be controlled economically by physical means. Quite apart from the adverse effect on yield, weeds in the past reduced the quality of many crops, made harvesting unduly difficult and impeded the introduction and development of mechanical devices for row crop work and for harvesting, as well as many other operations on the farm. It is gratifying these days to drive through the countryside at harvest time and see thousands of acres of farm crops which are virtually weed free; this is a very different picture from that which we used to see years ago and is a measure of the contribution of the chemical industry to weed control.

Quite apart from the obvious benefits of chemical weed control as an efficient means of removing weeds from crops other benefits accrue which are not quite so obvious. Probably the main of these is the speed with which chemical weedkillers can be applied and the consequent saving of time and labour. Today it is possible to spray with a ground machine anything up to 100 acres a day, and with an aircraft a substantially larger acreage can be sprayed, although of course aircraft are not so extensively used for weed control because of the danger of drift onto neighbouring susceptible crops. This general streamlining of an important farm operation, winning time as it does, is in keeping with the present day progressive trends in British agriculture.

Despite the successes of the past few years many difficulties remain to be overcome. This after all is to be expected in any biological science and therefore does not give us, the enlightened, any cause for alarm. Indeed it is the object of conferences such as this to allow specialists to meet together to discuss their problems and the possible solutions. After all progress is built up of mistakes rectified.

If one looks back over previous weed control conference programmes it is interesting to note how the trend in the papers which are presented has been moving away from specific observations towards the more general consideration of the place of chemical weed control techniques in agriculture. This is a line of investigation which must continue for many years to come.

It is questionable whether even at this time, when we have so many good weedkillers available, the farmer is obtaining the fullest possible benefit from them. And undoubtedly there are many new uses in which even the existing weedkillers could be profitably employed. The science of chemical weed control is not circumscribed, nor is it an end in itself but a discipline which must be knitted into the whole practice of agriculture if it is to make its fullest contribution.

To this end we have to strive to acquire a greater knowledge of

> the biology of weeds;
>
> the changing weed flora as influenced by the use of chemicals and by changing farm practices;
>
> the role of cultivation in the growing of crops and in the control of weeds;
>
> the economics of the use of chemical weedkillers in comparison with other methods of weed control and their influence on profitability and productivity, and the most effective and efficient methods of application.

This calls for the closest co-operation between scientists and technologists engaged in many different branches of agriculture: engineers, biologists, chemists, agriculturists and numerous others. The Royal Agricultural Society of England motto was not idly chosen as "Science with Practice".

While workers in the field of weed control can look back on many successes, much still remains to be done and this represents a stimulating challenge to all those engaged in this worthy pursuit.

The pattern of weeds on our farms is changing due to the use of chemicals and to the changing practices of agriculture. New varieties of seeds and plants, new machines and new methods of cultivation are being introduced year by year and there is a trend towards greater specialisation and to the growing of a more limited number of crops on our farms. There is also a trend towards the production of crops for processing as distinct from sale on the open market. This calls for the introduction of chemicals to meet new weed complexes as they arise and also of other chemicals to deal with problems in crops which hitherto may not have been of great importance.

Standards of cleanliness and quality set by a processing company are often much higher than those that have been required in ordinary practice, and one consumer's idea of quality can well be quite different from the standards of another. Weedkillers have a part to play in facilitating the growing of crops to meet these special and more stringent demands.

On our large cereal growing farms grass weeds are assuming ever increasing importance and this is a matter which is being, and will have to be, given increasing attention. For instance, couch grass is frequently mentioned as one of the most intractable problems facing the arable farmer today, and although some control can be obtained by the use of chemicals, it seems that the final solution may lie in the combination of cultivation, rotation and chemical weedkillers. As with couch grass, so also annual grass weeds are becoming more important, particularly in cereal crops, and although some measure of success has been obtained, British farmers would welcome more effective and more efficient means of controlling these weeds.

For some of our arable crops and market garden crops there is as yet no really effective selective weedkiller available and we must not forget the difficulties which face the farmers on special soil types such as the Fens where many of our weedkillers prove less effective. In this context it is as well to remember that the drainage of the Fenland depends on the ability of farmers and drainage boards to keep the water courses free of weeds. With the ever increasing costs of labour it will soon no longer be economic to remove weeds from drainage ditches by hand, or even by mechanical means, and we hope that it will not be so long before really effective and safe weedkillers can be developed for this purpose.

Another branch of agriculture in which it seems weedkillers have not been used to the fullest possible effect is grassland husbandry; my farmer's eye tells me this is a science too long neglected. For some reason, possibly for economic reasons, farmers have not taken advantage of the chemical weedkillers which are available for the control of noxious weeds in grass to anything like the same extent as they have exploited these materials on arable crops. Yet grass is the most important single crop that we grow in this country. If in fact this is an economic problem, then we look forward to the day when the returns that can be obtained from spraying grassland can be demonstrated and techniques can be worked out to give a good, but not too costly, control of grassland weeds. In this context, however, research into the balanced botanical content of a grass sward is a necessary prerequisite to a spraying programme.

Bracken control is to be discussed at this conference and although possibly the potential return from marginal upland areas may not be as great as from the lowland pastures, clearly if a chemical method of control of bracken, particularly a chemical which could be applied from aircraft, were to be developed, this would be an enormous step forward and a great help to our farmers in marginal areas. We must not forget either the exciting possibilities which have been opened up by the development of materials for the total or partial destruction of swards to facilitate reseeding and improvement.

I see that forestry is also to be discussed at this conference. This is an enterprise, though not an agricultural enterprise, which makes a great contribution to the national economy and provides employment in many areas where alternative regular employment is not available. With the present high cost of establishing plantations, and particularly the difficulty of obtaining labour to weed plantations in the young stages, chemical weedkillers can be of enormous benefit and it is to be hoped that it will not be so long before chemicals for use in forestry can be developed to the same high standards of efficiency as chemicals for use in agriculture.

The section devoted to weedkillers in potatoes is particularly interesting as here we are entering a new era. For generations it has been held that extensive cultivation is necessary for the health and well being of the potato crop, but as a result of recent work doubt has been cast on this assertion. Investigations into the possible uses of chemicals in the potato crop have provoked parallel enquiries into the best methods of cultivation, the biology of the crop, the influence of seed size and many other factors. All this work has tended to show how much remains to be learned about the biology of potatoes and is leading on to fundamental investigations which will also throw light on some of the problems connected with other root and row crops. We shall look forward with great interest to the session which is to be devoted to new trends in potato husbandry because it seems that here is a possibility of a major departure from traditional practices, involving a great reduction in the amount of cultivation which is necessary for the growing of the crop, or at least was thought to be necessary. We know from past experience with plantation crops such as blackcurrants and fruit trees that cultivations are not nearly as important as we once imagined, and it is likely that further developments in chemical weed control will show that it is no longer essential to expend energy in moving enormous quantities of soil year in and year out in order to obtain the best possible returns from many of our crops.

It is encouraging to see that a session is to be devoted to safety, toxicology, handling and residues of pesticides. With the publicity that has been given to the possible dangers of pesticide use, particularly insecticide use, it is cardinal that we in this industry should take the strictest possible precautions to see not only that the chemicals we introduce to the market are safe, and can be safely used, but also to demonstrate to the public that the hazards are not as great as have been horrifically portrayed. The chemical industry itself, in co-operation with Government and other official agencies, has a great responsibility for the proper instruction to the users of agricultural chemicals and here is a challenge which just must be met.

I feel that more attention should be paid to the education of farmers and operators, and although a start has been made in this direction, further efforts should be put into this particular activity. After all, chemicals are only as good in practice as the user allows them to be and no matter how efficient a chemical may be, unless it is properly and intelligently applied it will not give a reasonable account of itself. It is essential therefore to make every effort to ensure that farmers are first of all aware of the possibilities of the use of chemicals so that they can exploit them to the best possible advantage and, secondly, thoroughly familiar with the methods and techniques of application and safe handling.

In this connection I should perhaps mention that many of us feel that the progress in the development of new application techniques has not kept pace with the progress in the development of new chemicals. Many of the failures and disappointments which are experienced by farmers can be attributed not to any inherent defect in the chemical itself, but to faults in application, very often to the use of poor application equipment. To overcome these difficulties we look forward to a greater measure of co-operation between engineers and designers on the onehand, and the biologists and chemists concerned with the development of new chemicals on the other.

In conclusion I would like to say that the farming industry looks to the chemical industry to provide efficient and reliable chemicals which can be employed to increase the profitability and productivity of agriculture, and which can be used as a substitute for the sweat, labour, toil and energy which our forefathers found it necessary to expend in the battle against weeds.

I wish you every success in your deliberations.

WEED CONTROL IN ARABLE CROPS

E.K. Woodford

The Grassland Research Institute, Hurley, Berkshire.

You will have noticed that the programme for this conference contains several review papers. When the Programme Committee were informed by Council that it would be in order to arrange for two concurrent sessions in the afternoons we decided that some of the time in the plenary sessions should be devoted to Reviews. It was intended that these should survey the developments that had taken place in a particular branch of our subject during the two-year period since our last conference and that the authors should be asked to assess this progress in the context of what had gone before and what might be anticipated in the future. We hoped that such papers would set the scene for those of you who are not concerned with detail and at the same time would help to introduce the more specific Research Reports and Summaries that are to be considered at the afternoon Sessions.

So it happened that earlier this year I found myself not only committed to the task of preparing this Review on Weed Control in Arable Crops, but at the same time of having to transfer my scientific interests from The Weed Research Organisation to The Grassland Research Institute.

It has been our custom at past conferences to divide the agricultural part of our programme into quite separate sessions dealing with arable crops and grassland. In fact, one speaker at our last conference even went so far as to say "We must be careful not to translate the conventions of arable weed control into grassland". This distinction stems from our emphasis on improvement of naturally established grassland rather than the control of weeds in grass crops of sown species. The latter is a very important problem which, perhaps, because of the arrangement of our programmes has been neglected. It is a problem which logically falls into the province of weed control in arable crops and which will need much more attention in future years. I mention this not because I wish to include grasses among my arable crops this morning, but to illustrate the predicament I found myself in when trying to decide which crops to include. As a compromise I have adopted the classification we use in the Weed Control Handbook which separates grassland and grass seed crops from cereals and other arable crops and includes in grassland such crops as clover, lucerne and sainfoin.

I propose to consider arable crops in three groups :

1. Root crops
2. Other crops (kale, peas, beans, maize)
3. Cereals

I have left cereals until the last because they are the most important and are invariably given pride of place in any discussion.

First let me remind you of the approximate acreages of these crops in the U.K. These are shown in Table 1. In the right hand column of this table I have included a figure indicating the percentage of the crop acreage that is sprayed with herbicides. These figures are not based on any accurate survey data, because no data of this type have been made public. However, it is common knowledge that such information is collected by the larger manufacturers of agricultural chemicals and I have compiled my table by asking those who should know the answers to comment on, or correct, my estimates. The precise accuracy of the figures is not important. They are presented to emphasize trends that are well-known to all of you. First, we are badly in need of good weedkillers for the $1\frac{1}{2}$ million acres of root crops. This point was very effectively made by Mr. D. Pearce of Frederick Hiam Estates in his refreshing paper at our last conference on : "A Farmer's Angle on Weed Control". You may remember how he described that he grew 3,000 acres of cereals and 2,500 acres of roots and that all the cereals were sprayed but none of the roots. The table shows that only 2% of the 450 thousand acres of mangolds, turnips, swedes and fodder beet is treated with herbicides, and that after 15 years intensive research on sugar beet, still only 20 - 25% is treated. The carrot crop is the one exception. Carrots were one of the first horticultural-cum-agricultural crops to be sprayed with herbicides and there is now a wide range of chemicals to which it is resistant.

1. ROOT CROPS

The herbicide treatmentsrecommended for use in these root crops in the Fourth Edition of The Weed Control Handbook are given in Table II. The chemicals are classified in the left-hand column in accordance with their method of action and time of application. Pre-planting techniques are not of much importance but have been used in sugar-beet for many years, particularly for the control of wild oat. Contact Pre-emergence applications can be helpful on small areas of land where day-to-day supervision is possible, but are rarely practicable in large-scale mechanised farming. By far the most successful techniques for root crops are Residual Pre-emergence applications where the herbicides

Table I.

ARABLE CROPS - U.K.

ACREAGE TREATED WITH HERBICIDE

	1963 thousand acres	approx. acreage sprayed %
Cereals		
Wheat	1,928	75 - 80
Barley	4,713	70 - 75
Oats	1,295	60 - 65
Roots		
Potatoes	768	5
Sugar Beet	423	20 - 25
Mangold	89)	2
Turnip, Swedes and Fodder Beet	367)	
Carrot	32	65
Other Crops		
Pea	143	85
Bean	30	25
Kale	286	25
Maize	7	75

Table II Herbicides recommended for root crops (white squares)

New herbicides (black squares)

Approved chemicals		Carrot	Sugar beet	Potato	Mangold, Swede, Turnip	New herbicides
PRE-PLANTING	Soil applied					
	TCA		□			
	IPC		□			
CONTACT PRE-EMERGENCE	Foliar	□	□	□	□	
RESIDUAL PRE-EMERGENCE	Soil applied					
	CIPC	□	■			pyrazon
	CIPC + diuron	□	■			Du pont 634
	IPC + diuron		□			
	IPC + endothal		□	■		monolinuron
	linuron	□		□		
	prometryne + simazine			□		
	dinoseb			□		
POST-EMERGENCE	Foliar					
	vaporizing oil	□				
	sodium nitrate		□			
	linuron	□				
	prometryne	□				
	dalapon		□			
	barban		□			
	MCPA			□	■	picloram

work through the soil. Several Post-emergence treatments are listed but only those used for carrots are yet of any economic importance.

It is interesting to speculate why there is this emphasis on the use of soil-applied chemicals in agricultural root crops and in many horticultural crops, while in cereals and forage crops the emphasis is on foliar sprays. Is it just a matter of chance or is there some preconceived plan on the part of those who make these chemicals? Most manufacturers who sell soil-applied herbicides for use in annual agricultural crops complain about the difficulties of making them foolproof and often express the wish that they had a foliar spray that would do the same job. It would seem, therefore, that the real reason for the preponderance of soil-applied herbicides is that they are so much easier to find than selective foliar sprays. Many chemicals will enter plants via their roots, but few are capable of entering via the leaves. In addition, the soil environment often enhances the possibilities of selectivity by permitting variations in the positioning of the herbicide in relation to the underground absorbing organs of the crop and weeds. The soil also regulates the release of the herbicide and thus considerably extends the period over which it can act and the dose that is available.

The fact that most of the techniques of chemical weed control are the result of chance observation and not of preconceived plans should not dissuade us from thinking about the ultimate goal and the ideal herbicide. This is perhaps not the time to enter into a discussion of the pro's and cons of foliar versus soil-applied herbicides as we have another plenary session devoted to soil-applied herbicides tomorrow, but I do want to emphasize the need for serious consideration of our ultimate requirements and the type of ideal herbicide that we should be striving towards. The short-term research of commercial firms will be directed to the production of foliar sprays for annual crops, because such herbicides are likely to be more remunerative and easier to use, but this must not dissuade others from looking much further into the future and thinking about the most satisfactory method of utilising chemical energy to control unwanted vegetation. Soil-applied herbicides, if truly selective, have so many advantages over foliar treatments that I believe they should receive priority in any long-term research programme. Some of you may consider this goal is too difficult to obtain. Certainly if one considers all the physical and biological factors that control the action of a herbicide in the soil one wonders how any chemical can be effective under field conditions, but on the other hand, if Geigy could find chemicals with selectivity to maize of the magnitude and range of that possessed by simazine and atrazine, then there must be many more chemicals waiting to be found that could prove just as efficient for cereals.

Since our last conference there has been considerable progress in the development of new weed control methods for root crops and we are going to devote most of two sessions to the consideration of the results that have been obtained. Carrots and sugar beet will be dealt with in Session VIII (a) and a full Session, No. VII (a), of 21 papers, has been set aside for potatoes.

The more important new chemicals that will be discussed in these sessions are listed in the right column of Table II.

Carrots Most of the carrot crop is now sprayed with one or other of the herbicides available, and farmers have moved on to consider how best to exploit, by changes in husbandry, the weed-free environment that they can obtain without cultivations. The techniques of bed planting and lifting described by Green and Bleasdale at our Symposium on 'Crop Production in a Weed-free Environment' 2 years ago have been widely publicised and treated. The breakthrough in thinking and practice with carrots has had its influence on other root crops.

Potatoes Perhaps the most outstanding progress has been with the potato crop. It was at the 1960 conference that we first considered the use of herbicides. At our last conference there were 3 papers and this year there are no less than 21. This increase illustrates clearly the 'S' shaped growth curve of the rate of adoption of a new technique described to us in 1962 by Mr. W.E. Jones. During the last two years we have rapidly passed the first two stages in the process of acceptance at the bottom of the 'S', i.e.

(1) Awareness, when the farmer first hears about the new pactice.
(2) Acceptance, as a good idea, and are now on the steep upward slope resulting from
(3) Acceptance on a trial basis.

This acceptance by the farmer is being matched by great activity on the research side both in commerce and in official organisations. In a note dated the 15th June from the Weed Research Organisation this year Elliott lists details of 77 field experiments being carried out by official bodies in England, Scotland and Wales. All this is very gratifying, but there is still much agronomic work to be done before we can make full use of herbicides in Potato Husbandry. It is a complicated and fascinating problem that requires the combined efforts of the herbicide chemist, agronomist and agricultural engineer working in collaboration with plant physiologists and biochemists. It would be a pity if demand led to the supply of herbicides that were not fully tested in all respects. Labels of proprietary products, formulated for use in potatoes, have already been approved by the Agricultural Chemicals Approval Organisation. Such approval may condone changes in husbandry, such as the elimination of post-planting cultivations, that are an intrinsic part of the chemical technique. How far approval for herbicide use can be separated from approval for new agronomic methods necessary for the effective action of the herbicide is an interesting problem.

There is still much room for improvement of the selectivity of herbicides towards potatoes, both linuron and the proprietary mixture of prometryne and simazine can cause foliar symptoms of damage at the doses recommended. While it is agreed that such symptoms usually occur on the first leaves to be produced and that later leaves are perfectly normal, one wonders if there are not other slight changes in the make-up of the tuber that could influence subsequent dormancy and sprouting behaviour. The interesting interaction between 'solan', when applied as a spray on to potato foliage, and a range of chemicals used as tuber dressings, that resulted in increased foliar scorch, is a warning of the sort of side-effects that can take place. In the table I have listed monolinuron as the only new herbicide, but you will be learning about another new urea 'C.3126' (*N'*-(4-bromophenyl)-*N*-methoxy-*N*-methyl urea) in Session VII (a).

Sugar beet Progress in the development of selective herbicides for use in sugar beet has been slow despite the attention that has been paid to this crop. The last two years have been a testing period for several new herbicides, but particularly for pyrazone. Most of the research reports on sugar beet deal with this herbicide which looks as if it will come into use quite widely before our next conference. Again there has been, as with carrots and potatoes, new thinking about the spatial arrangements of planting the crop and the optimum densities for maximum yield.

The immediate prospect for 1965 in the U.K. is that band spraying will be recommended, with possibly a tentative recommendation for soil incorporation of the herbicide for later drillings. Pyrazone has shown itself to have a wider margin of selectivity than any previous compounds whilst its range of activity covers practically all the weeds of importance in this country except *Avena fatua* and *Viola tricolor*. The only other new compound which seems worth mentioning is 3-cyclohexyl-5, 6-trimethylene uracil (Du Pont 634). This has shown considerable selectivity. There seems no reason why tri-allate should not become established as a standard treatment and with its very high selectivity this seems an obvious compound for addition to pyrazone or Dupont 634 where necessary to broaden the spectrum of weeds controlled and include *Avena fatua*.

2. OTHER ARABLE CROPS

The herbicides at present recommended for this mixed collection of arable crops are given in Table III, and the newer herbicides.

Table III Herbicides recommended for "Other Crops" (white squares)

New herbicides (black squares)

Approved chemicals		Pea	Bean	Kale	Maize	Lucerne	New herbicides
PRE-PLANTING	Soil applied						
	IPC	□					
	TCA	□					
CONTACT PRE-EMERGENCE	Foliar	□	□	□			
RESIDUAL PRE-EMERGENCE	Soil applied	■					dinoseb acetate
			■				monolinuron
	simazine		□		□		
	CIPC + fenuron	□	□				
	CIPC + diuron	□	□				
	dinoseb (amine)	□					
	atrazine	■			□		Philips 40-21
POST-EMERGENCE	Foliar						
	dinoseb amine (NH_4)	□	□			□	
	MCPB	□					
	SMA			□			
	barban	□					
	H_2SO_4			□			
	desmetryne			□			
	2,4-D				□		
	2,4-DB			■		□	nitrophen FW 925
	dalapon			■		□	dicamba
	CIPC			■		□	picloram

Pea Despite considerable activity by the Pea Growers Research Organisation, the National Vegetable Research Station and commercial organisations in testing new herbicides, most of the crop is still sprayed with dinoseb, and there seems to have been little change in farming practice during the last two years. The newer forms of dinoseb are proving more selective, and there is the new Philips compound 4, 5-7 trichlorobenzyl-thiadiazole-213 (Philips 40-21).

Bean Field beans have increased in popularity during the years as a break in continuous cereal growing, but there are no new herbicide treatments apart from monolinuron. There has also been an increased acreage of dwarf or string beans for canning. Here the need for a good herbicide that eliminates the necessity for inter-row cultivations is doubly important as clods of earth thrown up by cultivations are picked up and interfere with the bean harvester.

Kale At our last conference Mr. Elliott announced his discovery of the selective action of desmetryne for the control of fat-hen in kale. This herbicide has been available to farmers during the last two seasons and results obtained have been well up to expectations. Desmetryne controls several other weeds as well as fat-hen, and has a marked soil action. There is, however, a need for a wider spectrum of weed control and experiments have been proceeding with mixtures containing sodium monochloroacetate and tordon, but there are difficulties of compatibility and tordon, like desmetryne, does not kill charlock (*Sinapis arvensis*). Kale, or 'choumollier' is an important crop in New Zealand, and the Weed Research Organisation have arrangements with the Government research people over there for a collaborate screening programme. Results of the U.K. work in this field are passed to New Zealand in time for them to be considered before they plant their crops in December. Similarly the Weed Research Organisation receives their results in late spring, thus enabling two crops to be tested in one year. The New Zealanders are favouring the use of 2, 4-dichlorophenyl 4, -nitrophenylether (FW. 925), but this herbicide does not seem to be of much use under British conditions.

3. CEREALS

The history of chemical weed control in cereals is a history very much of British achievement. It is a history of the gradual mastery of herbicides over a succession of difficult weed problems, each coming into prominence as partial control of the weed flora released the more resistent species from competition. It is a story full of excitement and progress which still has not reached its end, but which needs telling.

To remind you of the major events in this saga I have two slides, (Table IV and Fig. 1.). The first shows, in chronological order, the date of introduction of each new herbicide and the reason for its introduction. The second shows diagramatically the way in which the acreage of cereals treated with herbicides has increased and how the steady rise has been associated with the regular introduction of new herbicides. It is a great pity there are no official records of this revolutionary change in cereal husbandry in this country, but the shape of the curve as given cannot be very far from an accurate approximation, and it is clear that there has been a steady rise in the cereal acreage each year as new herbicides have been produced to deal with each remaining weed problem.

The regular production of new herbicides is well illustrated in the programmes of our successive conferences. These biennial meetings have sometimes coincided with the year of launching and sometimes with the year of assessment after a period of use under farming conditions. This is shown in Table V. The more interesting conferences have been those that corresponded with the announcement of new chemicals - 1956 was a vintage year in this respect and it looks as if this year, 1964, is going to be another. In the New Herbicide Session that follows this there are papers on several very interesting new herbicides, some of which hold out much promise for cereals -

Ioxynil

Bromoxynil

new Bipyridyls

Tordon (picloram)

We have also included a research report on 2-choroethyl-trimethylammonium chloride (C.C.C.), a chemical which is not a herbicide but which causes growth regulation of cereals. This we have done to remind you that chemicals can be used to benefit the crop as well as harm the weed and that both types of action may be important.

The two years that have just passed will probably be remembered as the seasons of mixtures. In the absence of any new herbicides, manufacturers seem to have concentrated on maintaining the upward shape of the acreage curve by wetting the farmer's appetite with new and better mixtures. There are many reasons why mixtures of herbicides may be beneficial. The usual reason put forward for combining two or more herbicides is to increase the spectrum of weeds that can be controlled. Often this increased range can be obtained without much additional cost as it would appear that the basic action of

Table IV

A HISTORY OF BRITISH ACHIEVEMENT

Year	Herbicide	Important Weeds Reason for introduction
1911	H_2SO_4	General
1932	DNOC	General
1945	DINOSEB	General - undersown cereals
1946	MCPA	General
	2, 4-D	General
1955	MCPB	MCPA Susceptible weeds of undersown cereals
	2, 4-DB	2, 4-D Susceptible weeds of undersown cereals
1957	MCPA + 2, 3, 6-TBA	MCPA Susceptible weeds + Cleavers and Mayweeds
1957	MECOPROP	MCPA Susceptible weeds + Chickweed and Cleavers
1958	MCPB + MCPA)	
	(MCPA)	
	2, 4-DB + (or)	Charlock and Runch in undersown cereals
	(2, 4-D)	
1960	BARBAN	Wild Oats and Blackgrass
	DI-ALLATE	Wild Oats
1961	DICHLORPROP	Redshank and Pale Persicaria
1962	MCPA + DICAMBA	Knotgrass and Redshank
1963	MIXTURES	
1964	MIXTURES	
	TRI-ALLATE	Wild Oats and Blackgrass

Table V

New herbicides introduced at

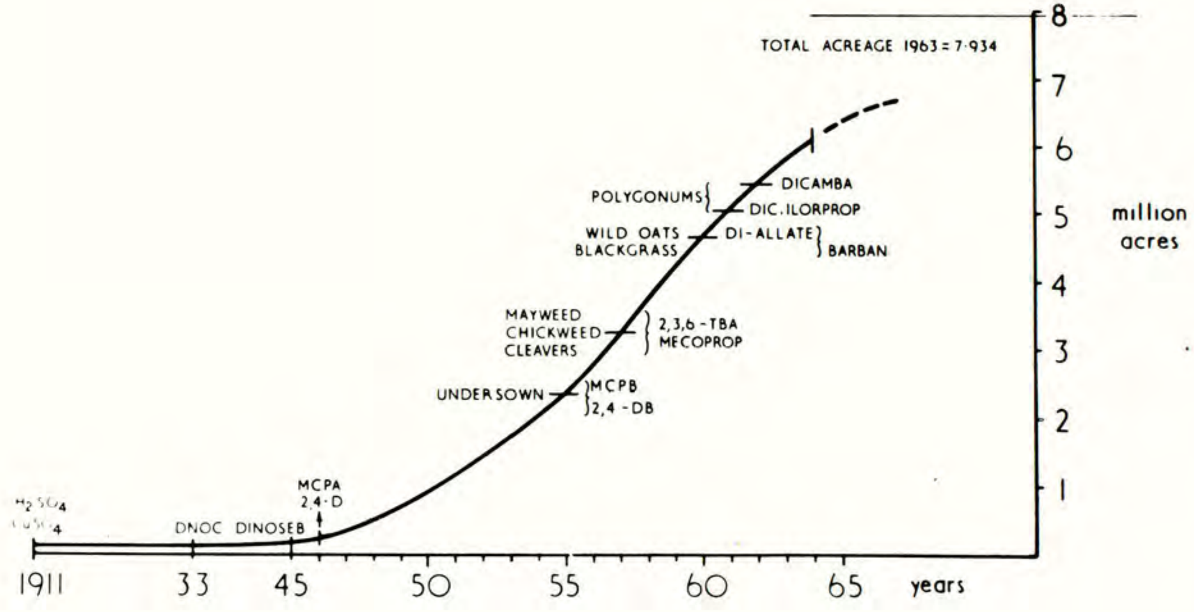
British Weed Control Conferences

Date of Weed Control Conference	New Herbicide	
1953	MCPA & 2, 4-D	Review of practice
1954	MCPB & 2, 4-DB	Announcement
1956	MCPP (Mecoprop)	Announcement
	TBA	
	Triazines	
1958	Diquat	Announcement
1960	barban	Review
	di-allate	
1962	2, 4-DP	Review
	dicamba	
1964	ioxynil, bromoxynil	
	picloram	Announcement
	new bipyridyls	

Fig. 1.

CEREALS

The progress of chemical weed control



many of the substituted phenoxy and benzoic acids is similar and in part complementary. It is also claimed that some herbicides have a synergestic action upon each other, but there is little evidence to indicate that this is of much practical importance in the mixtures so far made available to the farmer. The performance of a mixture of two growth-regulator herbicides can generally be predicted from a detailed study of the behaviour of each alone. It is, however, very necessary to test such mixtures extensively under field conditions before making any pronouncements about their usefulness. The low surface tension of one may increase the activity, if not the selectivity, of the other, as was shown by Holly many years ago when studying the mixtures of MCPA and MCPB. We also know that there is antagonism between the action of barban and certain phenoxy acetic acids when applied at about the same time.

Mixtures have other more commercial advantages. They can be used for patent applications. They can be advertised as new discoveries and serve as propaganda for persuading farmers to buy new and better products. Unfortunately not all such claims are justifiable and sometimes farmers are, I am afraid, persuaded to buy a new mixture at an increased price when they would have been as well off with a cheaper application of a straight herbicide. The number of herbicides that can be applied to cereals is large, as you have seen from previous figures and tables. These can be combined in many permutations and combinations and in varying proportions to give an almost infinite range of mixtures. So far in this country we have been limited to "2-way" mixtures (mixtures of two chemicals), but in Canada there is a "3-way" mixture, and theoretically there is no reason why a "4-way" mixture might not be a real advance. In previous conferences speakers have complained bitterly about the confusion that results from the same herbicide having many trade names. We have overcome this very largely by the promise that Industry has given to declare the name of the active ingredient on the label, but for mixtures this simple declaration is not enough and I would suggest that in addition we must be told the proportions of the constituents in the mixture. It has happened that the cost of a mixture per acre is 50% higher than the average cost of the ingredients per acre. Such mixtures cannot be an economic proposition for the farmer and it seems very doubtful if such extra costs are a real reflection of the greater difficulty of formulating mixtures. Many farmers know that MCPA and mecoprop from the same firm can be mixed in the spray-tank without any difficulty and it is apparently a common practice for a little MCPA to be added to mecoprop.

Most mixtures in this country are based on either MCPA or 2, 4-D, presumably because they are so much cheaper than any other herbicides. The only exception to this generalisation is a mixture of CMPP and 2, 4-5TP. The mixtures that are available are shown in Fig. 2. In Europe 2. 45T is used for the control of Galeopsis tetrahit,

Fig. 2.

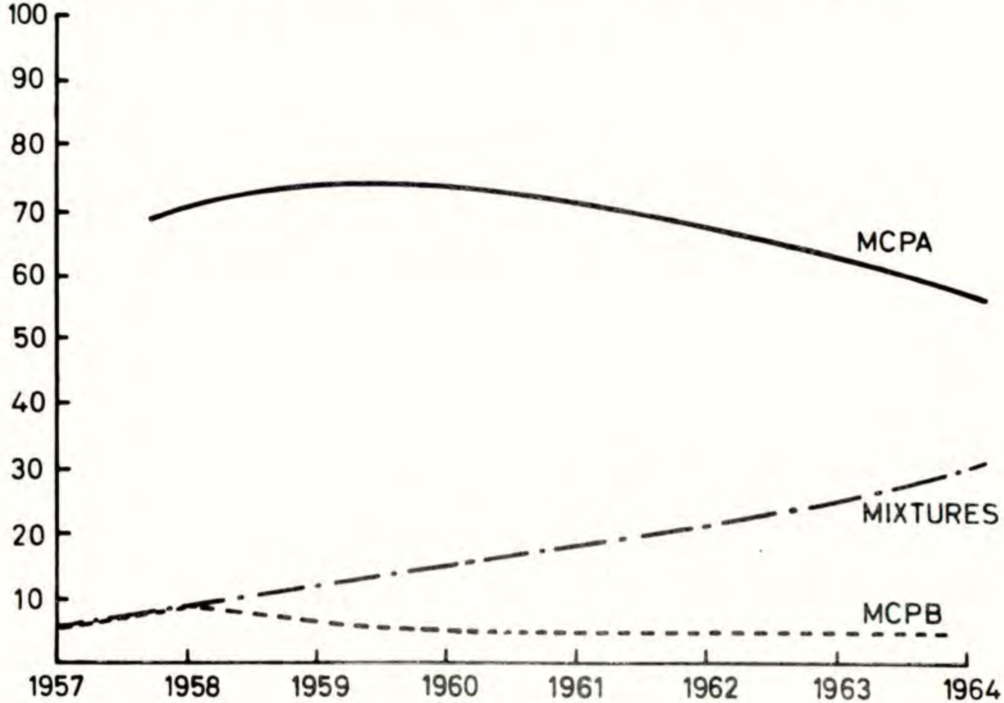
MIXTURES OF HERBICIDES FOR CEREALS

	ACETICS		PROPIONICS			BUTYRICS			BENZOICS		DINITRO
	2,4-D	2,4,5-T	MECOPROP	DICHLOR-PROP	FENOPROP	MCPB	2,4-DB	2,4,5-TB	2,3,6-TBA	DICAMBA	DINOSEB
MCPA	Germany	Austria Germany	Holland	⊘	⊘	⊘	⊘		⊘	⊘	Norway Ireland
	2,4-D		⊘	⊘		⊘	⊘				
		2,4,5-T	Austria Germany								
			MECOPROP		⊘						

Fig. 3.

CEREALS

TREND OF HERBICIDE USAGE
PERCENTAGE OF TOTAL ACREAGE SPRAYED



and mixtures of 2.45T with MCPA and CMPP are available in Germany and Austria, while in Holland mixtures of MCPA/CMPP are available, and Norway and Ireland still use dnBP-MCPA mixtures.

This trend towards the use of mixtures has resulted in decreased sales of the straight herbicides, and it seems likely that in 1964 one quarter of the cereal acreage in the U.K. was sprayed with mixtures. This change from tne use of straight MCPA in 1957 to the present time in the U.K. is shown in Fig. 3.

With the array of herbicides that was available to the farmer in 1964 it was possible for him to control most but not quite all annual weeds in cereals. If he was prepared to use the toxic di-nitro herbicide he could kill them all. The addition to his armoury of the new herbicides we are going to hear about in the next Session will permit him to deal with the last few resistant species - mayweeds and cornmarigolds, and replace dinoseb completely.

The outstanding herbicide requirements for cereals will then be :-

1. a herbicide for undersown cereals.
2. " that can be applied in the spring for annual grasses.
3. " for perennial weeds.

There is no indication from the research reports before this conference that there is any immediate prospect of problems 1 and 2 being defeated this next year. The perennial weed problem is perhaps a special one and should be dealt with during the time the cereal crop is not in the ground. In our climate most perennials are growing underground for a greater part of the winter and I have always maintained that the best method of tackling such weeds was by the use of soil applied herbicides immediately after harvest. At present we have to rely on the application of amino triazole or dalapon to foliage in the autumn. Properly used and combined with well timed cultivations, these herbicides should control infestations of couch in the south of England. In the north, however, the time interval between harvest and winter is not long enough.

Modern cereal growing which depends for high yields on early planting in the spring allows no time for control of perennial weeds by spring cultivations, and continuous cereal growing prevents control by means of a break in the rotation. Thus it is that on all sides one hears of the increasing menace of grass weeds in cereal crops. In a recent

Survey carried out in Cambridgeshire* it was reported that over 63% of the farmers claimed to have grass weed problems, but only 8% had a pest or disease problem. Usually it is the perennial grasses Agropyron repens, Agrostis stolonifera, Poa trivialis, but annual grasses such as Black grass (Alopecurus), and in Yorkshire and Lancashire Wind grass (Asper spicaventi) are also on the increase. This shift in the weed problems of cereal growing from the broad-leaved annuals to the perennial grasses is often rather unfairly associated with herbicidal usage. True, herbicides made it possible to eliminate annual broad-leaved weeds and encouraged the practice of continuous cereal cropping, but to blame herbicides for the breakdown of this monoculture which they made possible seems a little unfair. Herbicides are merely aids to good husbandry; if a system of farming, of which they are a part, begins to fail because of perennial weed invasion, the husbandry is at fault, not the herbicide. The husbandry can be modified by altering the crop rotation, but this is often not economic and in the future we hope that other new herbicides will be found that can deal with this new weed problem.

There is a growing belief that on many of our soils we cultivate more than is necessary either for the crop or the soil and we will be hearing in Session IX on Thursday morning how paraquat and diquat can be used to replace cultivations. We must, however, be sure that such treatments do in fact control all perennial weeds before we give up the cultivations normally carried out in the autumn. Paraquat or some other herbicide may in fact be able to kill all weeds, but it is necessary to consider the whole cropping cycle and the interrelations of herbicides and cultivations.

I mentioned earlier my belief that soil-applied herbicides should be our ultimate goal for selective weed control. At our last conference Holroyd discussed the possibilities of propazine and amiben for use as soil-applied treatments to cereals. The former has been widely tested, but does not possess quite enough selectivity and causes crop damage when drilling is not deep enough. Amiben has not been tested further because of its expense.

In Europe simazin is applied to winter cereals and this year linuron has been introduced in Belgium as a pre-emergence soil treatment for spring cereals. Many do not like the idea of putting chemicals on the soil, knowing of the persistence of certain chlorinated hydrocarbons.

* N.A.A.S. "Profitable Farming in Cambridgeshire"
No. 14 Results of Cambridgeshire Cereal Survey 1964.
and Winter Cereal Recommendations 1965.

This certainly needs careful study but I see no reason why herbicides should be any more of a potential hazard when applied to the soil than when applied to the foliage of plants. Uptake by the plant plus microbiological decomposition in the soil takes care quite adequately of a whole range of soil-applied herbicides now in commercial use. We know too that plants are not efficient at breaking down all foliar sprays and there have been instances in the past where contaminated straw has worried growers of cucumbers and tomatoes in glasshouses.

Safety of herbicides has been very much in the fore of late and I want to end on a train of thought that perhaps will not be too popular with the chemical manufacturers that have made this revolution in husbandry possible. We are now reaching the stage in cereals where 80% or more of all the crops in the country are sprayed and the steep slope of the acreage curve shown earlier must level off and perhaps before long begin to drop (Fig. 1). In the past it has generally been assumed, and probably quite rightly, that most fields of cereals would benefit from a herbicide treatment and that it was beneficial for farmers to carry out such a propylactic treatment as a matter of routine, primarily for the benefit that a clean crop gives at harvest time and not for any yield increase that might be expected. With time the weed seed populations of our soils are decreasing and in consequence the need for herbicide treatment must also be decreasing. Is it not now time we devoted more of our research time to finding out <u>when</u> it is economic to spray our cereal crops?

Discussion on the preceding paper

MR. M. N. GLADSTONE I cannot see why Dr. Woodford thinks it is more difficult to approve an efficient product because it happens to be a mixture of twelve products. Where is the difficulty? If it does a good job it doesn't matter if it has a hundred constituents.

DR. E. K. WOODFORD The approval of chemicals must be based on knowledge of the ingredients and much of this work on the phenoxyacetic acid type of product us based on a knowledge of the chemicals which comes not only from the firm producing the chemical but from many other sources. I would have thought that in most cases where one has to consider approval there is at the back of one's mind this fund of knowledge which is weighed against the practical evidence that comes in from the manufacturer's field trials.

DR. E. A. RILEY What Dr. Woodford says is very true. I think the problem only arises where a firm does not take the trouble to work out what the interactions are between components in the mixture. They just add A and B and hope to get the same result. In fact, it isn't always so and the components can possibly be down-graded in quantity to give the same effect. This means that the firms must do a great deal of basic work to find out the effects of mixtures before they are good enough for approval. The trouble is to get the firm to do the basic work.

MR. G. A. TOULSON I should like to refer to Dr. Woodford's statement about the possibility of using residual herbicides in cereals rather than materials for post-emergence application. The farmer often likes to see the weeds before he takes any action, and education is needed to persuade him to use soil-acting herbicides.

DR. E. K. WOODFORD I do not think there would be any difficulty about it for the farmer. Farmers will use a technique as soon as it is there. The horticulturist has done it in a way for weeds in blackcurrants: he puts simazine on the soil, decreasing the dosage by half every year; after seven years there is only 1% left. Whether you can decrease the rate will depend on the type of chemical. If someone could find a chemical in the next year which was really effective in cereals and could be applied to the soil, then I am sure the problem would be solved very soon. It is happening in maize: in some parts of the world they put simazine on 5 acres at 5 lb. in the first year and find that, having decreased from 5 to 3 to 2, they need put on no chemical at all in the 4th and 5th years because presumably the residue and weed seed population have both gone.

MR. X. de GOURNAY Dr. Woodford said that the cereal fields treated with herbicides will probably never reach 100% of the total cereal acreage and also that it is desirable to develop herbicides that can be used like simazine in maize. Some chemicals, such as tri-allate in barley, can like simazine be used at the time of sowing, but as they are ineffective against dicotyledonous weeds a second spraying may be necessary, and this might increase the future statistical percentage of treated acreage, possibly beyond 100%. Dr. Woodford also said that treatments performed every year could perhaps suppress the viable seed stock of the soil;

simazine was a good material for controlling Digitaria species in maize crops of south-western France five years ago, but it seems that, after the first successful applications, resistant types of those grass weeds have multiplied.

DR. E. K. WOODFORD The figures I gave were for acreage sprayed; I can see our commercial friends have other ideas. I did want to mention the chemicals that have been used pre-emergence in cereals. At the last Conference we had some papers on this - Dr. Holroyd mentioned propazine and amiben. Propazine did not prove selective and amiben was too expensive although it may have the selectivity required. In Germany simazine is used on cereals although in this country we think the Germans have been a bit rash. Now linuron is being used as a pre-emergence treatment in spring cereals so obviously some of you are thinking about it.

MR. R. F. NORMAN I am sure the real problem is the soil. The production of soil maps with an agreed nomenclature for the whole country is very necessary, because in different districts we find widely differing types of soil described by the same name. Is there in fact anything being done to generate this sort of information which is so vital to all concerned in research in this field?

DR. E. K. WOODFORD We did discuss this at the last Conference and the Head of the NAAS did make a statement. The Advisory services in this country are certainly beginning to take a much more active interest in the soil/herbicides interaction, and they are beginning to think in terms of a service to tell farmers about the soil-type of their land in relation to herbicide use, but it is a very difficult problem; I agree something like this will probably have to come. It will depend, of course, on the selectivity of the chemical itself and some will depend more on soil type than others. The Weed Research Organisation are taking a special interest in the work being carried out at the new Rickwood Experimental Farm. Our latest Government has, I think, separated the soil service from the agricultural research service; so this may not help.

PROFESSOR W. R. FURTICK This soil-applied material for cereals is something which has been of interest to us in Oregon. Now approximately 50% of our cereal acreage is sprayed pre-emergence, and we started in 1958. There was a general feeling that this type of treatment could not be adopted by growers; a great deal of effort was made to try to bring about the adoption but commercial companies gave up after two years work. Then in the following year we had to compile an inventory in order to keep track of the number of growers using the new technique. So it is possible to change habits of weed control without much extra expense, but it takes a lot of effort. As I said, I think there has been a 50% adoption of the new method; this acreage is therefore no longer sprayed with 2,4-D

WEED CONTROL IN CEREALS IN WESTERN CANADA

H. A. Friesen
Experimental Farm, Lacombe, Alberta, Canada

Cereal production is the main farm enterprise on about 75 million acres of land in Western Canada. Since the beginning of rapid settlement, after 1900, the land has been cropped almost exclusively to cereal grains under what might be described as asystem of extensive farming. This system of farming is based on short rotations, consisting of one, or in the moister regions, as many as four grain crops before summer fallowing. The short growing season, about 100 days, and the variable rainfall over most of the area not only severely limit the kinds of crops which can be grown but also restrict the amount of preparatory tillage which can be carried out to enhance the chances of producing a vigorous and weed-free crop. Grain farming has become highly mechanized with the emphasis on speed and one-man, once-over operations. By combining the pre-seeding tillage and seeding into one implement and by increasing the width of cut, one man can till and seed up to 100 acres or more in a 10 hour day. The combine harvester has effected similar increases in the efficiency and speed of the harvest operations. Unfortunately these advances in farming technique contributed to an increasing weed problem. The widespread adoption in the 1930's of the combine harvester, with its ability to scatter weed seeds to all corners of the farm, climaxed this steady worsening situation. The selective herbicide 2,4-D was therefore welcomed enthusiastically throughout the grain growing areas of Western Canada.

THE AREA

The grain growing region extends for about 1000 miles from Winnipeg in the east to the Rocky mountains in the west in a belt about 300 miles in depth from south to north, except in Alberta where settlement has progressed as far as 600 miles north of the United States boundary. While this area as a whole might be described as having a continental climate with rather fixed patterns ranging from semi-arid to sub-humid, its size and the mountains contribute to wide fluctuations in annual weather conditions. Four major soil zones or classes have developed under the different climate patterns (Slide 1).

Brown Soil Zone:

This zone covers some 34 million acres of treeless prairie in southwest Saskatchewan and southeast Alberta. The climate is semi-arid (Slide 2), and in its natural state is short-grass prairie with *Bouteloua* and *Stipa* spp. predominating. About 90 per cent of this area is occupied but only about 44 per cent is improved or cultivated (17). The soils are low in organic matter, drab brown in color and have undergone little or no leaching. Agriculture is largely confined to wheat farming or cattle ranching. The wheat farming is limited to the heavier textured clay and clay loam soils. A system of alternate fallow and wheat has been widely adopted as a safeguard against extreme drought and weeds. Annual weeds, notably *Salsola pestifer*, *Thlaspi arvense* and *Sisymbrium altisimum* are common throughout while *Brassica kaber*, *Coringia orientalis* and *Saponaria vaccaria* (cow cockle) are particularly troublesome on the heavy clay soils. With the exception of *Cirsium arvense*, perennial weeds do not present an intense and widespread problem in grain fields.

Dark Brown Zone:

This zone comprises some 30 million acres lying in a broad belt surrounding the Brown soil zone to the east, north and west. Total rainfall in this zone is not appreciably higher but evaporation is significantly lower than in the Brown zone. The increased moisture efficiency is reflected in the taller native prairie species of Stipa and Agropyron which predominate and in the darker color of the surface soil. Ninety-six per cent of the area is occupied and 62 per cent is improved. Wheat is the major crop but some coarse grains are also grown. The weeds found in the Brown zone also occur in this zone. However, Polygonum convolvulus has increased to alarming proportions throughout this area during the past decade. On the heavier or clay soils, wild oats, Avena fatua are troublesome, especially in seasons of above normal rainfall. Setaria viridis is widespread as are such perennials as Cirsium and Sonchus.

The rather dry climate in both of these soil zones has limited the type of farming largely to straight grain growing with the frequent use of the summerfallow. However, in the Dark Brown Zone the summerfallow is more often used after two or three crops rather than after every crop, as in the Brown zone.

Black Soil Zone:

This zone covers an area of some 42 million acres and it surrounds the Dark Brown Zone to the east, north and west. Areas of similar soils also occur in the Peace River region of Alberta and British Columbia. Total precipitation in the zone is only a few inches higher than in the other two zones but evaporation is considerably lower. These conditions have resulted in a luxuriant growth of native grass, predominently Festuca scabrella and the frequent occurrence of aspen and willow bluffs gives the area a park like appearance, and hence, it is usually referred to as the Park region. The soil is high in organic matter, 8 to 12 per cent, and very black in color when wet.

Agriculture in this zone is more varied than in the drier Brown and Dark Brown zones. This is the great mixed-farming area of the Prairie provinces, although some farmers practice straight grain production. Wheat is an important crop, but other grains notably barley and oats, as well as forage legumes and grasses are relatively much more important here than in the two brown soil zones. This is particularly true in central Alberta and southern Manitoba. Most of the weeds found in the Brown soil zones are also common in the Black, with the notable exceptions of Salsola pestifer and Sisymbrium altissimum. However, these vacancies are more than filled by Galeopsis tetrahit, Polygonum scabrum, Stellaria media, Spergula arvensis, Fagopyrum tataricum and Erysimum chieranthoides. Avena fatua is so prevalent in the moister parts of this region that wheat production is a hazardous venture. In addition to widespread and heavy infestations of Cirsium and Sonchus, such other perennials as Agropyron repens and to lesser extent Equisetum arvense and Taraxacum spp. are prevalent and troublesome.

Grey wooded Zone:

Although not as yet as important agriculturally, this zone has the largest land area, over 100 million acres, lying mainly across the northern prairie area. While it has a forest cover of poplar, willow, spruce and pine the climate is only sub-humid. The annual precipitation ranges from 16 to 22 inches over the most of the area, and decreases toward the north with an annual average of 11.9 inches at Ft. Vermilion in northern Alberta.

These soils are characterized by a grey, ash-like mineral layer lying beneath a thin layer of organic matter on the surface. The thickness of the grey leached layer varies from a few to as much as 10 to 12 inches. The surface soil is usually very slightly acid.

The heavy tree cover and inherent fertility problems have delayed settlement until quite recently, when the combined forces of increased demand for animal products and the availability of heavy equipment has spurred a rapid expansion of farming into this frontier area. This expansion has been most rapid and extensive in Alberta, which has in excess of 15 million acres of potentially arable but forest covered soils. Nearly four million acres of such soils are presently farmed in Alberta (24).

Mixed farming, consisting of coarse grains and forage legumes and grass mixtures is the common practice since it supplies animal feeds and develops soil productivity. The weed species and problems are closely similar to those of the moister Black soils but such species as _Spergula arvensis_, _Stellaria media_ and _Equisetum_ are more troublesome.

LAND USE

Farmer experiences and agronomic studies have both shown that almost the entire area is suited to cereal production, especially wheat. Land use statistics bear this out. Of the 75 million acres under cultivation in 1963, there were 26.9 million acres seeded to wheat, 8.1 to oats, 5.7 to barley and 1.5 million acres to flax. Rye, rapeseed, corn and potatoes totalled only about 1.5 million acres and there were about 5 million acres in cultivated forage crops. The remainder, about 27 million acres was in summerfallow. In addition to the above there are some 47 million acres of non-arable land being utilized as native range and brush pastures. The foregoing shows a rather low ratio of cultivated crop to fallow, namely, about 2:1. This low ratio of crop to fallow, while deplored by Hopkins (16) and others as being wasteful of land potential and resources, has remained remarkably constant since rapid settlement began after the turn of the century. Changes in marketing conditions are usually reflected in changes in the acreages seeded to a given crop, but to date this has usually meant increasing the favored crop at the expense of the less favored one, with little reduction in the fallow acreage. Thus, our large wheat sales in 1963 caused farmers to increase their wheat seedings in 1964 by about 2 million acres, but this was largely accomplished by reducing the 1964 oats and barley acreages. The inclusion of cultivated forages in the rotation has been gaining momentum in the moister parts of the Black and in the Grey wooded soil zones but as yet represents only a small fraction of the cultivated area. Therefore, weed control practices, both cultural and chemical, must be fitted into a pattern of almost exclusive cereal crop production, broken only by frequent summerfallowing.

WEED CONTROL PRACTICES

Cultural:

The basis of effective cultural weed control in Western Canada is the summerfallow. To effectively conserve moisture, the fallowed land must be kept free of weeds by careful and timely tillage throughout the growing season. Chepil (4) and Budd (2) have shown the fallow to be an effective method of reducing the numbers of weeds in the succeeding crop as well as the numbers of viable weed seeds in the soil of those species which have only a very limited dormancy. However, only six of the 58 species which they studied had a dormancy period of less than one year and only two of these, _Salsola pestifer_ and _Cirsium arvense_ were serious weeds. They found that weeds with dormancy periods longer than one year emerged and matured in the crop on fallow to the extent that they not only maintained but often increased the infestation. If two or more crops were taken between fallowings the infestation almost always increased. These conclusions were supported in more recent studies by Banting (1), who found that _A. fatua_ could be grown out and destroyed by repeated fallowing for three years. However, where a rotation of crop and fallow was used sufficient wild oats matured in the crop to maintain the infestation.

The weed control effected in the fallow season can be enhanced by timely and thorough tillage in the spring following the fallow year, aimed at the destruction of at least one stand of weeds prior to seeding the crop. In the drier parts of the area this is generally accomplished by seeding with a wide level discer or with a one-way disc so that tilling and seeding are combined into one operation. In the moister regions the tillage and seeding are usually separate operations to ensure a better weed kill. It is essential that the pre-seeding tillage be sufficiently shallow to permit planting the grain in firm, moist soil at a depth of about 3 inches. Because the worked surface soil usually dries out quickly the small-seeded weeds will be delayed in germinating and a relatively clean crop will result. However, experience has shown that seasonal variations in the weather make this a relatively unreliable weed control practice.

Chepil (4) has shown that most annual weeds germinate in April and May and that crops seeded after that time were relatively free of weeds. Unfortunately our short growing season demands that wheat must also be planted before the end of May, which largely precludes the use of the delayed seeding principle of weed control with this crop. However, the delayed seeding of an early maturing variety of barley or oats can be effectively used to control many of our common annual weeds notably _A. fatua_. Studies at a number of Experimental Farms in Western Canada (14) have shown over 80 per cent reduction in _A. fatua_ by delayed seeding to an early variety of barley (Table 1). It should also be noted that prolonged periods of wet, cool weather in the spring at Regina and Brandon greatly reduced the degree of control obtained. Forsberg (6) using similar procedures has reported significant reductions in the infestation of _Polygonum convolvulus_.

Table 1. Effect of delayed seeding on yields of barley and wild-oat control in the prairie provinces, 1952-1957.

Location	No. of Years	Barley bpa Normal Seeding	Barley bpa Delayed Seeding	Wild-oat Plants Square Yard Normal Seeding	Wild-oat Plants Square Yard Delayed Seeding	Per Cent Control Wild oats
Brandon	5	32	29	41	36	12.2
Melfort	4	27	36	50	11	78.0
Regina	5	27	15	34	27	23.0
Lacombe	5	37	43	154	46	70.1

Other cultural practices such as harrowing or rod weeding after seeding, the use of fertilizers, stubble burning and fall tillage of stubble each have merit, but due to their dependence on precise seasonal conditions of soil and weather, produce highly variable control.

To sum up, cultural methods, under the Canadian system of extensive grain growing, cannot be relied upon to provide adequate weed control in most seasons. A survey of 150 Manitoba farms by Friesen and Shebeski (7) showed an average infestation of 224 weeds per square yard; that crops grown on stubble had about 40 per cent more weeds than crops grown on fallow; and that the average reduction in the yield of cereals due to weeds was just over 15 per cent. This loss in yield was calculated to be $5.00 per seeded acre and if applied to the entire seeded acreage of the Western prairies would amount to well over 200 million dollars annually. In the face of such losses the enthusiasm of Canadian farmers for selective herbicides can be readily appreciated.

HERBICIDES

The selective herbicide, 2,4-D, which required the use of relatively small dosages that could be applied in low volumes of water with wide coverage equipment was admirably suited to the extensive farming operations of Western Canada. The addition of such a potent yet selective herbicide, priced well within his reach, caused the farmer to quickly envisage sweeping changes in his whole farming program, usually toward even more extensive production. However, it was learned that many weeds, notably the Polygonums, and Galeopsis tetrahit were only partially controlled, while Avena fatua and Setaria viridis were not controlled at all. Consequently, the vision that the use of 2,4-D might completely replace tillage in cereal production has not been realised because most farm fields support a rather broad array of weeds which vary widely in their tolerance. In spite of these serious limitations, 2,4-D applied at the proper rate and growth stage, has killed many species, suppressed others and thereby reduced their competition with cereal crops to the extent that highly profitable yield increases have been realized.

The acute awareness by farmers of crop losses due to weeds and the role that 2,4-D could play in reducing them is best illustrated by the record of herbicide use. In 1947, the first year in which records were kept, 500,000 acres were sprayed with 2,4-D, in 1950 this figure had jumped to 13.5 million and to 22 million by 1960. In 1963 nearly 26 million acres of crop were sprayed with 2,4-D or MCPA. This amounts to about 2/3 of the total seeded acreage.

In Canada, as Dr. Hay pointed out at your last Weed Conference, the National Weed Committee co-ordinates weed research. He also pointed out that very little research or experimentation is done by industry. Consequently, with the coming of 2,4-D the Experimental stations and the Universities were hard pressed to provide direction in weed control practices. This direction has come largely from the National Weed Committee, which is composed of research and regulatory workers interested in weed control and which annually reviews the experimental data and issues recommendations and suggests areas in need of further study. In the early days of 2,4-D the members of this committee, working to a large extent through co-operative projects showed that wheat and barley were most tolerant from the 4-leaf to the boot stages of growth. Treatment prior to this period caused many leaf, stem and head deformities and reduced the yield of wheat and barley by some 5 to 15 per cent, while later treatment reduced the yield more drastically due to floret sterility. Formal publications of the effect of 2,4-D on wheat, barley and oats are in the literature (8, 21). The tolerance of oats to 2,4-D, particularly the ester forms, was not only considerably less, but followed a different pattern than wheat or barley. A study (9) conducted at a number of widely separated sites in Western Canada concluded that on the basis of weed control and grain yields MCPA was preferable to 2,4-D in oats and flax, except where Salsola pestifer was to be controlled. If 2,4-D is to be used on these crops treatment should be made prior to the 3-leaf stage or during the 6-leaf to the flag-leaf stages.

This work also stressed the value of early tre tment because 1) the greater susceptibility of weeds if treated during the seedling stage, and 2) early weed removal resulted in less competition with the crop and better yields. The urgency for theearly removal of weed competition has also been demonstrated by Shebeski (23) who showed that yield losses could be avoided if mustard infested wheat was sprayed within 29 days of emergence; however, if the removal of the weed competition was delayed until 35 days after emergence, yield losses resulted.

The butyric forms, viz: 4-(2,4-DB) and 4-(MCPB) have been tested widely and over an extended period of years. While the precautions previously outlined for the standard acetic forms generally apply, the combination of high dosage and high price has resulted in very limited use of these herbicides in cereals, even those undersown with alfalfa or clovers.

In more recent years other herbicides have been developed and some have found a useful place in cereal growing. Notable among these are di-allate, tri-allate, barban, dicamba and TCA, which have undergone detailed laboratory and field study, and will be dealt with separately. Mecoprop has been tested for a number of years while dichloroprop, tordon and the hydroxybenzonitriles have been studied over the past 2 or 3 years. Each of these herbicides have shown greater potential for the control of Polygonum species than 2,4-D. However, to date only mecoprop has been recommended for field use.

Weed Reaction to Herbicides:

The first attempt to classify weed species according to their reaction to 2,4-D was made by the National Weed Committee (Western section) in 1947. Since that time 50 species of annual, winter annual and biennial weeds and 25 species of perennial weeds have been so classified. The early classification grouped the annual weeds into five groups according to the ounces of acid required to give acceptable control or kill (Table 2). To compensate for differing environmental and physiological factors a range of rates was given for each group. As new herbicides have become available the classification was expanded and presently includes MCPA, 4-(2,4-DB), 4-(MCPB) and dicamba. There is a strong possibility that mecoprop, dichloroprop, tordon and ioxynil will be included in the 1964 classification . In 1963 the format was changed in that the groupings were simply omitted and dosages quoted for each species. Pre-emergence use has not been included in the classification because of its inconsistency.

Table 2. Rates of 2,4-D and MCPA recommended as sprays on wheat, oats, barley, rye, Corn (not under-seeded with legumes).

		OUNCES ACID EQUIVALENT PER ACRE				
Crop	Formulation	Weed Group 1	Weed Group 2	Weed Group 3	Weed Group 4	Weed Group 5
	2,4-D					
Wheat, Barley	Ester	3 to 4	4 to 6	6 to 8	(9 to 12)	(12 to 16)
Rye and Corn	Amine	4 to 5	5 to 7	7 to 9	(10 to 14)	(15 to 20)
(Oats in emergency cases)	Amine	4 to 5	5 to 7	(7 to 9)		
	MCPA					
Oats, Wheat	Ester	3 to 4	4 to 6	6 to 8	(9 to 12)	(12 to 16)
Barley, Rye	Amine	4 to 5	5 to 7	7 to 9	(10 to 14)	(15 to 20)
& Corn	Sodium Salt	5 to 6	6 to 8	8 to 10	(11 to 15)	(15 to 20)

Rates in brackets may cause crop injury.

Of the 75 species classified according to their reaction to herbicides, only about 16 annual and four perennial species are both widespread and troublesome problems. Brassica kaber, Thlaspi arvense, Salsola pestifer, Chenopodium album, Axyris amaranthoides, Galeopsis tetrahit and Avena fatua along with the perennial species Cirsium, Sonchus and Agropyron repens were the most prevalent species prior to the advent of selective herbicides. These species, with the exception of Avena fatua and the perennials have been effectively controlled by 2,4-D and/or MCPA. As expected, the species more tolerant to these herbicides have increased to alarming proportions, notably P. convolvulus, Fagopyrum tataricum, P. scabrum, Stellaria media, Spergula arvensis and Saponaria vaccaria.

Dicamba:

The failure of 2,4-D, even with two 5 oz/ac applications in the early stages, to give satisfactory control of P. convolvulus, Forsberg (6), and the remarkable control with dicamba of this and other troublesome members of the Polygonaceae and Caryophyllaceae families has resulted in concentrated field and laboratory studies of this herbicide over the past 2 or 3 years. A co-operative project headed by the writer and conducted at seven stations in the three provinces, has shown that wheat and oats could be treated with dicamba during the 2-and 3-leaf growth stages at dosages up to 4 oz/A without serious crop injury, i.e. the yield loss due to the herbicide was sufficiently small to be more than offset by the increased yield due to removal of the weeds. However, crop injury was often apparent at dosages in excess of 1.5 oz/ac. Barley has not been studied as extensively in the field as wheat and oats but the results to date suggest that this crop is somewhat less tolerant than wheat. Laboratory studies (Friesen 10) showed that the behavior pattern of dicamba was similar to 2,4-D in that the activity was centered in the regions of high meristematic acticity. Thus early treatments affected mostly the main stems while later ones affected the tillers and still later treatments affected the inflorescence. Crop injury progressively increased with these advancing growth stages. Dicamba showed a much higher degree of activity than 2,4-D, a ready mobility and a greater persistence in the plant so that the protective effect of growth stage could be readily overcome by increasing the dosage.

The co-operative study and others have shown that dicamba alone will not give satisfactory control of our common Cruciferae. This problem has been solved by using mixtures of dicamba with the amines of 2,4-D or MCPA. The mixtures appear to have the added advantage of giving satisfactory control of the Polygonums and Caryophylaceae with dosages of dicamba in the range of 1.5 to 2 oz/ac. In 1964, the first year in which dicamba was used commercially, virtually all of it was applied in mixtures with 2,4-D or MCPA and mecoprop.

Dicamba has shown strong activity against the top growth as well as some indication of effect on the rootstock of Cirsium, especially at dosages in excess of 6 oz/ac. Because preliminary observati ns indicated that dicamba was readily taken up from the soil, a study of the behavior of this herbicide in the soil appeared to be warranted, especially where the use of higher dosages to control perennial weeds were contemplated. It was found (11) that dicamba applied to the soil surface moved readily with added water and that it persisted much longer than 2,4-D in both autoclaved and not autoclaved soils. While the possible build-up of dicamba to levels toxic to crops as the result of annual applications of low dosages for selective weed control in cereals was not precluded as a result of this study, the probability of crop injury from such treatment appears remote. This speculation is rather consoling since there are about 12 million acres infested with P. convolvulus and even large acreages infested with P. scabrum, Fagopyrum tataricum, and Spergula arvensis on which the use of dicamba might be anticipated.

The efficacy of a two-way mixture of dicamba with 2,4-D or with MCPA have been compared with a three-way mix of dicamba, 2,4-D and mecoprop by sveral workers. Present results (unpublished) do not indicate significant differences. Greenhouse results (unpublished) suggest a greater activity for dicamba-MCPA than for dicamba-2,4-D mixtures.

Wild Oats Herbicides.

The search for a selective herbicide to control wild oats (Avena fatua) in grain crops has been a major project at most Experimental Stations and Universities in Canada throughout the 1950's. In the course of this work a great many potential herbicides were screened and tested but it was not until 1959 that the pre-emergence herbicide di-allate was recommended for use on flax and barley and the post-emergence herbicide barban for use on wheat and barley.

In a series of laboratory studies, it was shown (12) that if the wheat seed was planted at least 0.5 inches below a layer of di-allate treated soil there was significantly less injury than if planted in the treated soil itself (Table 3).

Table 3. Wheat yields and plants per square yard when di-allate and tri-allate were incorporated into the soil at different rates before and after seeding at four Experimental Farms in Western Canada, 1962.

Herbicide	Rate (lb/ac)	Time of Incorporation	Wheat Yield (Bu/ac) Brandon	Indian Head	Regina	Lacombe	Plants Sq. Yd Regina
Check	0.0	pre-seed	35.7	24.5	36.1	33.8	274
Check	0.0	post-seed	36.6	25.8	37.6	33.4	282
Di-allate	1.0	pre-seed	26.2	22.8	30.5	32.8	105
Di-allate	1.0	post-seed	26.4	26.0	36.2	34.0	203
Di-allate	1.5	pre-seed	15.7	19.3	30.0	33.2	83
Di-allate	1.5	post-seed	19.7	26.6	37.2	34.9	214

Wild oats, presumably due to their differing mode of coleoptile development, do not have this protection. The significant finding of this study was that the herbicidal activity was via the coleoptile rather than the root system. Field experiments have been reported by Molberg et al (20). As in a parallel series of experiments by Parker (22) and Holroyd (15) much of the precision in selectivity in the laboratory is lost under field conditions. However, in the Canadian and English studies there was a greater measure of selectivity when the seed was placed below the treated soil, increased wild oat control with deeper incorporation (i.e. discing was better than harrowing) and less activity in the field than the laboratory. The latter was considered to be due to the very poor mixing of the herbicide with the soil by disc type machines and the rather pronounced effect of dry surface soil. This was confirmed by another study (13) when air-dry soil sprayed and mixed with di-allate failed to control oats planted in moist untreated soil below it. The di-allate in the air dry soil could be re-activated by the addition of water. It would appear therefore that the herbicide is active only in the vapor phase but actual proof that this is in fact the mode of movement from the soil to the coleoptile has not as yet been established. Strong retention of di-allate in the soil has been noted by many workers, i.e. treatments applied in May were still giving a high degree of wild oats control in October. Fall application has met with some success in limited trials, although in our trials, a higher dosage is indicated. Studies of accumulative effects in the soil have been underway at Lacombe for several years. On our soil, with 12 per cent organic matter, there has been little indication of a build-up, harmful to wheat, from annual dosages of 3 lb/ac of di-allate or tri-allate.

The laboratory studies followed by extensive field tests have formed the basis on which di-allate and tri-allate are both presently recommended for post-seeding-but-pre-emergence application at 1 to $1\frac{1}{4}$ lb/ac to control wild oats in barley and wheat. Barley has shown greater tolerance, especially to tri-allate and this herbicide is recommended at rates up to $1\frac{1}{2}$ lb/ac before or after seeding. The crops should be seeded at a depth of three inches. Incorporation by double harrowing or shallow discing (two inches) should follow directly after spraying. In this way the wheat or barley seed is placed at least 0.5 inches below the treated soil and the risk of crop injury is thereby significantly reduced. These rates and methods of use give 80 per cent control, therefore, the higher rate of 2 lb/ac is suggested for the tolerant crop, flax. Leggett (19).

Barban is recommended as a post-emergence treatment on barley and spring and durum wheat at rates of 4 to 5 oz/ac in 5 gpa of water at a pressure of not less than 45 psi. Experience with barban in Canada has been similar to that in England and the Continent, namely, uneven wild oats emergence and the consequent poor control. Under good field conditions, control seldom exceeds 70-75 per cent. Increasing the spray pressure to 90 psi and the dosage from 4 to 5 oz/ac where infestations are heavy (in excess of 150 plants per square yard) will enhance the degree of control but will not overcome the problem of uneven emergence of the weed. The narrow margin of safety for treating wheat and barley might suggest the existence of significant varietal differences but none have been demonstrated in Canada to date.

Mixing barban with MCPA or 2,4-D while proven feasible, has only limited possibilities because of the precise timing needed for the barban treatment. Our trials in 1964 have shown that the mixing of dicamba with barban resulted in little or no wild oats control.

Barban, di-allate and tri-allate have not been used as extensively as 2,4-D or MCPA, largely because of the much higher relative cost. In 1963 about 60,000 pounds of all carbamates were sold compared with nearly nine million pouhds of 2,4-D and/or MCPA. Barban was used somewhat more extensively than di-allate because it is a post-emergence treatment and is slightly lower in price.

In the barley growing areas, barban must compete with delayed seeding of an early maturing variety as a control measure. The relatively narrow margin between these treatments is illustrated in Table 4.

Table 4. Relative cost and returns with *A. Fatua* control practices (Barley yields based on long term Alberta averages)

1. Optimum Seeding Date + Barban 4 oz/ac		2. Delay Seeding	
A. Fatua control 70%		*A. Fatua* control 80%	
Husky barley 50 bu/ac		Gateway barley 43 bu/ac	
Barley @ $1.00/bu	$50.00	Barley @ $1.00/bu	$43.00
Cost barban -	3.00		
-	$47.00		
Profit margin	$4.00/ac		

TCA

Setaria viridis is becoming increasingly prevalent throughout the Dark Brown and Black soil zones in Canada. On the lighter textured soils in these zones it is presently one of the major weed problems. Because it tends to emerge later than most annual weeds, delayed seeding of the crop is usually impractical. Dalapon at $\frac{3}{4}$ lb/ac or TCA applied at 4 to 6 lb/ac when the *Setaria* is in the 2-leaf sta e has given good control in flax. Dryden and Whitehead (5) reported sufficient differences in tolerance to low dosages of TCA between **Setaria** and barley and oats to supress the growth and prevent seed formation in the weed. These results combined with those of other workers have led to the conclusion that 2 to 4 lb/ac of TCA will give satisfactory control of **Setaria** without undue injury to barley and oats. The weed control and likelihood of crop injury are both increased in seasons when surface soil moisture is high. Serious injury to wheat will usually result from dosages in excess of 1 lb/ac. Clearance for the use of TCA in cereals has not as yet been obtained from Food and Drug authorities.

CONCLUSION

The impact of weed control practices on cereal production are difficult to assess precisely since they are completely confounded with such other inputs as fertilizers, fungicides, insecticides and the greatly increased degree of mechanization since World War 11. It is significant that all these factors have helped maintain production at a high level, especially in years of stress due to drought. Thus in 1937, a year of extreme drought, the average yield of wheat in Saskatchewan was only 2.7 bushels per acre (18). In contrast, under greatly improved farm practices in 1961, a year of equally severe drought, the average yield was 8.2 bushels per acre.

Probably the greatest impact due to herbicide research will be felt in the years ahead. To date the major effort has necessarily been expanded on learning what can be accomplished in the field with herbicides and only in very recent years have highly qualified personnel been assigned to explore the other implications of these growth regulating compounds. As more and better herbicides and other techniques become available it it not unreasonable to expect our whole system of farming will be revolutionized. The basic research into the life processes of the plant itself, stimulated largely by the recent successes of agricultural chemicals, will open up vistas in plant genetics, butrition and metabolism which will work fundamental changes in cereal production far greater than those which have been made to date.

References

1. BANTING, J. D. (1962) The dormancy behavior of *Avena fatua L* in cultivated soil. Can. J. Plant Sci. 42:22-39.

2. BUDD, A.C., W. S. CHEPIL and J.L. DOUGHTY (1954) Germination of Weed Seeds. III Influence of crops and fallow on the weed seeds in the soil. Can. J. Agr. Sci. 34:18-27.

3. BURROUGHS, V.D. and P. J. OLSON (1955) Reaction of small grains to various densities of wild mustard and the results obtained by their removal with 2,4-D or by hand. Can J. Agr. Sci. 35: 193-201.

4. CHEPIL, W.S. (1946) Germination of weed seeds. I Longevity, periodicity of germination, and vitality of seeds in cultivated soils. Sci. Agri. 26: 307-346.

5. DRYDEN, R. D. and C.W. WHITEHEAD (1963). The effect of TCA on green foxtail in competition with cereals. Can. J. Plant Sci. 43: 451-456.

6. FORSBERG, D. E. (1956) Report on wild buckwheat studies at Experimental Farm Scott, Sask. Proc. NCWCC p 33.

7. FRIESEN, G. and L.H. SHEBESKI (1960) Economic losses caused by weed competition in Manitoba grain fields. I Weed species, their relative abundance and their effect on crop yields. Can. J. Plant Sci. 40: 457-467.

8. FRIESEN, G. and P. J. OLSON (1953) The effect of 2,4-D on the developmental processes in barley and oats. Can.J. Agr. Sci. 33: 315-329.

9. FRIESEN, H. A. and D. R. WALKER (1956) A comparison of MCP and 2,4-D for control of annual weeds in grain crops. Can.J. Plant Sci. 37: 69-81.

10. FRIESEN, H. A., H. BAENZIGER and C. H. KEYS (1964) Morphological and cytological effects of dicamba on wheat and barley. Can. J. Plant Sci. 44: 288-294.

11. FRIESEN, H. A. The movement and persistence of dicamba in soil. (to appear in WEEDS 13:1, 1965.)

12. FRIESEN, H. A., J. D. BANTING and D. R. WALKER (1962) The effect of placement and concentration of 2,3-DCDT on the selective control of wild oats in wheat. Can.J. Plant Sci. 42: 91-104.

13. FRIESEN, H. A. (1961) Effect of applying 2,3-DCDT to air-dry soil on the control of wild oats. Res. Rept. Natl. Weed Comm. (Western Canada) p. 183.

14. Cultural control of wild oats. Can. Dept. Agric. Pub. 1044 (1959).

15. HOLROYD, J (1964) Field investigations concerning the selective phytotoxicity of di-allate to Avena spp. in wheat and barley Weeds. Res. 4: 142 - 146.

16. HOPKINS, E. S. (1950) Summerfallow in the Prairies. Agric. Inst. Review pp 19-23.

17. HOPKINS, E. S. and A. LEAHEY (1944) Crop rotations in the Prairie Provinces. Canada Dept. Agric. Pub. 761.

18. Handbook of Agricultural Statistics. Part I Field Crops 1908-1958. D.B.S. Agr. Div. (1959)

19. LEGGETT, H.W. (1960) Summary, Wild oats control. Res. Rept. Natl. Weed Comm. (Western Canada) p.27.

20. MOLBERG, E.S., H. A. FRIESEN, E.V. MCCURDY AND R. D. DRYDEN (1964) Placement of di-allate and tri-allate for control of wild oats in wheat. Can.J. Plant Sci. 44: 351-358.

21. OLSON, P. J., S. ZALIK, W. J. BREAKEY and D. A. BROWN (1951) Sensitivity of wheat and barley at different stages of growth to treatment with 2,4-D. Agron. J. 43: 77-83.

22. PARKER, C. (1963) Factors affecting the selectivity of di-allate against *Avena spp* in wheat and barley. Weed Res. 3: 259-276.

23. SHEBESKI, L. H. (1954) Effect of mustard in wheat and flax. Proc. NCWCC.

24. TOOGOOD, J. A., C. F. BENTLEY, G. R. WEBSTER and F. W. MOORE (1962). Grey Wooded soils and their management. Univ. of Alta. Bull. 21.

DEVELOPMENTS IN WEED CONTROL IN FRUIT CROPS ON THE EUROPEAN CONTINENT

W. van der Zweep, D. van Staalduine and P. Goddrie
Wageningen and Wilhelminadorp, the Netherlands

We are of course very honoured with the invitation to present to this conference a review of weed control developments in fruit crops on the European continent. We are not very familiar with the situation in one of the most important continental crops, the grape vine, but we shall try to comment on developments here in the best way possible.

As in the United Kingdom, also on the European continent there is increasing interest in the use of herbicides in fruit crops. In top fruits, bush and cane fruits, vines and strawberries chemical weeding around the base of the plant, strip weeding along plant rows and overall treatments are becoming more and more familiar in techniques of management.

For top fruit and bush fruit plantations opinions differ as to the influence of grass or cover crops on the yield and quality of the harvested fruit. On this occasion we cannot go into detail and would only indicate that the interaction between the fruit crop and any other vegetation present is a variable and is determined by a whole range of ecological factors. Consequently for any specific crop there are widely divergent opinions as to the effect of ground cover, depending on different systems of management, of soil and of climate. In some areas it is not so much the competitive influence of the vegetation on the crop that worries the growers, but more the frequent occurrence of damage due to night frosts where dense vegetation or mulch is present.

Many growers like to have some kind of soil cover under top fruit during autumn and winter, mainly to facilitate harvesting and pruning and to protect the soil against erosion and deterioration of soil structure. In this case and also when lupins, white clover or vetches are purposely planted as green manures the soil cover will influence the types and doses of herbicides that can be used.

It seems justified to make the generalisation that because of the use of weaker root stocks modern fruit growing techniques require that, at least within the rows of the crops, the stem bases or a narrow band along the row should be kept free of vegetation for part, if not for the whole year. In some crops, like vines, strawberries and raspberries and also under more arid conditions in tree fruits the area between the rows has also to be kept bare.

As might be expected the introduction of herbicides into fruit plantations has caused general concern about possible undesirable side effects of the chemicals on the crop. Much research on this aspect is required, because in modern fruit growing undesirable side effects of pesticides are of greater commercial importance than ever before. Requirements as to the safety of herbicides have to be high because modern orchards carry an increasing number of trees or bushes per unit area and the plants are coming into greater and more uniform production at an increasingly early age.

Although it is generally recommended to start a new fruit plantation on land free of vegetation this ideal is rarely obtainable. It is therefore of interest that at some research stations, for instance at Jork (Karnatz, pers. comm.) studies are under way on the possibility of planting apples and pears into weedy soil and using herbicides to control the vegetation from immediately after planting. This technique has not yet reached the practical grower, however.

Chemical weed control in fruit crops, excluding strawberries, can best be characterized as a two stage process. During the first stage the existing vegetation has to be removed and, once this is achieved, the second stage is to maintain the weed-free condition. In the vegetation present perennial weeds are generally of great importance if frequent mechanical weed control has not been practiced before the use of herbicides started. The presence of species like Agropyron repens, Agrostis spp., Polygonum amphibium and Equisetum spp. greatly influences the choice of the herbicide programme. For the various fruit crops we may conclude that, by and large, in Europe we are still in the first of the two stages. In most European countries the initial treatment in orchards, vineyards and bush fruit plantations has been a mixed application of a triazine, usually simazine, with the addition of amitrole (Jacobs, 1962; Karnatz, 1964) Mukula and Säkö, 1961; Stryckers and Braeckman, 1963). It seems that mixtures of diuron and amitrole are much less generally used, although they are undoubtedly of similar herbicidal value and safety to the crops (Stalder, 1964). In apple and pear growing areas there is little tendency to replace simazine by atrazine, because of the greater risks of crop injury involved, but in vineyards there is more interest in atrazine.

The above mentioned herbicides have really introduced chemical weed control in the orchard, but almost from the outset their introduction has been accompanied by the problem of resistant weeds. In particular the general increase of Convolvulus arvensis has to be mentioned. The same weed is also becoming increasingly important in the Netherlands, where in 1963 and 1964 another herbicide, paraquat has come into widespread use.

The Dutch preference for paraquat can be largely explained by the fact that until the summer of 1964 the use of products containing amitrole had not obtained official approval for application in fruit plantations. The short residual action of paraquat necessitates repetition of the treatment, but even then, in addition to Convolvulus, several species cannot be fully controlled. There are, however, indications that diquat-paraquat mixtures give better results against Polygonum species than paraquat and also the effect of adding more wetting agent to the paraquat seems to need further study.

The increased occurrence of dicotyledonous perennials has greatly stimulated interest in the auxin-type herbicides. Particularly in vineyards, but also in other fruit crops, the use of these herbicides is regarded with great suspicion, although from research centres like Colmar in France (Julliard, 1961) and Cornell and Davis in the U.S.A. (for example Leonard et al, 1961) is has been clearly demonstrated that in vineyards careful applications of 2,4-D do not necessarily endanger the crop. In European fruit plantations and vineyards there is more interest in the salts of MCPA and in many instances very good effects have been obtained with this chemical, without injury to the crop. In Germany the application of a commercial mixture containing MCPA in apple and pear orchards has obtained official approval. In some other commercial preparations other auxin herbicides (not yet officially disclosed) are substituted for MCPA. It is to be expected that in the next few years much research emphasis will be put on developing safe applications of auxin herbicides for the control of specific weed species. In view of the data presented by Luckwill and Lloyd-Jones (1960) it will be necessary to pay considerable attention to varietal differences in the reaction of fruit crops to auxin herbicides.

A herbicide that has received some attention in 1964 is dichlorothiobenzamide, a product related to dichlobenil, that is already officially approved for use in orchards in some countries. The practical value of this herbicide has not yet been fully assessed. Its action on some troublesome perennials like Cirsium arvense and Tussilago farfara seems to be good, but other species, like Ranunculus repens and some perennial grasses are apparently more resistant. The granular formulation has given better results than the wettable powder, probably because in the latter form the herbicide is more susceptible to volatilization.

Among the substituted uracils bromacil in particular has shown great promise for annual and perennial weed control in fruit crops, but it is too early to indicate a real practical development. So far there is indication of weeds proving resistant. We are interested in obtaining more information on the physiological resistance of the crops and on the behaviour of the product in the soil. This also holds for the dichlorothiobenzamide.

Although it is not true that dalapon has disappeared from the weed control scene in fruit crops its use in Europe can best be considered as an early stage in the development of chemical weed control methods. Its tendency to lead more to suppression of grasses than to their eradication at rates tolerated by the crop has always made dalapon a product of limited value for weed control in fruit plantations. In mixture with simazine or atrazine and with diuron it is still in use, however.

There seems to be a general reluctance to give recommendations on the use of herbicides in stone fruits like cherries, peaches and apricots. In general there is a lack of experience. The basis of a suspected difference in susceptibility between apples and pears and stone fruits is not known. Except for their greater susceptibility to dalapon cherries are always considered just as tolerant like apples and pears.

One of the most intriguing scientific aspects of chemical weed control in fruit crops is the stimulation of growth observed after applications of triazines. Karnatz (1964) in particular has reported on this stimulation: the increase in leaf size, in N-content of the leaves, shoot length, fruit size and stem diameter. Similar effects were studied in the U.S.A. by Ries et al (1963). It is very difficult to assess in practical experiments the basic factors involved. In the Netherlands we have the impression that the phenomenon is more pronounced when the band treated in the row is not too narrow and similar observations in other countries lead to the conclusion that it is very difficult to exclude competition effects from the explanation. On the other hand similar observations as to a possible stimulatory effect of triazines in the absence of weeds are known, for instance on the growth of cuttings of berries and on the growth of cereals. It is not to be expected that the basic underlying factors will be understood before we obtain some insight into the effects that sublethal quantities of these herbicides have on the physiology and development of plant tissues. The studies of Foy and Bisalputra (1964) in California may perhaps give us some clue in this respect. They studied the effects of prometryne on cotton leaves and observed typical effects on the structure of the mesophyll tissue with low concentrations.

In black currants, gooseberries and raspberries weed control problems are in a certain way intermediate to those in top fruit and those in strawberries. Complete freedom from weeds, at least during the growing season is required. It is frequently difficult not to wet the foliage of lower branches with the spray liquid. In practice the use of herbicides seems to be much less general than in the United Kingdom, but in the field of research there are developments similar to those observed in this country. Also in these crops auxin herbicides have to be studied, because of the increase in the perennial weed flora. Simazine remains the weed killer most generally used, with paraquat used as contact herbicide.

In weed control in strawberries the developments are not much different from those taking place in Great Britain, although the varieties grown are frequently not the same. The varieties grown are generally healthier than they were a few years ago and the number of years for which the crop is maintained on the land is changing. There is currently greater interest in longer cropping periods because of better methods for controlling Botrytis and for killing weeds. Interest in the matted row system and to a lesser extent in the bed system of growing strawberries is also increasing for the same reasons.

Planting time comes earlier than is usual in the United Kingdom and consequently there is great interest in the application of chloroxuron shortly after planting. This product has a great selectivity. During the autumn after planting in late summer the use of simazine is generally not recommended, although in several countries simazine is used in Senga Sengana 2 months after planting. This treatment is of course especially recommended on soils with not too low a content of organic matter (>5%). Autumn treatments do not guarantee weed freedom until harvest and therefore retreatment with chloroxuron in early spring has become accepted on soils where simazine cannot be recommended at that period.

Interrow applications of paraquat are becoming of local importance and for this technique special machinery has been developed, for instance for low pressure, large droplet sprays.

Even before the introduction of chemical weed control in strawberries there was interest in post-harvest defoliation, a practice frequently thought to increase the initiation of flower trusses and to decrease fungal attack. In the Netherlands there is research interest in combining mechanical or chemical post-harvest defoliation with chemical post-harvest weed control. In our experiments an emulsifiable formulation of PCP applied simultaneously with simazine is promising on non-defoliated or previously mown strawberry plants.

As to new herbicides there is interest in the use of diphenamid and the uracil DuPont 634, but it is too early to assess the practical importance of these compounds.

There is relatively little information available on the intrinsic physiological resistance of fruit crops to the herbicides used in practice. As to the soil-applied herbicides it is generally assumed that "depth protection" of the root system is the main factor in the selectivity of the treatments and the general recommendation not to apply these products to trees in between one and three years after planting is a general safety measure based upon this knowledge.

Only through nutrient culture experiments, pot experiments and by filling plant holes with soil through which the herbicide has been uniformly mixed can some insight be obtained into the potential physiological effects of the products on the crop. Studies by van Oorschot and Haker (1964) with several varieties of strawberry grown in Hoagland's solution and in soil containing low concentrations of simazine have shown these plants to be susceptible to concentrations similar to those affecting such plants as oats, i.e. about 0.05 ppm. Consequently varietal differences in reaction observed in the field such as the relative tolerance of the variety Senga Sengana are probably largely the result of differences in morphological and phenological development. Other studies by van Oorschot on the effect of simazine on the photosynthesis of the strawberry give proof of its small capacity to inactivate simazine. Strawberries are much more resistant to chloroxuron, which was also studied at similar concentrations. Of course this information is not in disagreement with the interesting practical application of simazine in strawberry runner beds, for which Holloway (1962) has summarized explanatory information.

In Germany Mohs (1961) has grown root stocks of apples (M 11 and A 2) and cherries in a nutrient solution and applied several herbicides to the medium after the leaves were expanded. The growth of the plants as measured after 60 days was not reduced, but was slightly stimulated by concentrations of simazine of 0.0875 and 1.75 ppm. Because of differences in the experimental environment these data cannot be easily compared with other information. Mohs' results, however, suggest that, in some fruit crops at least, there is a degree of physiological tolerance to herbicides taken up through the roots.

Another interesting question is whether the susceptibility of a fruit tree or grape vine to a herbicide is determined by the susceptibility of the root stock or of the scion variety. In the U.S.A. Tweedy and Ries (1964) concluded that the resistance of the scion is the dominating factor. In Europe no information has been published on this subject but attention is being paid to it.

A special aspect of research on susceptibility in perennial crops is the effect of annually repeated applications at normal or purposely increased rates. As in the United Kingdom no undesirable effects were found under many situations where these experiments have been carried out during at least 3 - 5 years. Typical results of these studies are those of Dermine (1962) and Wurgler (1961). The entire complex of problems related to the long-term effects of herbicides on the development of fruit crops and on the characteristics of the soil is so complicated that from the research point of view we must unfortunately conclude that the surface of the problem has, as yet, hardly been scratched.

In fact fruit plantations where the soil was maintained bare of vegetation were known long before herbicides came into use, particularly where moisture supply was deficient. The new factor introduced by the use of herbicides is, of course, the element of non-cultivation. Because of the studies of Dr. Robinson the principle aspects of this system of fruit growing are so well known to this audience that there is no need to go into detail here. It cannot be said that in Europe the possibilities of non-cultivation are stimulating fruit experts to the same extent as they seem to do in the United Kingdom. We are of the opinion, however, that under many of our conditions and especially where soils are hard to cultivate, the principles of non-cultivation will gradually become more accepted. Non-cultivation in the rows of apples and pear orchards is already increasing and likewise non-cultivation in strawberry alleys. The combination of non-cultivation and the supply of organic matter in one or another form to the non-cultivated area has not yet developed into practical systems. The matter does not seem very urgent either as long as growers prefer to have some vegetation in the non-cultivated strips during autumn and winter.

We should like to conclude with some remarks concerning developments in the construction of equipment for herbicide applications in fruit crops. Very rapidly the need for specialized spraying machinery has been fulfilled. Because of the fact that the spray cone of the nozzles reaches beyond the spray boom no special "feeling"-system are necessary to prevent the machinery from touching the stems. In general the introduction of chemical weed control has greatly facilitated the care of the area in the immediate proximity of the stem bases and consequently contributed to a better health of this important stem section.

In discussing strawberries we have already mentioned the use of spraying equipment for the areas in between the rows, especially for the application of bipyridilium herbicides.

References

DERMINE, E. (1964) Désherbage chimique en culture fruitière. A propos de rémanence de certains désherbants chimiques dans le sol. Rev. Agric. (Bruxelles) 15, 423-435.

FOY, C.L., and BISALPUTRA, T. (1964) Anatomical effects of prometryne on leaves of glanded and glandless cotton. Plant Phys. 39, Suppl. LXVIII.

HOLLOWAY, R.I.C. (1962) A review of the rooting behaviour of fruit plants, in relation to the use of soil acting herbicides. Proc. 6th Brit. W.C.C., 2, 561-567.

JACOBS, R.H. (1962) Entwicklung, Stand und Anwendung chemischer Unkrautbekämpfungsmittel auf Triazin- und Aminotriazolbasis im Weinbau. Wein Wiss. 17, 77.

JULLIARD, B. (1961) Nouveaux essais de désherbage au vignoble. Comptes Rendus 1re Conf. Columa, Paris, 402-407.

KARNATZ, H. (1964) Weitere Versuchsergebnisse bei der Bekämpfung von Ungräsern in Obstanlagen. Mitt. Obstbauversucher. Alten Landes 19, 109-117.

LEONARD, O.A., BAYER, D.E., and WEAVER, R.J. (1961) Results of tests using 2,4-D in vineyards. The Hormolog 3, 10-11.

LUCKWILL, L.C. and LLOYD-JONES, C.P. (1960) Metabolism of plant growth regulators. Ann. Appl. Biol. 48, 613-625, 626-636.

MOHS, H.J. (1961) Untersuchungen zur Frage der Anwendung von Herbiziden im Obstbau. Mitt. Obstbauversuchsr. Alten Landes, Beih. 3, 64 p.

MUKULA, J., and SÄKÖ, J. (1961) Chemical weed control in fruit crops. Experiments conducted in 1956-60. Public. Finnish St. Agric. Res. Board 189, 26 p.

RIES, S.K., LARSEN, R.P., and KENWORTHY, A.L. (1963) The apparent influence of simazine on nitrogen nutrition of peach and apple trees. Weeds 11, 270-273.

STALDER, L. (1964) Einige Erfahrungen mit chemischen Unkrautvertilgungsmitteln in Niederstammanlagen. Schweiz. z. Obst- und Weinbau 73, 64-72.

STRYCKERS, J., en BRAECKMAN, H. (1963) Amitrol als komponent van herbicidencombinaties in de fruitteelt. Meded. Landbouwh. Opz. Stations van de Staat, Gent 28, 1175-1187.

TWEEDY, J.A., and RIES, S.K. (1964) Nature of decidious fruit tree tolerance to herbicides. 1964-Meeting Weed Soc. America, Abstr. 92.

VAN OORSCHOT, J.L.P., and HAKER, J.G. (1964) The susceptibility of strawberry plants to simazine. Jaarboek I.B.S. Wageningen, 51-59.
WURGLER, M. (1961) Discussion 6me séance Désherbage en Viticulture et Arboriculture fruitière. Comptes Rendus lre Conf. Columa, Paris, 442-444.

GRASSLAND OR WEEDLAND ?

J. D. Ivins
Department of Agriculture, University of Nottingham

Summary. The relative value and the relative abundance of particular plants occurring in grasslands is discussed and possible reasons for the sward composition of permanent grassland are suggested.

. . . .

British grasslands alone are considered here although the principles apply to grasslands in many parts of the world. The grasses themselves are considered first then the out-and-out weeds which are uneaten by livestock and which occupy space and utilise resources which could be utilised by edible species and, finally, the miscellaneous plants which are eaten by livestock. As far as the grasses are concerned, no attempt is made to draw a clear line between useful species and weeds. Ingalls (1872) states that "one grass differs from another grass in glory. One is vulgar and another patrician. There are grades in its vegetable nobility". The report by Baker (1960) on permanent grassland in England, suggests that our grassland is definitely plebeian with over half of inferior quality and with approximately four million acres occupied by very poor grasses. There is a great deal of evidence on the seasonal and total production and the nutritive value and digestibility of the different grasses and with this evidence in mind an assessment of the botanical composition of a sward gives a very clear picture of its potential production. On occasions it has been fashionable to argue that we do not grow grass to please botanists but to feed livestock. This is perfectly true, but, just as the varying potential performance can be assessed by comparing various ages and makes of cars, so can the potential production of grasses be assessed by comparing different species. Whether that potential is realised depends on many factors, in particular stocking rates and the capacity of the stock for milk or meat production.

Whether a grass is a weed or whether it is useful depends on the circumstances. Under some hill conditions Yorkshire Fog (Holcus lanatus) is more valuable than a number of other grasses such as the fine-leaved fescues or Nardus, whereas in lowland grassland it is little more than a weed, occupying space which could be occupied by species which are more productive, more palatable and of higher feeding value. Again, the replacement of some hill swards by Agrostis would lead to considerable increases in production whereas Agrostis rarely achieves the level of production which may be expected from lowland grassland.

Some grasses such as sweet vernal (Anthoxanthum odoratum), Yorkshire Fog (Holcus lanatus) and meadow foxtail (Alopecurus pratensis) abounding in meadows cut for hay each year run to flower early in spring, for example, meadow foxtail flowers in late April. Although to some extent species differ in this respect, work at Hurley and elsewhere shows that the digestibility of herbage deteriorates most rapidly after flower-head emergence of grasses. A fall of half of one per cent per day has been recorded for several grasses. Imagine then the digestibility of the hay cut in July from these grasses which flowered in April. The hay may look good and it may smell sweet, depending on the weather, but the larger proportion of the dry matter is destined to the farmyard manure heap as undigested residues, having made no contribution to the nutrition of the animal. This is perhaps a more subtle manner in which grasses may prove inferior, but it is a most important point, for hay, and for that matter any herbage whether fresh or conserved, of low digestibility necessitates much supplementary feeding even to satisfy the maintenance requirements of the animal.

It is likely that further studies on the nutritive value of herbage, as indicated by digestibility, will establish even more clearly which grasses are weeds i.e. plants out of place in a particular set of conditions.

Several possible reasons for the state of our permanent grasslands come to mind. Apart from the survey, these areas receive comparatively little attention and most of the research in grassland is concerned with the top flight of grasses. While white clover versus nitrogenous fertilizers are debated as a major issue, the fact is frequently ignored that a great proportion of grassland has neither white clover nor does it receive nitrogenous fertilizer. Leys versus permanent grassland are debated without any definition of the type of permanent grassland and this is a most variable commodity. One permanent sward may be similar to another one only in that it is green for a particular period of the year, and unless the particular permanent grassland in mind is described misunderstandings arise. Members of an audience may be urged to plough up permanent grassland to the point when, if asked, they might stage a demonstration against Agrostis. Yet it is possible that few are aware that their own acres are dominated by Agrostis and as Agrostis is, without doubt, the most common plant in our grasslands it is possible that intensive courses in the identification of grasses might serve a very useful purpose.

Perhaps the situation arises from the fact that often the sward is allowed to set the limit to production rather than establishing a target for production and matching the sward and its treatment to this target. Just as one would not hope to break the sound barrier in a Tiger Moth one cannot hope to get five hundred gallons of milk per acre from an Agrostis-fescue sward. If the target is the maintenance of only one bullock to two acres then the Agrostis-fescue sward will suffice, but if the target is the growth of two bullocks to the acre then Agrostis and fine-leaved fescues are weeds. Soil, climate, topography, size and system of farming and, above all, target of production have to be taken into account, but if the conditions permit the growth of better species in terms of productivity and nutritive value then the inferior grasses are surely weeds, if high production is the aim.

Also the harmful effects of winter grazing and consequent poaching in high rainfall areas may not have been emphasized sufficiently. The tendency for farmers to turn out their dairy cows each day during winter is one contributing factor to the low quality of some grassland. Often there are spectacular results from a change over to a yard-and-parlour system which permits cattle to be kept off the land in winter, leading to a reduction in the amount of annual meadow grass (Poa annua) and broad-leaved weeds. There are many lessons to be learned from the fact that usually the first-quality permanent grasslands are found - when they are found - on the beef fattening farms, rather than dairy farms.

A further point which may account for the condition of some grassland is the lack of an easy measure of grassland output. The effect of weeds on the yields of arable crops is easily seen whereas with grassland there is the difficulty with the definition of a weed and the fact that its produce is not directly saleable. Furthermore, the ley may have been over-sold. All leys are not necessarily good leys for some in their third year may bear little if any resemblance to the seeds mixture. The ley is better than permanent grassland only if it consists of superior species - superior because of a longer productive season, greater total productivity and higher nutritive value of herbage. Given a ley and a permanent pasture of similar botanical composition it would take the most refined techniques of experimentation to detect the slightest difference if one existed. Much cruder methods would show the superiority of ryegrass (Lolium perenne) over Yorkshire Fog (Holcus lanatus) whether in permanent pastures or leys and either grass can dominate either type of sward.

The full picture of soil conditions and the treatment which it has received over the years can be read from the composition of a sward. It is over 30 years since Martin Jones showed how this could be changed by management, almost at will, and the prevalence of inferior grasses which Baker reported suggests oceans of room for the application of these principles. Furthermore, one can direct reseed, use chemical treatments or any other means of grassland improvement,but little will be gained unless continued attention is given to soil conditions and sward management. Many examples of deterioration after reclamation can be cited.

Looking beyond the grasses clearly some plants are out-and-out weeds. They are not eaten by livestock and of these the most extensive are thistles, in particular creeping thistle (Cirsium arvensis) and rushes (Juncus spp.). It may be claimed that rushes are useful in providing shelter for sheep but unless eaten by livestock any grassland plant is virtually useless - no matter what its chemical composition. Certainly many plants are weeds in the garment sense for they do little more than clothe the nakedness of the earth.

During 1964 observations have been made on the weediness of grasslands, within an area bounded by York, Holyhead, Exeter, Reading and the Wash. It is not claimed that all the grassland in that area has been seen and the limitations of such a survey are fully appreciated. Nevertheless, the fact remains that of the grasslands inspected, over one-third (some 38% of fields) have a problem of some magnitude or other with thistles, mainly creeping thistle (C. arvensis). The problem varies from localised patches of sufficient size to be unsightly to almost complete dominance, and it seems that thistles are rapidly chasing other species in the race to be second only to Agrostis in the grassland league. Exactly what this means in reduced productivity may be argued. Usually grasses were growing among the thistles but if the moisture, light energy, and nutrients used by the thistles had been used by edible species and the dry matter had been palatable and digestible then clearly the amount of animal food produced per acre would have been greatly increased. The thistle is not alone as an out-and-out weed and in the wetter areas rushes present a similar problem and in some hill areas bracken, as is known only too well. It would go against all accepted principles of the physiology of plant growth to suggest that these weeds were having no effect on the growth of grasses and it would accord with those principles to suggest that the reduction in productivity was in proportion to their abundance.

A further group of plants in British grasslands are not so easy to praise or condemn for they are eaten to some extent by livestock, for example, creeping buttercup (Ranunculus repens) and dandelions (Taraxacum officinale). Others are sought out by livestock and are eaten often in preference to grasses and clovers, the outstanding one here being ribgrass (Plantago lanceolata).

Worden (1946) considered that the behaviour of cows in seeking out weeds and material from the hedgerows may be due to fibre deficiency or to lack of other nutrients which are not present in sufficient amounts at that time. Stapledon (1948) recording observations on the palatability of "herbs" attributed grazing animals with the ability to select because they sense the need for a particular balance, whether for minerals, dry matter or fibre and digestible nutrients. Brynmor Thomas (1949), when discussing the deficiencies of the modern ley with its simple flora, pointed out that certain herbs such as sheep's sorrel (Rumex Acetosella) and ribgrass are distinctly superior to the grasses and clovers in their content of the major mineral elements. Under some conditions it is likely that nothing would be lost by the inclusion of ribgrass in seeds mixtures, or by allowing it to survive in permanent grassland, for Milton (1943) found that in the early years after sowing, ribgrass outyielded perennial ryegrass when both were not manured, and Stapledon (1940) referred to the fact that under poor conditions at Cahn Hill lambs were fattened satisfactorily on ribgrass swards. Furthermore, Von Gruenigen (1949) suggested that some deficiency diseases in livestock in Switzerland might be due to the lack of miscellaneous plants in the swards which they graze. This is the case for these plants.

Against them is the immediate but small point that they often hinder the curing of hay, owing to their succulence. Against them is the fact that the case itself is based on suggestions with no definite evidence whilst there is some evidence against the idea of nutritional wisdom (Tribe and Gordon, 1950). Against them is the fact that given the opportunity stock will seek out and eat some plants such as yew (Taxus baccata) with results which suggest that their instinct is for suicide rather than nutrition.

In 1954 and again in 1955, a series of swards was sown down at Sutton Bonington in an attempt to measure their relative productivity in terms of milk production and milk composition using identical twin dairy cows. The experiments showed the importance of stocking rate and animal potential in relation to milk yields, but that is another issue. Two of the swards were sown with similar mixtures - timothy, meadow fescue and white clover, but one had ribgrass and chicory in addition. For three years the productivity, milk composition and fertility of the twin dairy cattle grazing these areas was recorded. No supplementary feeds were given and the milk production averaged just over 700 gallons per acre from each sward (spring calvers - summer grazing). It was impossible to detect any differences in milk production or composition or any effect on fertility from the inclusion of the "herbs". As far as could be discovered, the only thing that happened was that under intensive stocking these palatable species were grazed out by the third year, but the fact that it was not possible to measure their value does not mean that invariably these plants are of no value.

The success which some farmers are achieving by using pure swards of Italian Ryegrass for milk production must be recognised here. Frequently mineral supplements, in particular magnesium, are fed, but the need for this probably arises from the use of generous quantities of fertilizers rather than simplicity of the sward in itself.

The possible case for ribgrass applies only to those plants in grassland which are both productive and palatable. The common daisy is palatable but in terms of productivity would support rabbits rather than sheep to the acre - mineral efficient rabbits perhaps. On the other hand, the common buttercup (Ranunculus acris) is reasonably productive but unpalatable and is clearly a weed, so points made for some species cannot be used as arguments in favour of weedy grassland generally - only in support of productive and palatable species to a limited extent and only then in the absence of sufficient information on their value. There is the point that many herds giving high levels of production from grassland manage very well without them. There is the point that these palatable plants are not at all prevalent in pastures which are grazed year by year - and so in fact contribute little to the grazing animal - but they are very common indeed in meadows which are put up for hay each year.

Generally what is understood by intensification of grassland production - fertilizer use, controlled grazing and high stocking rates - leads to a simplification of the sward and a reduction in the proportion of weeds, but this is a comparatively slow process and any relaxation is followed by reversion. Possible factors of grassland management which lead to the weediness of pastures are winter grazing especially if accompanied by poaching, severe grazing in early spring and undergrazing in late spring and summer. The issue is that the superior grasses generally start growth earlier in spring and at this time conditions for plant growth - temperature and light intensity in particular - are not at the optimum. Recovery after grazing is relatively slow and as later starting species come into action they find themselves in competition with weaker plants and so are able to dominate. Among these late starters are serious weeds such as creeping thistle (C. arvensis) and the inferior grasses - inferior because they are later to start and earlier to cease growth. Stocking density is an important factor here. The dairy farmer with a fixed herd size exerts an intense grazing pressure when herbage is in short supply - as in early spring. When herbage is plentiful the pressure is much reduced, whereas the beef grazier and the lamb producer, adjust stocking rates to the amount of herbage available, thus maintaining a fairly uniform grazing pressure. Attention has already been drawn to the fact that first class perennial ryegrass swards are more likely to be found on the beef farm than on the dairy farm.

The experiences of Milton (1943) with ribgrass are recalled where under poor conditions it outyielded perennial ryegrass when both were not manured. If these results are coupled with the evidence that fertilizer usage, in particular nitrogenous fertilizer, leads to a simplification of the sward in favour of the grasses, they justify the suggestion that low fertility or at least low nitrogen, may account for the scarcity of the better grasses and the abundance of some weeds. Other weeds may be able to tolerate soil acidity to a much greater extent than do the better grasses - an obvious remedy here. Certainly Agrostis and fine-leaved fescues do this and the last thing one should do to a lawn, where these species are required, is to lime it. This encourages one to question whether sheep's sorrel (Rumex Acetosella) has a higher content than the grasses of the major mineral elements such as calcium, when both are adequately limed and manured. It is also possible that competition between weeds and grasses in relation to other plant nutrients might be studied to advantage.

In the grassland world there will be continued debate on leys versus permanent pastures, nitrogenous fertilizers versus white clover, silage versus hay, strip-grazing versus paddock-grazing, simple versus complex seeds mixtures, and a dozen other points including grassland or weedland. The facts are (Baker, 1960) that excluding the rough grazings, 8% of the permanent grasslands in England are first-grade ryegrass pastures, 12% are second grade, 22% are Agrostis-ryegrass swards, 38% are Agrostis dominant, 8% Agrostis with rushes, 9% fine-leaved fescue and 3% dominated by Nardus and Molinia.

Fields may give a speckled appearance in spring from the white of the daisy and the brown of Luzula turning to red of sorrel and the yellow of dandelions and buttercups - a pleasant picture perhaps but one which does not yield meat or milk.

Although the debates which are listed are important it may be argued that often they are permitted to cloud the first issue which is the composition of the sward and the evidence suggests that there is vast scope for improvement.

References

BAKER, H.K. (1960) Permanent grassland in England. Proc. 8th Int.Grassld. Congr. 394-9

INGALLS, J.J. (1872) In praise of Blue Grass. Reprinted in U.S.D.A.,Yrbk. 1948

MILTON, W.E.J. (1943) The yields of Ribwort plantain (Ribgrass) when sown in pure plots and with grass and clover species. Welsh J. Agric. 17: 109

STAPLEDON, R.G. (1940) Re-grassing: an essential part of food production. Welsh P.B.S. Advisory Bulletin No.1

STAPLEDON, R.G. (1948) The nutritive influence of the herbs of grassland. Farming, 2: 86

THOMAS BRYNMOR (1949) Some reflections on the modern ley. Scot.J.Agric. 22: 47

TRIBE, D.E. and GORDON, J.G. (1950) An experimental study of palatability. Agric. Progr. 25: 94-101

VON GRUENIGEN, F. (1949) The importance of weeds for the nutrition of cattle. J. Brit. Grassld. Soc. 4: 273

WORDEN, A.N. (1946) The relation of Husbandry to Animal Health. E.Counties Vet. Society Paper, February 1946.

Discussion on preceding paper

Mr. R.M. Deakins One of the main problems that is arising with our intensive farming system, particularly on the heavier land is the presence of the broadleaved dock. The building up of fertility is tending to encourage the weed. As yet there seems to be no very effective herbicide for controlling it in these intensively managed farm conditions. I would like to hear from anybody who thinks they have an answer to this problem.

Mr. J.G. Elliott Could Mr. Deakins define the situation a bit more. Is he interested in white clover, or in using nitrogen, or what?

Mr. R.M. Deakins With the concentration of grazing we are encouraging these docks and the question arises whether you have clover or not. Rather than raise the controversy about clover or nitrogen, I would only say that we use both.

Mr. J.G. Elliott Are you interested in knocking out the docks or leaving the clover?

Mr. R.M. Deakins This problem is getting so serious that we prefer to do without the clover.

Mr. J. Holroyd There are a number of chemicals that knock out docks fairly successfully. If you use a mixture of dicamba and MCPA or 2,4-D you can do this very successfully. There will be no damage to the grass but you will knock out the clovers.

Mr. L. Jones Most of these docks will at one time or another have been seedlings. At this time they can be controlled by things that do not affect clover. I should like to ask Mr. Deakins if he could give any guidance on whether he has observed the sort of management which goes before an invasion of docks. Is it following certain management or is it a gradual increase all the time. Is he still referring to seedlings?

Mr. R.M. Deakins It is following the modern practice of going from grass to grass that gives very little chance to get rid of the seedlings and there is an increasing population of dock during the life of the ley, which may last these days for anything from 10 to 15 years. I do not know about dicamba but, quite frankly, MCPA and 2,4-D are no good at all.

Mr. J.F. Ormrod I should like to ask Professor Ivins his views on the status of rough-stalked meadow-grass, whether it is a weed or not and what are the factors leading to the invasion of a ley in the very early years of its life. I should welcome suggestions as to how to get rid of it in these conditions.

Prof. J.D. Ivins Where rough-stalked meadow-grass is compared with the fescues it is not a weed, but compared to perennial ryegrass it is classified as a weed in the conditions applying. High nitrogen encourages poaching during the winter period and this may be responsible in the cases you have in mind. The great disadvantage of this species is that a drought period will be harder on it than on most other grasses.

It is difficult to suggest how to get rid of it except by promoting conditions of management which discourage it. I cannot suggest how else we can get rid of it from a ley. The quickest answer would be to re-seed. This is really begging the question, however, and I do not know the answer.

Mr. J.G. Elliott My colleague, Mr. G.P. Allen, has some experience on rough-stalked meadow-grass in his trials. From our experience, we would agree that rough-stalked meadow-grass must be regarded as a weed in a pasture, especially as in a dry summer it just stops growing.

Regarding your suggestion to re-seed I would remark that these weeds are tending to come into leys in the year of establishment. They may not always show as a serious weed problem for two to three years. Soil disturbance gives rise to germination of seed in the first instance and the first year is the time they come in, and therefore re-seeding must be an inefficient way of controlling them. There is here the need for a selective herbicide to ensure the long-term period of the same sward.

Dr. H.P. Allen I would welcome Prof. Ivin's views on the economic aspect of grassland improvement. How clearly can the economics of such information be passed on to the farmer? Is the present state of our permanent swards merely due to lack of interest in improvement or is the economic aspect the main brake!

Prof. J.D. Ivins I would put first and foremost the fact that we have no ready means of measuring the type of grassland. A farmer knows full well by talking with his neighbours that he has to do something about it but we have no ready measure without a great deal of recording of the type of grassland. This is the first point.

Secondly, in some instances it is still possible to make a living on unimproved grass. This might have some part to play in it.

Thirdly, although we talk about the correct mixture of grasses, the means for the identification of these grasses is not available. One knows how second-year students have difficulty in identifying grasses in the vegetative condition let alone the farming community. So that is another problem. I think this all adds up to a large area of comparatively poor grassland.

WEED CONTROL IN HORTICULTURE - A REVIEW

D. W. Robinson
Agricultural Institute, Kinsealy, Co. Dublin.

INTRODUCTION

Compared with agriculture, chemical weed control in horticulture made a slow beginning. During the late 1940's and early 1950's when MCPA and 2,4-D were revolutionizing weed control practices in agriculture, little occurred to change conventional methods in horticulture. During this period a few herbicides, notably sulphuric acid, mineral oils and dinoseb, were accepted by vegetable growers, but in general, little change took place until about 1956. Then chemical weed control in horticulture was at approximately the same stage as it has been in agriculture ten years previously.

A number of reasons can be put forward to account for this slow beginning. Until recently few herbicides were produced specifically for horticultural crops. The horticultural industry, on the whole, consists of small acreages of a large number of crops. This market could not be expected to interest keenly the larger chemical companies compared with the bigger and less complex agricultural and overseas markets. In addition, some of the earlier herbicides made available to growers gave variable results due partly to insufficient knowledge of their performance under different soil and climatic conditions. 2,4-DES, for example, often gave good results where the soil was moist and warm and where tolerant weeds such as grass were absent; but too often these conditions were not fulfilled, weed control was disappointing and doubts were raised about the value of chemical methods.

Later, when more effective, soil-acting herbicides became available, there was an understandable fear of these chemicals on the part of many growers because of their long persistence in the soil. The risk of crop loss resulting from herbicide residues in the soil is greater than in agriculture because of the more rapid turnover of crops where vegetables are grown. With fruit crops there was the hazard of a build-up in the soil following the use of repeated annual applications. For these reasons many growers preferred to forgo the use of herbicides for a few years until more was learned about their long-term effect.

There was, in fact, a decided note of discouragement in the papers on vegetables and fruit at the first British Weed Control Conference in 1953. Then it was felt that it was impossible to be optimistic about the use of post-emergence sprays for many vegetables because of their susceptibility to most of the herbicides available at that time. The early discovery of herbicides for soft fruits was also considered to be remote. But such pessimism was completely unfounded. In the last few years significant developments have occurred both in research and practice. In Britain accurate information on the increase in acreage treated with herbicides is not available, but data from the U.S.A. (Table 1) show the considerable change that occurred with horticultural crops between 1959 and 1962 (Shaw 1964). While the acreage treated is still small compared with agriculture, the rate at which herbicides are being accepted by growers in America, particularly nurserymen and fruit and nut growers, is very striking.

Table 1

A comparison of the extent of chemical weed control on farms in United States in 1959 and 1962 (From Shaw 1964)

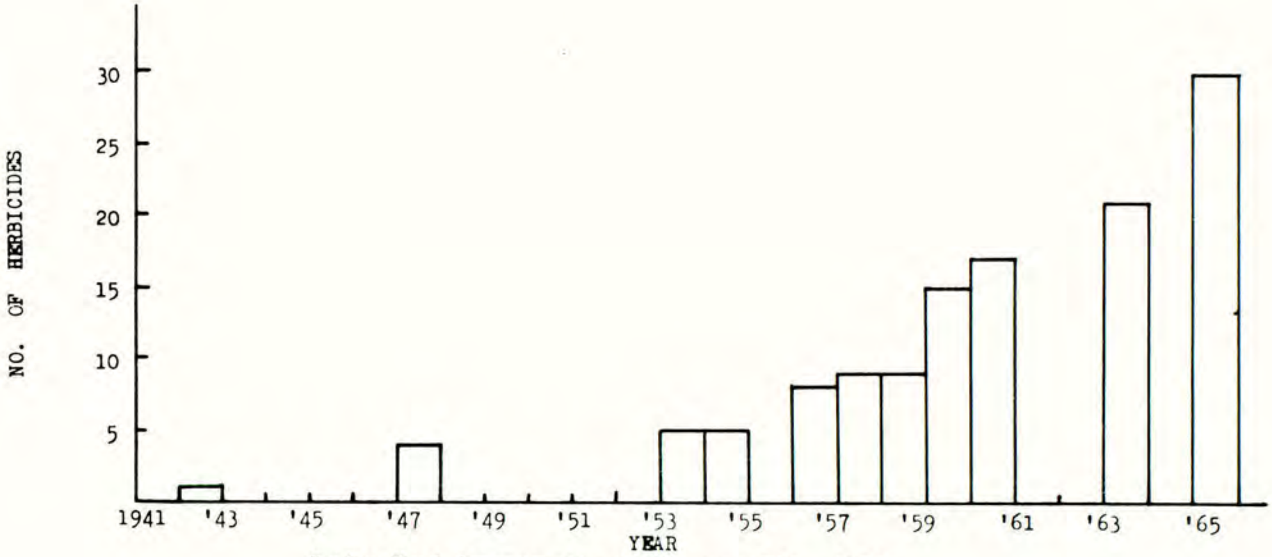
Crop	Acreage treated, thousands 1959	1962	Change in acreage; percentage
Corn	20,052	25,302	+ 26
Small grains	20,723	18,931	- 9
Sugar beet	2,093	2,665	+ 27
Pastures	2,400	4,715	+ 96
Hay	272	421	+ 51
Vegetables	276	952	+ 246
Fruit and nuts	5.0	267	+ 5,200
Ornamentals	2.2	51	+ 2,220
Lawns	60	672	+ 1,020
Total	45,883	63,976	+ 39

Although precise data are not available in Britain, estimates of field advisers and information from commercial firms point to a continued increase in the area of horticultural crops treated. Data supplied by one large processing firm (Smith 1964) show that in 1964, 95 per cent of the peas grown under contract for it was treated post-emergence with dinoseb and that part of the remaining acreage was sprayed with a pre-emergence herbicide; approximately 80 percent of the dwarf bean acreage was sprayed pre-emergence with dinoseb, a treatment recommended by Roberts only in 1959; in 1964 the entire spinach acreage was treated with chlorpropham although no herbicide was used in this crop in 1960.

Another way of assessing progress in chemical weed control is by the number of herbicides recommended officially to growers. When the British Weed Control Council first made recommendations in 1953 only five herbicides were recommended for horticultural crops (British Weed Control Council 1953). Just over ten years later this number has increased to over thirty (British Weed Control Council 1964).

Figure 1

HERBICIDES FOR VEGETABLES



Number Used Commercially By Growers 1942 - 1952

Number Recommended by British Weed Control Council 1953 - 1965

VEGETABLES

Prior to 1940, chemical methods of weed control for vegetables were practically non-existent. In 1942 sulphuric acid was recommended for weed control in onions (Blackman 1943). Since then herbicides became available for other crops, slowly at first, and then more rapidly from 1956 onwards (Fig. 1). The increase in the number of herbicides available has been particularly marked in the last few years and it is now possible to make recommendations for practically all crops. Since the last Conference nine herbicides have become available for vegetable crops in Britain for the first time, viz. desmetryne, linuron, prometryne, atrazine, solan, dimexan, CDEC and acetate and oil formulations of dinoseb.

For years it has been recognised that one of the factors complicating chemical weed control is the great change that occurs in weed populations when herbicides are used. This points to the need for alternative herbicides to prevent the build up of tolerant species and the advisability for growers to ring the changes with herbicides when alternatives are available. In this connection, a welcome development in the last two years has been the addition of linuron, prometryne and solan to the mineral oils and contact pre-emergence herbicides for weed control in carrots and other umbelliferous crops. Each of these new herbicides is effective against a useful range of weeds, although not against all species, but by selecting the appropriate herbicides or rotation of herbicides to deal with a particular problem, growers are now able to contend effectively with most annual weeds.

An equal range of herbicides to deal adequately with all common weeds is not yet available for all crops, but with the intensive screening of new herbicides in progress it seems likely that alternatives will soon be available for a number of crops.

Non-cultivation

Now that it is possible to obtain complete freedom from annual weeds in several crops, the whole question of cultivation practice is being re-assessed. We heard at the Symposium on 'Crop Production in a Weed-free Environment' (British Weed Control Council 1963) that the need for cultivation to maintain satisfactory soil conditions for plant growth does not appear to be as important as was once thought. It is true that under some conditions a surface crust may have harmful effects on seedling crops by hindering emergence, by preventing adequate gaseous exchange or by encouraging the development of microbial pathogens. But Hawkins (1963) has shown that an impervious surface crust is not formed readily. Sale (1964) too has demonstrated in a number of experiments that a thick cap formed by rain or irrigation has little effect on lettuce (a crop normally considered sensitive to capping) once the seedlings are established. In the last few years it has been shown, both experimentally and in practice, that many vegetables may be grown successfully without post-sowing cultivation, for example, peas, beans, carrots, parsnips and parsley (Anon.1964a).

As the problem of weeds and the need for cultivation diminished, much of Bleasdale's work at the National Vegetable Research Station has been directed towards determining the most suitable method of plant spacing for maximum yield. His repeated demonstration, that the more uniformly crop plants are distributed the higher will be the yield, has had considerable influence on present-day practice and has contributed much to changing ideas on cropping.

To obtain more uniform plant spacing, some growers have found it expedient to use a system of management recommended by Bleasdale (1963) in which crops are sown in beds of closely spaced rows straddled by a tractor. Compared with normal spacing yield increases of 30 - 40 per cent have been obtained from carrots sown in rows $3\frac{1}{2}$ in. apart (Anon. 1963a). The bed system has also been used successfully for other crops, for example, onions, red beet, parsnips and green-top swedes (Bleasdale 1963, 1964), although problems associated with drilling and harvesting have slowed up acceptance of this system to some extent.

It is sometimes argued that the value of close row spacings and high yields per acre has been overemphasised as land is not the most expensive factor of production and much equipment and harvesting machinery have been designed for widely spaced rows. However there are many additional advantages of close rows and high yields per acre that are worthy of consideration.

Close row spacings increase the eveness of crop both in respect of plant size and uniformity of ripening. With greater emphasis on quality, the production of uniform crops is becoming increasingly important both for processing and normal marketing. In root vegetables the size of the root can be readily controlled by varying the plant density and length of the growing season. Greater uniformity of crop maturity is becoming more important as selective hand picking is giving way to mechanical harvesting in one destructive operation. Harvesting machinery for root crops designed to lift entire beds has the marked advantage that, as tractor wheels have not passed over the soil in the beds, clods are less troublesome at lifting time. Furthermore the early crop canopy from close rows reduces rain impact and hence soil crusting and prevents the establishment of late germinating weeds.

Interesting progress has been made on the use of herbicides for killing swards prior to sowing cereals or grass. Results at present suggest that satisfactory crops can be grown in pastures which, instead of being ploughed and cultivated, have been destroyed by herbicides (Arnott and Clement 1962, Hood et al 1963). So far few critical investigations have been conducted in Britain on the possibilities of this technique for vegetables, presumably because these crops are usually grown on productive land which can readily be ploughed. With so many other problems demanding attention there has been little incentive to develop techniques that would enable vegetables to be established without cultivation.

Recent trials at Loughgall, however, showed that although many vegetables could be grown without post-sowing cultivation, crop establishment and yield were poor where no pre-sowing cultivation was given (Anon. 1964a). In these trials sowing at an even depth was difficult because of the compact surface soil. In addition no nitrogen was applied until the crops were established and the poor results on the killed sward may have been due to patchy establishment and to inadequate release of mineralised nitrogen from the uncultivated dead turf. Unreplicated trials in England have shown that on some soil types where fertility is high, and where the seed can be sown satisfactorily, good crops of carrots, onions and other vegetables can be produced without pre-sowing cultivation (Bloomfield 1964). The ability to use unploughable land will probably not be of great interest to vegetable growers in Britain. But, apart from possible economic benefits, other advantages of using herbicides instead of cultivation may result, for example, the maintenance at the soil surface of organic matter built up over a period in ley, the reduction of erosion on sloping ground, the conservation of soil moisture in drier areas and the absence of disturbance of viable weed seeds lying below the germinating zone.

As well as reducing costs and resulting in changed cropping practices, herbicides are further influencing vegetable production. As Shaw (1964) has pointed out 'Herbicides are crop production chemicals. They differ from pesticides in that they reduce man-hour requirements'. Now that herbicides provide a substitute for hand labour, there is a trend for vegetable growers to extend into larger acreages. Coupled with advances in mechanical harvesting, herbicides are resulting in vegetable production becoming more automatised, units are becoming larger and factory techniques more widely used. Many growers are now very dependent on herbicides; without them their cropping system would need to be altered.

FRUIT

Recent advances in the use of herbicides in fruit crops have possibly been even more spectacular than in vegetables. Progress since the last Conference has not been marked by any great increase in the range of herbicides available but rather by the enthusiastic acceptance by many fruit growers of herbicides marketed previously.

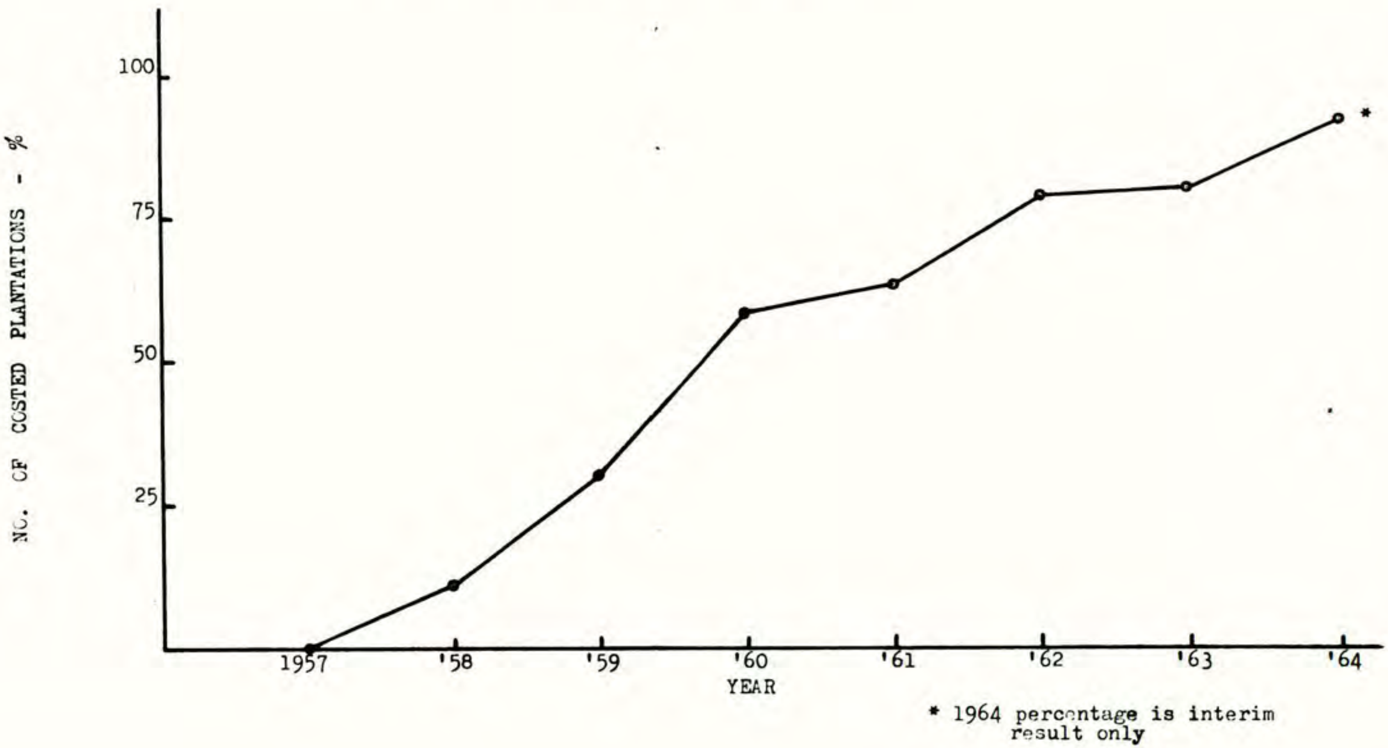
An indication of the way herbicides have been accepted by blackcurrant growers and absorbed into practice is given by the results of a survey carried out by Rendell (1961) and Shore (1964) of the University of Bristol (Figure 2). These data, although not based on a statistically random sample, illustrate clearly the remarkable increase in the use of herbicides in this crop. In 1957, none of the plantations costed was treated with herbicides; in 1964, results to date indicate that 92 per cent was treated. The results also show that to a large extent the increase in the number of plantations treated has been due to the greater use of simazine. While this herbicide has been widely accepted, many growers have had grave misgivings about using such a persistent chemical. Fears have been based mainly on the possibility of injury resulting from the use of repeated annual applications.

Work carried out by Burschel, Sheets, Holly and others suggest that these fears may be groundless where normal herbicidal doses are used. Burschel (1961) showed that the decomposition of simazine in soils occurs as a first order reaction. Sheets (1964) has pointed out that, assuming the disappearance of a herbicide conforms to a first order rate equation, if 80 per cent of an annual application of 2 lb/ac is inactivated each

Figure 2

Blackcurrant Survey - (Univ. of Bristol)

<u>USE OF HERBICIDES</u>



year and this application is repeated indefinitely, the amount still present in the soil when the time for the next application arrived would eventually approach 0.5 lb/ac.

Holly and Roberts (1963) have shown that in Britain the time required for the disappearance of 80 per cent of the activity following application of 2 lb/ac of simazine ranged from 7 to 27 weeks according to the year. While the rate of inactivation of simazine will vary greatly with soils and climate (Burschel 1961) and there might be a small carry over under some conditions, the possibility of large accumulations is remote. Furthermore the results of pot trials show that many fruit crops possess some degree of innate tolerance to simazine (Caseley 1960, Ivens 1964). Consequently the risk of injury from repeated annual application of normal doses would appear to be slight under conditions in Britain. This is supported by the results of field trials where repeated applications for periods of up to six years have had no adverse effect on strawberries, raspberries, blackcurrants or gooseberries (Robinson 1964a).

The outstanding progress of the last decade has eliminated most of the weed problems in soft fruits. The two principal remaining problems are now:-

(1) annual weeds in newly planted strawberries
(2) perennial weeds in all soft fruits.

Annual weeds in newly planted strawberries

The weed problem in newly planted strawberries is being tackled in different ways. Testing of new herbicides with greater selectivity is giving promising results. Yesterday we heard of good results obtained in trials with chloroxuron and about its satisfactory use in practice (Hughes 1964, Davison 1964, Lewis and Ayers 1964).

A similar problem in new strawberry plantings exists in the U.S.A. There diphenamid has given good weed control and has shown a high degree of selectivity at different times in the growth cycle of the strawberry (Peabody 1964). Results in Britain with diphenamid have also been promising (Ivens 1963, Anon. 1963b). Both diphenamid and chloroxuron have the disadvantage that neither is effective against all common annual weeds; Senecio vulgaris and Poa annua, for example, show a high degree of tolerance to diphenamid and chloroxuron, respectively. This has encouraged work on attempting to increase the tolerance of newly planted strawberries to simazine by using adsorbents in the vicinity of the root zone at planting time. Trials in Northern Ireland in 1963 showed that activated charcoal was the most effective of a number of adsorbents and that the most suitable practical way of applying the adsorbent was by means of a root dip (Robinson 1964b). This method does not, of course, protect new roots that grow away from the charcoal-coated roots but it does seem to give a useful measure of protection on some soils, and further work is justified.

In particular more information is needed on other methods of applying charcoal (for example in transplant water) and on the usefulness of different brands of charcoal as these vary greatly in price and effectiveness. Preliminary trials suggested that steam-activated brands are more suitable than those that have been chemically activated. Whether this is due to differences in the adsorptive capacity of the charcoal or to phytotoxic effects from impurities, needs to be clarified. Trials at Loughgall have shown that charcoal can also reduce the toxicity to strawberries of atrazine and bromacil and it seems possible that this adsorbent will have uses with a number of herbicides on other crops.

Perennial weeds

Now that we have herbicides that deal effectively with annual weeds in fruit crops, the problem of perennial weeds is becoming much more important. Not only are perennials unaffected by many of the herbicides used today, but are actively encouraged by the absence of competition from annual weeds. The risk of rapid spread of perennials is particularly severe where non-cultivation methods are adopted on land not substantially free from these weeds. This is both a major advisory and research problem. With present knowledge, perennial weeds need not be such a problem. If, before the crop is planted, perennials are controlled by herbicides and cultural methods, chemicals used after planting to control annuals will suppress perennials also. But any survivors need to be treated promptly during the first few years after planting. Since herbicides began to be used extensively in fruit four years ago, Convolvulus sp., Rumex sp., Urtica dioica and Agropyron repens have become the most troublesome species in many areas. With the exception of Agropyron much can be done to keep these weeds suppressed by treatment with auxin herbicides in the autumn. Although very severe injury has often been caused by auxins in the spring, it seems they could be used in the autumn more often than at present. But suitable precautions need to be taken; spraying, for example, should be confined to direct spot-treatments with a low-pressure sprayer only, kept exclusively for herbicides. More research on the control of perennials after planting is also warrented with such herbicides as atrazine, 2,6-dichlorothiobenzamide and bromacil, and more emphasis by advisers on the necessity for clean ground before planting and on prompt and vigorous action against survivors.

Non-cultivation

Fruit growers, like many vegetable growers, are now faced with the problem of deciding whether their chemical methods of control will supplement or replace cultural methods. Where a grower is using certain soil-applied herbicides, cultivation has the disadvantage of diluting them through a bulk of soil, thereby shortening their active life. On the other hand there is a deeply entrenched belief that soil compaction, caused by rain, irrigation and especially during harvesting operations, will adversely affect crop growth. Experience has shown, however, that the appearance of non-cultivated soil is usually worst during the first few months after cultivations have ceased. If the grower can refrain from breaking up the crust mechanically at this stage, most soils tend to improve in appearance over a period of years. The development of crop roots near the surface seems to improve soil structure. Worm burrows are more permanent as they are not destroyed by cultivation and worm casts consisting of well structured soil, become scattered gradually over the surface. Fallen crop leaves tend to accumulate in some plantations and the presence of moss and algae may also improve the appearance of the soil surface.

The main question is the effect of these unusual soil conditions on crop yield. Trials at Loughgall have shown that, in general, the yield of raspberries has not been affected but that of blackcurrants, gooseberries and strawberries is sometimes slightly increased on non-cultivated plots (Robinson 1964a). In these trials the weed control programme was based mainly on simazine. It seems possible then, that the slightly higher yields obtained in sprayed plots may have been due to the 'fertilizer effect' of simazine described yesterday by Gast and Grob (1964). But trials conducted to obtain information on the effect of non-cultivation on crop roots showed that in spite of the presence of a thick crust, roots had developed extensively in the surface soil (Robinson 1964c). This zone is usually the most fertile, so that surface rooting may also contribute to the increase in yield. This is supported by the results of leaf analysis which show that leaf P and K as well as N are sometimes higher in foliage from non-cultivated plots (Robinson 1964a).

Permitting plant roots to grow in the surface soil can have a pronounced effect in some circumstances. In Co. Waterford, young apple trees on cultivated and herbicide-treated plots showed striking differences on a potash deficient soil which has been treated in March with muriate of potash at 4 cwt/ac (O'Kennedy 1964). On clean-cultivated plots the trees showed severe potash deficiency and made little growth but where no cultivation was given tree growth was normal (Table 2). The data show that in October, the levels of soil K in the herbicide-treated plots were much lower than

Table 2

Tree growth and potassium status of foliage and soil in cultivated and non-cultivated (herbicide-treated) plots

(N. D. O'Kennedy, Pomology Research Centre, Ballygagin)

			Cultivated	Non-cultivated (herbicide-treated)
Extension growth Mean per tree (cm).			511.0	1350.0
Girth (cm)			9.0	11.4
Leaf K (p.p.m.)			0.4	0.8
Soil K (p.p.m.)	Depth from soil surface (inches)	1.5	147.8	67.5
		3.0	91.5	46.5
		4.5	56.8	38.3
		6.0	38.8	32.8
		7.5	31.7	27.0
		9.0	28.8	23.0
		10.5	26.5	21.0
		12.0	23.7	19.3
		13.5	24.8	20.0
		15.0	25.8	20.7

in the cultivated plots. This was due presumably to the greater uptake of K by the surface roots in the non-cultivated plots. The tilled plots were cultivated to a depth of about 5 in. and the data show that much of the K remained in this zone. The destruction of surface roots by cultivation probably accounts for the deficiency of K in the plant.

It seems unlikely that the elimination of cultivation would have had such a striking beneficial effect if the soil had not been deficient in potash. Nevertheless the results demonstrate that one of the expected disadvantages of non-cultivation in perennial crops viz. P and K deficiency due to the failure to incorporate these fertilizers, may not be so important in practice. On the contrary, non-cultivation may result in increased nutrient uptake in some circumstances. Work with radioisotopes has shown that the surface roots make a very high contribution to feeding the plant. This helps to explain the results in this trial where potassium applied to the soil surface only, was more beneficial to the plant than where the fertilizer was incorporated but the surface roots destroyed in the process.

Some of the advantages of non-cultivation in vegetables also pertain in soft fruit crops. As with vegetable crops non-cultivation is giving rise to new spacing systems and completely new growing methods. As direct planting of blackcurrant cuttings is now practicable on a field scale, closer, more efficient spacings of blackcurrants are becoming popular. Growers are realizing that if herbicides are to be used, it is no more expensive controlling weeds in an acre of closely spaced bushes than in an acre of widely spaced ones.

Consequently closer spacings are likely to become more popular in a number of crops. Generalization on this topic would, however, be unwise as in some plantations of strawberries, more vigorous plant growth has occurred where cultivation has been abandoned and normal plant spacings have proved inadequate. Clearly more research is needed on the subject of plant spacing of both fruits and vegetables under the weed-free conditions that will prevail in the future.

<u>Erosion</u>

The increased risk of erosion as a result of decreased water acceptance on capped soils has been confirmed in many areas. This is one of the most serious disadvantages of non-cultivation on sloping sites, not only because of the loss of moisture and fertile top soil but, because the system will have encouraged surface rooting, crop roots may become exposed and desiccated. Means of checking erosion will usually be necessary on sloping sites. Measures cheaper than manure and less hazardous than straw are urgently needed if the full advantages of non-cultivation are to be exploited.

Mulches of chopped-up prunings have proved effective in blackcurrant and raspberry plantations. Such mulches rot down fairly quickly and help to retain fallen crop leaves as a mulch over the surface. The effect of such treatment on plantation hygiene is under investigation in Ireland at present but as yet there is no indication of any increase in pests and diseases. However the amount of prunings available for mulching would only be adequate in an established plantation and alternative means would be needed in new plantings.

Temporary cover crops are worth considering for this purpose. For example, Italian rye grass has been used successfully in gooseberries at Loughgall. Simazine applied at 1 lb/ac in March gave control of annual weeds for three months; grass was then sown on the bare non-cultivated surface without incorporation in July and was killed with an overall application of paraquat in January. This provided enough organic matter on the soil surface to check erosion until grass was sown again the following July.

The possibility of minimising erosion by planting fruit crops into a killed sward should also be considered. Trials in New Zealand (Porter 1961) and Northern Ireland (Anon. 1964b) suggest that suitable herbicides may be used to replace cultivation in the preparation of land for planting strawberries.

In spite of expectations, the elimination of cultivation does not appear, on a range of soil types, to have resulted in soil conditions that are unsuitable for plant growth. On the other hand, problems of erosion and perennial weeds cannot be taken lightly. But these problems are not unsurmountable. For growers with the ability to control weeds completely, without the need for cultivation, the benefits are considerable, for example, the increasing reduction in the cost of weed control over a period of years, the greater freedom of crop spacings, the development of a more pleasant working surface, and the possibility of increases in crop yield. It seems inevitable that the acreage of fruit under non-cultivation will increase.

Advisory Service

With so many useful herbicides available today, it might be thought that the task of the adviser will become easier. This is not so. The need for specialist advice on the use of herbicides in horticulture is likely to increase rapidly. In the near future most growers will be forced on economic grounds to use chemical methods of control. In addition to an inevitable increase in the acreage treated, the number of herbicides available is likely to grow, as more selective or less expensive herbicides are found. As shown by the results of the Blackcurrant Survey (Rendell 1961, Shore 1964), however, the arrival of better herbicides does not usually mean the disappearance of the less effective ones. Growers will have learned how to use them and some will be slow to change. In any case the older herbicides will probably still be better under some soil conditions or when certain weed species are present. For example the rapid increase of *Polygonum aviculare* (knot grass) in some blackcurrant plantations where simazine has been used for several years suggests that an occasional application of chlorpropham would be useful.

Progressive growers are becoming acutely aware of the impact that herbicides are having on horticulture, of the revolution of growing methods that has started, and of the need to select the best of a number of different but competing herbicides for each crop.

On the whole present-day advice on herbicides and new cropping methods is inadequate to meet the demands of progressive growers. It is unrealistic to expect the general adviser, dealing with the whole range of cultural, management and technical problems facing horticulture today, to keep abreast of developments in this rapidly expanding field. With the increasing specificity of herbicides and their greater dependence on soil type and weed flora, with the need in some situations for rotations or mixtures of herbicides, it is difficult for the adviser attached to a commercial firm to give completely unbiassed advice. It is reasonable to suppose that in Britain as in the U.S.A., more crop loss is caused by weeds than by insects and diseases combined. Yet there are in Britain many specialist advisers in pathology and entomology, but none, as yet, in weed science. All trends today indicate that weed control in horticulture is rapidly becoming more complex and that there is an urgent need for specialist advisers in this field.

I have already referred to the lack of official statistics on the use of herbicides in the U.K. Surveys of the type carried out for agriculture by Boyd (1957), Church and Woodford (1959), Church et al (1962) have not been conducted in horticulture and precise data are difficult to obtain. Now that effective chemical means of control are available for nearly all crops, it would be useful to know to what extent herbicides are being used in horticulture, how correctly and how efficiently. Such information would indicate which applied problems should be given priority by research workers and where weaknesses occur in an advisory programme, as well as being of interest to commercial firms. For example, Mr. K. M. Round, Horticultural Advisory Officer for Kent has estimated that, although 50 to 60 per cent of the blackcurrants in his county are sprayed with herbicides, only about 5 per cent of the raspberry acreage is treated (Roach 1964). This is surprising as the two main herbicides used in blackcurrants, simazine and paraquat, are just as effective and possibly more selective in raspberries, while the cost of cultural weed control is usually higher in this crop.

It is interesting to speculate the reason for this difference. Is it that raspberry growers are less progressive than blackcurrant growers? Is it that the blackcurrant grower, who is more likely to be growing on contract, has the advantage of receiving an advisory circular each spring from the contracting firm along with more frequent visits by fieldsmen? Whatever the reasons Round's estimates indicate the need for more factual data on the extent to which herbicides are being used.

Probably as much as in any other field, future progress will depend on the closest possible liaison between the adviser, the applied research worker and the grower. There are signs today that if the present rate of advancement is maintained, weeds will be eliminated before long, at least on the better holdings. There must be a sense of urgency about the need for objective reappraisal of our growing methods, if horticulture is to be suitably adjusted to take full advantage of new techniques. Any one-sided approach to this problem will be of limited value and the closest co-operation between all concerned with the use of herbicides will be required.

Progress during the last eight years has been outstanding. The contribution that herbicides are making to more efficient horticulture is obvious, and should allow us to abandon the apologetic manner that is often adopted when herbicides are being recommended for horticultural crops. The literature contains many warnings that chemicals should only be looked on as an adjunct to good cultivation and not as a substitute. Three of the first seven speakers at the last British Weed Control Conference stressed the continued need for good husbandry as the first essential of our farming, implying, I think, that there is some antagonism between chemical methods of weed control and good husbandry. But surely the intelligent use of herbicides is good husbandry. Similarly cultivation, no matter how well done, is not good busbandry, where it confers no benefits other than improving the appearance of the soil to the human eye.

It is clear that in spite of the slow beginning, the use of herbicides is now well established in all branches of horticulture. Remarkable advances have been made but much remains to be done. Certainly the future presents a wonderful challenge and opportunity for everybody working with herbicides. We have seen much fascinating change in the last few years but it seems that the years ahead will be no less interesting.

References

ANONYMOUS (1963 a) Carrots held by cutting the tops. The Grower. 60, 17, 687-688.

ANONYMOUS (1963 b) Screening trials of herbicides on strawberries. Horticultural Centre, Loughgall, Annu. Rep. 1962. 18-19.

ANONYMOUS (1964 a) Non-cultivation trials. Horticultural Centre, Loughgall, Annu. Rep. 1963, 29-31.

ANONYMOUS (1964 b) Non-cultivation experiments. Horticultural Centre, Loughgall, Annu. Rep. 1963. 3-8.

ARNOTT, R.A. and CLEMENT, C.R. (1962). Sowing winter wheat on leys destroyed with a herbicide. Nature 195, 1277.

BLACKMAN, G.E. (1963) Weed control in horticultural crops by sulphuric acid spraying. J. Min. Agric., 49, 219.

BLEASDALE, J.K.A. (1963) The bed system of carrot gorwing. S T L 27. Min. of Agric. Fish. and Food.

BLEASDALE, J.K.B. (1964) Private communication.

BLOOMFIELD, A. (1964) Private communication.

BOYD, D.A. (1957) Weedkiller usage in England and Wales: Information from surveys of farm practice. Proc. 3rd Brit. Weed Control Conf. 1956, 17-22.

BRITISH WEED CONTROL COUNCIL (1953) Proc. Brit. Weed Control Conf. 1953. 455-456.

BRITISH WEED CONTROL COUNCIL (1963). Symposium No.2. Crop production in a weed-free environment. Blackwell Scientific Publications.

BRITISH WEED CONTROL COUNCIL (1964) Weed Control Handbook. Blackwell Scientific Publications, Oxford. (In press).

BURSCHEL, P. (1961) Untersuchungen über das Verhalten von Simazin im Boden. Weed Res. 1, 2, 131-141.

CASELEY, J. (1960). The tolerance of fruit crops to some residual herbicides. Annu. Rep. Long Ashton Res. Sta. for 1960. 59-63.

CHURCH, B.M., and WOODFORD, E.K. (1959) A pilot survey of herbicide practice in N.W. Oxfordshire. Farm Econ. 9, 252.

CHURCH, B.M., DODD, C.V.T., MILLER, T.E. And PAGE, J.B. (1962) Herbicides practice in arable farming districts of Eastern England. 1959-60 Weed Res. 2, 3, 153-164.

DAVISON, J.G. (1964) Weed control in strawberries with chloroxuron. Proc. 7th Brit. Weed Control Conf. 1, 177-182.

GAST, A. and GROB, J. (1964) Triazines in top fruit and viticulture. Proc. 7th British Weed Control Conf. 1, 217-226.

HAWKINS, J.C. (1963) The oxygen requirements of soils and root systems British Weed Control Council Symposium No.2. 40-43, 68-69.

HOLLY, K. and ROBERTS, H.A. (1963) Persistence of phytotoxic residues of simazine in soil. Weed Res. 3, 1, 1-10.

HOOD, A.E.M., JAMESON, H.R. and COTTERELL, R. (1963) Destruction of pastures by paraquat as a substitute for ploughing. Nature, 197, 748.

HUGHES, H.M. (1964) Herbicides for early planted strawberries. Proc. 7th British Weed Control Conf. 1, 173-176.

IVENS, G.W. (1963) Recent results from strawberry herbicide trials. Proc. 6th British Weed Control Conf. 1962, 2, 579-588.

IVENS, G.W. (1964) Pot experiments on the susceptibility of perennial crops to soil-applied herbicides. Proc. 7th British Weed Control Conf. 1, 227-234.

LEWIS, A.V. and AYERS, M.R.L.W. (1964) Investigations using chloroxuron as a residual herbicide in strawberries. Proc. 7th Brit. Weed Control Conf. 1, 183-190.

O'KENNEDY, N.D. (1964). Private communication.

PEABODY, D.V. (1964) A comparison of diphenamid and the currently recommended simazine treatments for annual weed control in strawberry plantings. Abstracts 1964 Mtg. of Weed Soc. America. 39-40.

PORTER, L.A. (1961) Chemical soil preparation for strawberry growing. Proc. 14th New Zealand Weed Control Conf. 48-52.

RENDELL, J. (1961) Blackcurrant survey. Three year report 1957-1959, Univ. of Bristol.

ROACH, F.A. (1964) Private communication.

ROBERTS, H.A. (1959) Dinoseb pre-emergence 3 lb per acre can keep runner beans clean. The Grower, 51, 166-7.

ROBINSON, D.W. (1964a) Investigations on the use of herbicides for the elimination of cultivation in soft fruits. Scientific Horticulture 16, 1962-63, 52-62.

ROBINSON, D.W. (1964b) The use of adsorbents and simazine on newly planted strawberries. Weed Res. 5. (In press).

ROBINSON, D.W. (1964c) A revolution in horticultural practice. Agric. in Northern Ireland 39, 5, 142-143.

SALE, P.J.M. (1964) The growth of established lettuce as affected by soil capping. J. Hort. Sci. 39, 3, 162-172.

SHAW, W.C. (1964) Weed science - revolution in agricultural technology. Weeds 12, 3, 153-162.

SHEETS, T.J. (1964) Review of disappearance of substituted urea herbicides from soil. Agricultural and Food Chemistry 12, 1, 30-33.

SHORE, M.M. (1964) Private communication.

SMITH, M.L.G. (1964) Private communication.

Discussion on preceding paper

Mr. L.O. Slocock I should like to put in a word here on behalf of the poor relations of fruit and vegetables in the field of weedcontrol - I mean ornamentals. Herbicides are now being widely used on these plants and although simazine can be used safely on a high proportion of cultivated tree and shrub genera, there are clearly several which are injured at very low dosage rates. I was most interested to hear Dr. Robinson describe a charcoal dip technique and would like to know whether he has any experience of the use of this in ornamentals. It occurs to me that it is highly relevant to the treatment of such simazine - susceptible genera as Viburnum, Euonymus, Deutzia, etc.

Dr. D.W. Robinson We have looked at this technique in a number of crops. We tested dipping brassicas in charcoal to try to increase their tolerance to certain herbicides but did not find a sufficient increase. As I mentioned in my paper, we cannot expect any great increase in tolerance. This technique is likely to be most satisfactory with semi-tolerant species where we can use it to tip the balance in favour of the plant. We have done a little work on nursery stock and have obtained some reasonably good results, but more work is required on this technique.

THE BEHAVIOR OF HERBICIDES IN SOIL[1]

Robert P. Upchurch
Department of Crop Science, North Carolina State
of the University of North Carolina, Raleigh, North Carolina, USA

INTRODUCTION

The selection of important historical dates concerning our knowledge of herbicide behavior in soil is largely a matter of opinion. The discovery of 2,4-D as a herbicide marked the beginning of a new era in weed control technology. Long before this time investigations by Dr. A. S. Crafts on herbicide persistence provided background, techniques and impetus for soil-herbicide research (Crafts, 1939). When Templeman (1946) reported the successful use of 2,4-D as a selective soil-applied herbicide, a new dimension was added to our concept of how weeds might be controlled. A great many investigations have been devoted to improving and extending the pre-emergence technique and especially attempting to understand its variability. From these studies has grown our knowledge of photodecomposition, volatility, incorporation and the influence of specific soil factors on herbicide toxicity to mention only a few items.

A decade ago Ennis (1954) illustrated many of the problems and opportunities associated with the pre-emergence weed control technique. Since that time many new herbicides have been brought under consideration and we can now provide to a certain extent sound data where Ennis could only speculate. At the last British Weed Control Conference, Holly (1962) described in an excellent manner our state of knowledge on the behaviour of herbicides in soil. A comparison of these papers by Ennis and Holly well illustrates the advances being made in our understanding of the behaviour of soil-applied herbicides.

Research papers too numerous to mention have contributed to our knowledge on herbicide behavior in soil. Very helpful review articles on the specialized topics of adsorption and the physical basis of behavior have been contributed by Bailey and White (1964) and by Hartley (1964), respectively.

The purpose of this presentation will be to illustrate some selected principles of herbicide behavior in soil which are of special importance and to describe some of the soil-herbicide research activities of the Crop Science Department in North Carolina.

GENERAL DESCRIPTION OF HERBICIDE BEHAVIOR WHEN APPLIED TO SOIL

At the beginning it is well for us to have a gross concept of the kinds of things which may happen to a soil-applied herbicide. We will naively assume that a uniform application is made to the soil surface in such a fashion that we actually deposit all of the chemical dispensed on the soil surface. At the soil surface it may undergo volatilization,

---

[1] Invitational paper for presentation at the Seventh British Weed Control Conference, November 23, 24, 25, 1964, Brighton, Great Britain.

photodecomposition or movement into the soil. At the soil surface or in the soil, it can be adsorbed by soil components, chemically changed, and it can be influenced by microbial and plant action. The extent of each of these processes will be governed by temperature, sunlight, rainfall, incorporation and the particular properties of the soil and of the herbicide being applied. The plant species in the environment and whether we wish to kill or protect them will determine whether or not a given herbicide reaction in the soil is good or bad.

SPECIFIC ADVANCES IN KNOWLEDGE IN RECENT YEARS

The concept of fields of force is of obvious importance in controlling the adsorption of herbicides in soil but this concept has not been used to its full extent. Whether a herbicide is electrically neutral, positive or negative will influence its interaction with the soil. The electrical charge on each soil component will also influence the interaction. We are concerned with unit charges of a coulombic nature as well as weaker forces which may originate from various sources (Bailey and White, 1964). Each molecule of diquat possesses a double positive charge, and it can be expected to react with negatively-charged clay up to the cation exchange capacity of the clay. Ionized 2,4-D has a unit negative charge and is repelled by the negatively-charged clay. Diuron does not have a unit charge, but it is generally considered to have a net positive charge of small magnitude. It would, therefore, be expected to react with a negatively-charged clay but not to the extent which would be expected for diquat. The reaction of these three herbicides with soil organic matter is less descriptive since soil organic matter may have positive, negative and neutral sites.

Of great practical importance is the fact that the electrical charges on many herbicides are regulated by the hydrogen ion concentration (pH) of the medium. For 2,4-D this involves the simple process of ionization. Under increasingly acid conditions the negatively-charged 2,4-D ion is converted to the non-charged molecular form. At a pH of 3.2 one-half of the 2,4-D will be present in the charged form and one-half in the non-charged form. This value of 3.2 is the pK value of 2,4-D. For an s-triazine the effect is the opposite. Under increasingly acid conditions the s-triazine becomes charged through association with a proton. The pK of prometone is 4.2

Of a complicating nature is the fact that the electrical charge on various soil components is also regulated by the hydrogen ion concentration. The acid groups on organic matter progressively ionize as the hydrogen ion concentration is decreased giving rise to an increased negative charge or cation exchange capacity. Conversely, the NH_2 groups in the soil associate with hydrogen ions as the soil becomes more acid, thereby giving rise to a positive charge or an anion exchange capacity. There are other sites in organic matter with specific electrical characteristics. The nature of all of these types of sites and their relative abundance in various types of organic matter is poorly understood.

In general, the electrical properties of clay are thought to be little influenced by pH.

Before the fields of force concept can be exploited fully to better understand herbicide behavior in soil, we must know a great deal more about the specific electrical charges on herbicides and on soil components. We need to know the origin, sign and magnitude of the electrical charge and to know its variability in the soil environment. Whereas, the fields of force concept is adequate to explain the adsorption of diquat on clay, it has not been developed to the point where it can be used to explain the adsorption of diquat or any other chemical on soil organic matter. At this time adsorption by organic matter can only be described in terms of an equilibrium reaction which usually follows an adsorption isotherm. Weak electrical charges are involved. One presumes that such interactions will be explained ultimately in terms of specific electrical charges. The importance of this lack of understanding is illustrated by the fact that the soil organic matter content is the dominant soil factor in controlling the behavior of most herbicides.

The problem of desorption is a fundamental one which is just beginning to receive attention. Scientists are interested in the ultimate fate of herbicides which are trapped within the lattices of expanding clays. Chemicals such as diquat which are bound by coulombic forces would presumably be desorbed substantially only in the presence of a chemical which would exchange for the diquat and be bound more tightly. The desorption of most herbicides on most soil components may be illustrated by the adsorption of a substituted urea herbicide which follows an adsorption isotherm on most substances (Geissbuhler et al., 1963). In this situation a given amount of herbicide adsorbed will be complemented by a given amount in solution. The equilibrium is both concentration and temperature sensitive. The desorption process will be continuous as long as some feature of the soil system serves to reduce the concentration in solution. This can be brought about in various ways including microbial decomposition, plant uptake and leaching. The desorption process can be reversed if the concentration in the soil solution is increased as, for example, by evaporation of soil moisture. For most herbicides one presumes that herbicide in the desorbed phase represents the biologically-active fraction although more definitive experiments in this regard are needed.

Photodecomposition accounts for one of the sources of variation in the performance of pre-emergence treatments. The work of Jordan et al. (1964) on monuron may be used to illustrate the influence of ultraviolet light on the breakdown of herbicides. Photodecomposition would be of greatest importance where the herbicide remains on the soil surface for an extended period without rainfall. Soil incorporation of herbicides helps to minimize the influence of this factor.

The control of volatility by incorporation in the soil is essential for chemicals such as EPTC and trifluralin. Vapor losses not only reduce the performance and reliability of herbicides but the vapors may also injure crop plants as does dinoseb when used in cotton production. Techniques for demonstrating the toxicity of herbicide vapors have been described by Dawson (1963). It cannot be assumed that a chemical which has a low physico-chemical volatility constant will perforce be non-volatile from a biological viewpoint.

The recognition that water and certain herbicides may compete for adsorption sites in soil represents a great advancement in our understanding of the behavior of herbicides in soil. The excellent paper by

Deming (1963) on volatility shows that increasing temperature at low soil moisture levels retards the loss of CDAA because the moisture loss is increased and more sites are made available for CDAA adsorption. At higher soil moisture contents the increased moisture loss is not great enough to free sites for CDAA adsorption while the direct effect of temperature on CDAA vapor pressure causes a greater loss of CDAA with increase in temperature. Our best understanding at this moment is that CDEC and the thiolcarbamates such as EPTC react in the same fashion. Incorporation provides a way in which herbicides displaced from adsorption sites by water may be retained in the soil. Better information is needed on relative importance of competitive adsorption for various herbicides.

We now realize that certain soil-applied herbicides may act principally through the shoot as does EPTC (Dawson, 1963) or through the root as does diuron. It is further known that some herbicides are selective primarily because of the difference in depth from which the crop and the principal weeds originate (e.g., diuron-cotton), whereas physiological tolerance of the crop may serve as a real basis for selectivity in other cases (e.g., simazine-maize).

From what has been said about photodecomposition, volatility, competitive adsorption and root vs. shoot action of herbicides, the procedure of incorporation becomes of great importance. The proper depth of incorporation must be adequate to prevent excessive loss at the surface but not so great as to excessively dilute the herbicidal action of the chemical (Ashton and Dunster, 1961). Where selectivity is based completely on the relative depth of germinating weed and crop seeds, incorporation will likely decrease the margin of safety on the crop species unless the increased effectiveness of the incorporated treatment permits a reduction in the rate of application of the herbicide.

Broad guidelines on the use of herbicides so as to prevent effects on crops which follow can now be formulated. At our present state of knowledge, compounds such as fenac and picloram should be used on agricultural lands with the greatest caution. Other chemicals such as 2,4-D and dalapon are conceded generally to be innocuous several weeks after application at normal use rates. The detoxication of the substituted urea and s-triazine herbicides proceeds at a slow pace regulated by moisture temperature and time. In the north central part of the United States normal pre-emergence use rates of the s-triazine create concern about residual problems the following year, whereas similar rates in the southeastern part of the United States under higher temperatures, higher rainfall and a longer growing season lead to no such problems. We also have an understanding of about how much diuron we can use in cotton production without creating residual herbicide problems.

Nothing is so clear as our need to increase the rate of most herbicides to compensate for an increase in soil organic matter content. Yet our current techniques for getting the user to make this adjustment are entirely inadequate. Soil organic matter not only influences herbicide effectiveness; it controls herbicide residual toxicity. For a given herbicide rate the risk of residual carry-over is inversely correlated with soil organic matter content.

The leaching process is of obvious importance in relationship to weed control, crop safety and movement of herbicides out of the crop root zone. Most of our thinking on this subject has been on the basis of delay in movement due to adsorption. We are indebted to Dr. Hartley for his lucid description of the process of hydrodynamic delay (Hartley, 1960).

Several intriguing papers have appeared on the influence of formulation on the behavior of soil-applied herbicides (Danielson, 1959, and Danielson et al., 1961). While none of these developments have led to radical changes in use procedures at the soil level, it is reasonable that they should.

ILLUSTRATIONS OF WORK IN NORTH CAROLINA

Since my presence at this Conference is due largely to the fact that there has been considerable interest in North Carolina on the behavior of herbicides in soil, it seemed logical to discuss with you some of the main features of our research program. General appreciation is hereby expressed to my colleagues who have participated in this work over the years. Among them are Drs. J.B. Weber, T.M. Ward, M.R. Vega and Messrs. F.L. Selman and F.T. Corbin.

Our ability to understand the behavior of herbicides in soil is limited by knowledge about the herbicides themselves. Measurements are being made on the influence of pH on the ultraviolet ligh absorption by herbicides. Such studies are useful from an analytical viewpoint, indicate fundamental changes in properties of the compound and sometimes provide the basis for calculating pK values. For example, we have found the ultraviolet light absorption of prometone to increase as pH is adjusted from 3.0 to 5.6 at a wavelength of 213 millimicrons. We are also attempting to measure the influence of pH on water solubility and to measure the net electrical charge on herbicide molecules using a continuous flow electrophoresis apparatus.

Several years ago we devoted much attention to the movement of herbicides in the laboratory using metal columns three feet high and four inches in diameter. More recently we have used columns twelve inches in diameter in the greehouse to more nearly approach field conditions. While these techniques have been laborious, they have increased appreciably our knowledge about herbicides. More efficient techniques for leaching studies are needed.

We have devoted considerable attention to identifying soil factors which influence the toxicity of herbicides in soil. Upon varying systematically the level of soil nitrogen, phosphorus, potassium and calcium, we found an interaction between phosphorus and the phytotoxicity of diuron. An examination of this effect for a number of other herbicides revealed a very great interaction between phosphorus and amitrole. The higher the soil phosphorus level the more toxic the soil-applied amitrole. Our best judgment to date is that phosphorus enhances the uptake and/or translocation of amitrole by the formation of an amitrole-phosphorus complex.

The toxicity of many herbicides in solution is influenced in a similar fashion by varying pH levels of the solution. The chemicals are commonly least toxic at pH 5.0 and more toxic at higher and lower pH values. Some herbicides depart from this norm. Diuron becomes more toxic as the pH of the culture solution is adjusted from 4.0 to 7.0 while the reverse is true for dalapon and dinoseb. For the most part, pH effects observed in culture solution can be repeated in soil growth media. Dinoseb is an exception since increasing pH from 4.0 to 7.0 decreases its toxicity in culture solution while the reverse is true in soil media. The reason for this difference is yet to be deduced.

Special attention is being given to the influence of pH on the detoxication of herbicides in soil. A selected high rate is stored in soil at pH values of 4.0, 5.0, 6.0 and 7.0 for periods of 2,4 and 8 weeks at which time cucumber bioassays are run in four-ounce volumes of soil using serial dilutions to determine residual toxicity. The amount of detoxication is determined by reference to a standard series using soil stored without herbicide. The detoxication rate of some herbicides is very sensitive to pH changes, whereas the detoxication rate of other herbicides is not influenced by pH. Where major pH effects are noted, the basis for the effect is being examined. As a first approach, microbes are being isolated from the detoxication media and their capacity to detoxify the herbicide in question at various pH levels is being examined.

A series of greenhouse studies led to the conclusion that soil organic matter is the most critical soil factor associated with the variable toxicity of a wide variety of herbicides. These studies have been extended to field conditions where the activity of simazine, chloropropham and diuron applied as pre-emergence treatments was found to be highly correlated with soil organic matter. In contrast, CDAA gave uniform and reliable performance between about 3 and 40 percent soil organic matter and erratic performance below 3 percent soil organic matter.

Our ultimate objective is to predict correctly how much herbicide is required for proper weed control performance. We are returning to the growth chamber and attempting to develop prediction equations for the toxicity of herbicides added to synthetic soil media formulated from a wide variety of materials. The cucumber bioassay is being used. The soil media include varying proportions of pure kaolinite and montmorillonite clays, exchange resins, charcoal, soil organic matter, nylon and quartz.

There is underway at our Station a major effort on the mechanisms of adsorption and desorption of herbicides. Adsorption patterns for paraquat, diquat, prometone and 2,4-D have been established for kaolinite clay, montmorillonite clay, an anion exchange resin and charcoal at two temperatures and for various exposure times. The disposition of herbicides within the clay lattice is being studied by X-ray diffraction analysis. A manuscript on these studies is now complete.

The influence of herbicide structure on adsorption is being investigated using a nylon as an adsorbent. Special consideration has been given to the carbamate as a class. Adsorption was highly dependent upon the aqueous solubility of the chemicals which was accounted for by regression analysis thereby allowing the identification of chemical factors which influence adsorption in excess of their influence on solubility. Adsorption appeared to occur by hydrogen bonding primarily through the keto group of the carbamate and secondarily through the imino hydrogen of the carbamate.

In the field a comprehensive herbicide residue experiment is being conducted with a dual purpose. The residual properties of diuron are being evaluated and techniques for evaluating residues are being studied. We are entering the last year of this four-year six-acre experiment which includes as variables soil organic matter, herbicide rate, frequency of herbicide application, type of test crop and number of replications. The relationship between bioassay results and field test crops is being evaluated. One of the principal results to date is that soil organic matter is inversely correlated with the risk of residual carry-over from diuron. We also conclude that midseason applications of substituted herbicides must be used with great caution on low organic matter soils if sensitive crops such as tobacco or peanuts are to be grown the next year.

Another field effort has concerned the evaluation of the use of multiple application of incorporated herbicides. Indications to date are that a unit quantity of many herbicides is more effective if it is applied in three increments rather than one. When normal rates of diuron, chloropropham and simazine were applied as a single pre-emergence application without incorporation, the weed control obtained was 50, 54 and 44 percent, respectively. Under the same conditions the same total amount of herbicide applied in three increments at weekly intervals with incorporation provided 82, 74 and 92 percent weed control, respectively. Further work on this technique is justified.

In summary it may be said that great advances have been made in recent years in our knowledge of the behavior of herbicides in soil. While most of the important processes through which herbicides may undergo are probably known, the relative degree to which each herbicide participates in each process must be ascertained. We must understand more thoroughly the herbicides themselves and the nature of the soil to which they are applied. All things considered, it appears that we are just now in a position to outline the systematic studies which must be conducted. A rich vein lays before us ready to be mined.

References

ASHTON, F. M. & DUNSTER, K. (1961) The herbicidal effect of EPTC, CDEC, and CDAA on Echinochloa crusgalli with various depths of soil incorporation. Weeds 9 312-317.

BAILEY, GEORGE W. & WHITE, JOE L. (1964) Soil-pesticide relationships. Review of adsorption and desorption of organic pesticides by soil colloids, with implications concerning pesticide bioactivity. Ag. and Food Chem. 12 324-332.

CRAFTS, A. S. & ROSENFELS, R.S. (1939) Toxicity studies with arsenic in eighty California soils. Hilgardia 12 177-199.

DANIELSON, L. L. (1959) Mode and rate of release of isopropyl N-(3-chlorophenyl) carbamate from several granular carriers. Weeds 7 418-426.

DANIELSON, L.L., GENTNER, W. A. & JANSEN, L. L. (1961) Persistence of soil-incorporated EPTC and other carbamates. Weeds 9 463-476.

DAWSON, J. H. (1963) Development of barnyardgrass seedlings and their response to EPTC. Weeds 11 60-67.

DEMING, J. M. (1963) Determination of volatility losses of C^{14}-CDAA from soil surfaces. Weeds 11 91-96.

ENNIS, W. B., JR. (1954) Some soil and weather factors influencing usage of pre-emergence herbicides. Soil Sci. Soc. of Florida 14 130-139.

GEISSBUHLER, H., HASELBACH, C. & AEBI, H. (1963) The fate of N'-(4-chlorophenoxy)-phenyl-NN-dimethylurea (C-1983) in soils and plants. I. Adsorption and leaching in different soils. Weed Res. 3 140-153.

HARTLEY, G.S. (1960) Physico-chemical aspects of the availability of herbicides in soils. In Herbicides and The Soil. Second British Weed Control Council Symposium. pp. 63-78.

HARTLEY, G. S. (1964) Herbicide behavior in the soil. In The Physiology and Biochemistry of Herbicides. Edited by L. J. Audus. Academic Press, London and New York. pp. 111-161.

HOLLY, K. (1962) Herbicides acting through the soil - a review. Proceedings Sixth British Weed Control Conference. pp. 467-477.

JORDAN, L. S., COGGINS, C. W., JR., DAY, B.E. & CLERX, W. A. (1964) Photodecomposition of substituted phenylureas. Weeds 12 1-4.

TEMPLEMAN, W. G. (1946) Selective weed control by plant growth promoting substances. Jour. Min. Agr. 53 105-108.

Discussion on preceding papers

Dr. G. S. Hartley Owing to the enormous surface of water available in soils, non-specific adsorption, requiring no specialised sites and dominated by the mutual attraction of water molecules, is likely to be very important for most herbicides. Is there any evidence that the highly specific mechanism of base exchange in clays has any real relevance to adsorption of herbicides?

Professor R. P. Upchurch Certainly the point you mention can be summed up by saying that the solubility factor of chemicals in water can be of overwhelming importance for many herbicides and we have observed this. This is an elementary truth and must be taken into consideration. The high degree of adsorption of diquat in soils in spite of high diquat water solubility illustrates that specific adsorption sites can be highly relevant.

THE DEVELOPMENTAL PHYSIOLOGY OF RHIZOMATOUS AND CREEPING PLANTS

P. F. Wareing
Botany Department, University College of Wales, Aberystwyth

The term "rhizomatous" I shall take to refer to plants with underground creeping stems, while "creeping plants" I shall assume to be those which spread by means of aerial runners or stolons, or by creeping roots. (The term stolon is sometimes applied also to underground creeping stems, especially where they are slender and extensive, but the author prefers to refer to all subterranean organs of this type as rhizomes). Although the distinction between subterranean and aerial creeping stems is somewhat arbitrary, as shown by the fact that some species, such as nettle (*Urtica dioica*), produce both types of organ, nevertheless, to the practical agriculturalist concerned with eradication of these two different types of weed the difference may be vital and have a profound effect on the methods adopted. Valuable discussions of the biology of stoloniferous and rhizomatous plants, especially in relation to their mode of overwintering and spread are given by Raunkiaer (1934) and Salisbury (1961). For the present purpose it is sufficient to make the distinction between plants, such as *Agrostis stolonifera*, in which the growing points overwinter at or above soil level, and those in which the aerial shoot dies completely and in which the perennating organs are entirely constituted by subterranean rhizomes, as in bracken, coltsfoot and bindweed. Plants of the former type may produce either runners, as in creeping buttercup (*Ranunculus repens*) or rhizomes, as in *Epilobium* spp.

Typically, rhizomes are diageotropic (i.e. grow horizontally), lack chlorophyll and have greatly modified, scale-like leaves. Sometimes the internodes are short, as in *Polygonatum*, but in others the internodes may be greatly elongated, as in *Agropyron repens*. Rhizomes arise as axillary shoots from subterranean nodes of parent shoots. In most species, the tip of the rhizome ultimately ceases to grow horizontally and instead it turns upwards and gives rise to a vertical, leafy aerial shoot.

Runners arise above ground from the basal nodes of aerial shoots which may either have extended internodes, or the internodes of the parent shoots may be greatly reduced to form rosettes, as in *Fragaria vesca*, *Hieracium pilosella* and *Ranunculus repens*, whereas the runners themselves may have greatly extended internodes.

A few species, such as creeping thistle (*Cirsium arvense*) and Sheep's Sorrel (*Rumex acetosella*) spread by creeping organs which morphologically are roots on which are found adventitious buds giving rise to aerial shoots. A list of the more important rhizomatous and creeping weed species is given in Table I.

Seasonal patterns of growth

The seasonal pattern of growth and development has been described for several important rhizomatous plants, including *Agropyron repens*

Table I. Important Rhizomatous and Creeping Plants

Rhizomatous plants	Plants spreading by runners
Achillea millefolium	Agrostis stolonifera
Aegopodium podograria	Ajuga reptans
Agropyron repens	Anagallis arvensis
Calystegia sepium	Hieracium pilosella
Carex spp	Potentilla anserina
Circaea lutetiana	P. reptans
Convolvulus arvensis	Ranunculus repens
Epilobium spp	Stachys sylvatica
Equisetum arvense	
Euphorbia spp	**Plants spreading by creeping roots**
Filipendula ulmaria	
Juncus spp	Rumex acetosella
Oxalis spp	Cirsium arvense
Petasites hybridus	Convolvulus spp
Pteridium aquilinum	Calystegia spp
Tussilago farfara	Linaria vulgaris
Urtica dioica	Hypericum perforatum
	Solanum dulcamara

(Palmer, 1958; Buchholtz, 1962), Sorghum halepense (Anderson et al., 1960; Oyer et al., 1959), Pteridium aquilinum (Braid, 1959; Conway, 1959) and Tussilago farfara (Bakker, 1960). As examples, the pattern of rhizome growth will be described in two important weed species.

(i) Agropyron repens (couch grass)

In Agropyron repens the plant produces new rhizomes in the spring from basal lateral buds. Usually 7 lateral buds at the base of the primary shoot grow out, and of these the 4 most basal ones develop into rhizomes and the remainder into tillers. The tip of each rhizome grows in a horizontal direction below the soil surface during the spring and summer, before turning upwards in the autumn to form a primary aerial shoot. This shoot develops into a mature plant during the following year. Under favourable growth conditions secondary rhizomes and tillers are formed during the first growing season. Rhizome development is dependent upon a sufficient light intensity and does not occur under shaded conditions in the summer or under long days at low light intensity and warm temperatures in a greenhouse in the winter. On the other hand, active rhizome formation occurs during the winter in a warm greenhouse under 18-hour photoperiods provided that high intensity supplementary illumination is given. It is clear, therefore, that a sufficient light intensity is necessary for rhizome development in A. repens but whether there is also a photoperiodic effect is not known, since the effects of short-days at high light intensity have not been reported. In several other species of grass, however, it appears that rhizome development is favoured by long days (Evans et al., 1964). Similarly, runnering is favoured by long days in strawberry.

(ii) Bracken (Pteridium aquilinium)

Couch grass may be regarded as an example of a rhizomatous species whose aerial shoots normally remain evergreen during the winter, whereas bracken affords an example of a species in which the overwintering organs are entirely below ground.

The morphology and growth of the rhizome system of bracken has been described by a number of workers (Watt, 1940; Webster and Steeves, 1958; Dasanayake, 1960; O'Brian, 1963). Three shoot types were described by Watt for plants growing in England, viz:

(i) Long shoots which arise solely by division of long shoots and are characterised by long internodes. These travel in the deeper layers of the soil (50 - 100 cm).

(ii) Short shoots, which arise from any of the other shoot types, and grow obliquely or vertically upwards through the soil until, at a depth of 2.5 - 10 cm, they turn and grow parallel to the soil surface. Short shoots bear most of the fronds and have short internodes.

(iii) Intermediate shoots, which differ structurally from long shoots only in the shorter length of the internodes. They arise from intermediate and long shoots but bear few fronds. They grow parallel to the long shoots but above them.

In his studies on Pteridium aquilinum var. esculentum, growing in Australia, O'Brien regarded the 'intermediate shoots' as transitional between long and short shoots. Under Australian conditions long shoots grow all the year round with peaks of activity in autumn and spring, whereas short and transitional shoots grow only in the autumn and winter. Under British conditions the long shoots continue growing steadily in the autumn and winter, until the soil temperature reaches a minimum, when there is a period of quiescence (E. Conway, personal commun.). The short shoots have a much longer period of dormancy, which may be related either to apical dominance of the parent branches or to the greater variations in temperature, soil water-content, etc., near the soil surface.

There appears to be a correlation between the presence of a physiologically active frond and absence of growth of the rhizomes. Thus, transitional and short apices grow only when the frond is dead or damaged by frosts, so that the frond appears to be "apically dominant" over the rhizome. On the other hand, the long shoots which bear few fronds are the only ones which grow all the year round.

Not only are rhizomes and creeping roots organs of vegetative spread, but they are also storage organs. This latter function means that they are able to grow very rapidly when conditions become favourable in the spring, at which time the food resources tend to become reduced; at this time they may be very vulnerable to methods of control, so that information regarding the seasonal fluctuations in reserves is important in agriculture. However, in A. repens, there does not seem to be a very marked seasonal fluctuation in carbohydrate reserves (Pinckney, 1945; Schirman and Buchholtz, 1960).

Whether the species spreads by rhizomes, runners or creeping roots, the rate of growth may be very rapid. Thus, in favourable soil conditions bracken may advance by several feet per year, and in colonising the polders of Holland, coltsfoot may extend 9 - 10 ft per year (Bakker, 1960). Again, the roots of creeping thistle may extend 20 - 40 ft in a single season (Salisbury, 1961).

Dormancy in rhizomes

Rhizomes exhibit various forms of dormancy. In discussing this subject it is important to distinguish between "innate" and "imposed" dormancy (i.e. dormancy brought about by unfavourable conditions). It is also necessary to distinguish between dormancy of the main apices of the rhizomes and that of their lateral buds.

It is well-known that many seeds and the buds of woody plants show winter dormancy which is overcome by exposure to chilling temperatures, and the rhizomes of certain species show a similar type of winter dormancy. Thus, the rhizomes of lily-of-the-valley (Convallaria majalis) fail to grow if lifted in October and planted under warm conditions, but if they are exposed to 1 - 3 weeks of chilling around 0°C they then grow rapidly when transferred to warm conditions (Hartsema, 1961). This type of dormancy does not appear to have been reported yet for important weed species. The cessation of rhizome growth in potato is accompanied by the formation of tubers, which normally show a phase of dormancy.

In A. repens, the rhizomes do not seem to show innate winter dormancy, since they are capable of growing actively during the winter if plants are lifted from the open ground in September and transferred to a warm greenhouse, provided they are given supplementary illumination (Palmer, 1958). Several other forms of dormancy have been described for this species, however (Buchholtz, 1962; Hay, 1962). The optimum temperature range for bud activity is from 15° to 25°C, and temperatures above 30°C greatly reduced bud growth (Meyer and Buchholtz, 1960). Thus high temperatures appear to cause a form of "summer dormancy" of the buds of A. repens.

Considering now the lateral buds, it appears that these frequently remain inactive because they are inhibited by apical dominance of the main apex of the rhizome; thus, in Agropyron repens, buds normally remain inactive throughout the entire life of the rhizomes, but if the latter are cut up into segments the lateral buds will grow at most times of the year (Johnson and Buchholtz, 1962). However, during the period April - June, under North American conditions, the lateral buds fail to grow out if the rhizomes are cut into segments, and they exhibit "late-spring dormancy". This type of dormancy occurs when there is rapid top-growth and rhizome growth of the plant, and it appears to be related to low levels of nitrogen in the rhizome tissue at this time. It appears that the aerial shoots deplete the nitrogen during the spring flush of growth. This hypothesis is supported by the finding that the inactive buds of rhizome sections can be stimulated into growth by supplying nitrogen in various forms, viz. as ammonium, nitrate or amino nitrogen. This form of dormancy does not appear to be of universal occurrence in A. repens (Hay, 1962), and under field conditions it may be overcome by applying nitrogen fertilizers in the autumn or spring.

Yet another form of bud dormancy in A. repens appears in compacted soil, since even when the soil is chopped into 2 inch blocks, fewer buds develop than when rhizome sections are removed and planted in fresh soil (Meyer, 1961; Hay, 1962). It seems unlikely that poor soil aeration is the operative factor in this form of bud dormancy, since although bud activity is reduced by high CO_2 and low O_2 concentrations (Meyer and Buchholtz, 1963), these conditions are not likely to occur normally in the soil to the degree necessary to reduce bud activity.

It has been calculated that there may be as many as 2.5 million buds per acre on the rhizomes of A. repens (Hay, 1962), and the majority of these will be capable of regenerating the plant if apical dominance is removed by sectioning of the rhizomes during cultivation. Hence, an understanding of the physiology of bud dormancy and activity is an essential basis for control of this weed.

The plagiotropism of rhizomes and runners

One of the characteristic features of rhizomes and runners if their capacity to grow more or less horizontally through the soil, in contrast to the normally erect, leafy aerial shoots. Where a plant organ grows at an angle to the force of gravity, the general term "plagiotropism" is used, and the special case where the organ grows horizontally is referred to as "diageotropism".

Light appears to play an important role in the plagiotropic habit of runners which in many species grow vertically in the dark. Czapek (1895) and Maige (1900) have shown this to be true of Rubus caesius, Potentilla anserina, Trifolium repens, Stachys sylvatica, and Hieracium pilosella. On the other hand, according to Czapek, the stolons of Nepeta hederacea and Potentilla repens grow horizontally in both light and dark, and Raunkiaer (1934) found this to be true also of Ajuga reptans and Ranunculus repens. Thus, it seems necessary to distinguish between "induced plagiotropy" and "inherent plagiotropy".

In Stachys sylvatica and Urtica dioica, which have both aerial stolons and subterranean rhizomes, it appears that both types of organ show light-induced plagiotropism, since if the rhizomes are planted at a depth of 15 cm they immediately become erect, whereas when they are near the soil surface they grow horizontally. It would appear that sufficient light penetrates the uppermost layers of the soil to induce the normal plagiotropism of the rhizomes. Clapham (1945) also obtained evidence that small quantities of light penetrating the upper layers of soil may play a role in the plagiotropism of rhizomes of Polygonatum multiflorum, since in complete darkness they tend to grow upwards, but when exposed to very low intensities of light they grow downwards. Clapham suggests that this light response constitutes the mechanism of depth perception in this species.

Bennet-Clark and Ball (1951) have shown that the rhizomes of Aegopodium podograria are very sensitive to light, and that even 30 seconds' exposure to red light causes a downward curvature. In darkness or under infra-red radiation the rhizomes grow horizontally.

In addition to their sensitivity to light, diageotropic rhizomes also respond to gravity, as is shown by the fact that if they are displaced from their horizontal position they very soon show growth curvatures which restore them to their original position, as in Aegopodium podograria (Bennet-Clark and Ball, loc. cit.).

Little is known regarding the mechanism of gravity perception in rhizomes, but in view of the probable role of auxin in the geotropism of aerial shoots, it is generally assumed that the horizontal growth of diageotropic organs is the resultant of a balance between a tendency to upward curvature due to higher auxin concentrations on the lower side and some other process tending to cause downward curvature. In Aegopodium podograria, Bennet-Clark and Ball were lead to postulate the accumulation of an "antihormone" on the upper side of the rhizomes, to counteract the effects of the higher auxin concentrations on the lower side. Clapham (1945) postulated that the horizontal growth of Polygonatum rhizomes is due to a balance between negative geotropism (upward curvature) and a downward curvature caused by light reaching a sensitive region, possibly near the bases of the aerial shoots.

Palmer (1956) observed that the shoots of several tropical species of grass, including Cynodon dactylon, became horizontal in bright light but became erect when the entire plant was darkened. On the other hand, if the parent plant was kept in light and only the stolons kept in darkness, the latter remained horizontal. If the parent plants were then shaded, the runners gradually turned upwards. In these grasses light evidently produces some stimulus in the parent plant which is transmitted to parts of the plant growing in the dark. He was able to show that light produces a positive geotropic response and that the responses are not phototropic. The positive geotropism of the stolons counterbalances the inherent negative geotropism, and so results in plagiotropic growth. The same author had previously shown that a stimulus evoked by bright illumination is transmitted from the aerial parts of Agropyron repens to the subterranean rhizome where a positive geotropic response results (Palmer, 1955).

Not only are there mechanisms for regulating the depth and orientation of the rhizome, but there are mechanisms ensuring that the crown of the aerial shoot occurs at the surface of the soil. Thus, if the crown of Johnson grass (Sorghum halepense) is buried 6 inches below the soil, the internodes elongate until the shoot apex is brought to the surface, where adventitious roots are formed from the node and a new crown is developed (Oyer et al., 1959). Similar responses have been reported for other species (Raunkiaer, 1934). It is clear that this response will be important in the re-establishment of weeds after burial during tillage operations.

The cessation of rhizome growth and the transition from horizontal to vertical growth which occurs in many species present a number of interesting problems. It is stated that plagiotropic organs behave differently from diageotropic organs in that severing from the main stem or root usually causes them to become erect. By contrast, horizontal rhizomes generally maintain their behaviour for some time when severed from the aerial parts of the shoot (Bennet-Clark and Ball, 1951). It is also known that the plagiotropic rhizomes of the potato plant become erect and form green expanded leaves when the aerial shoots are decapitated and axillary buds are removed from it (Booth, 1959). This observation suggests that plagiotropic growth of the rhizomes depends upon apical dominance of the erect, leafy shoots. In *Agropyron repens*, the cessation of rhizome growth in autumn does not appear to be controlled by environmental conditions but by the senescence of the aerial shoots (Palmer, 1958), suggesting that apical dominance may also be important in rhizome growth in this species.

In other species, it appears that seasonal temperature changes may have marked effects on the orientation of the shoots. Vöchtung (1898) and Lidforss (1903) have shown that in *Lamium*, *Cerastium* and other species the normally erect shoots adopt a plagiotropic habit in the autumn and winter, in response to the lower temperatures. In the garden chrysanthemum (*Chrysanthemum morifolium*) rhizome growth takes place actively in the autumn at the time of flowering and senescence of the old, erect shoots. Under normal outdoor conditions they grow diageotropically for a short time and then turn upwards. If, however, these rhizomes are grown under short-day conditions in a warm greenhouse, they develop into leafy shoots, but the latter have abnormally short internodes and adopt a diageotropic growth habit; they are also incapable of initiating flowers in response to short-days (Schwabe, 1950). If the rhizomes are exposed to chilling conditions, however, they turn upwards, show normal internode extension and will form flowers under short-day conditions. In *Epilobium hirsutum* plagiotropic growth is a short-day response, which can be overcome by applying gibberellic acid to the plants (Schwabe, 1962).

Hormonal factors in rhizome and stolon development

Although light undoubtedly plays an important role in the plagiotropic responses of stolons and rhizomes, the question still remains as to why the lateral shoots arising in the basal part of the plant differ in morphology and growth habit from lateral shoots arising on the aerial, upper part of the parent shoots. Recent studies suggest that hormonal factors, arising within the plant itself, also play a vital role in rhizome and runner development, as shown by a consideration of the development of rhizomes in the potato plant (Booth, 1959 and 1963). As already mentioned, apical dominance appears to be an important factor in rhizome development in this species, suggesting that hormonal factors may be involved, and indeed the work of Booth has revealed the striking effects of both auxin and gibberellins in this plant. If an aerial shoot of potato is decapitated near the tip, without removal of the axillary buds, the ones at the uppermost few nodes quickly grow out as leafy shoots and assume leadership. This outgrowth of the uppermost axillaries can be only slightly inhibited by applying auxin to the decapitated stump, and if gibberellin alone is applied the main observable effect is that the internode extension of the shoots is increased. However, if auxin and gibberellin are applied simultaneously to the cut stump, there is a spectacular change in the development of the axillaries, which now grow out horizontally as typical rhizomes, with elongated internodes and greatly reduced leaves, and this occurs in the upper part of an aerial shoot, at a considerable distance from the soil.

We have recently demonstrated that other growth substances, notably the "kinins", have pronounced effects upon rhizome development in the potato (Kumar and Wareing, unpublished). Thus, if 6-furfuryl-amino purine ("kinetin") or 6-benzyl-amino purine are applied to the tips of normal rhizomes, these very quickly turn upwards and commence to develop green leaves. Similarly, if these substances are applied to the lateral ends of decapitated plants to which auxin and gibberellin have been applied as described above, then horizontally-growing leafy lateral shoots are developed instead of rhizomes. From the foregoing observations it seems probable that endogenous hormonal factors play an important role in normal rhizome development, and that the balance between the levels of auxins, gibberellins and kinins is of great importance.

However, the problem still remains as to why rhizome development is normally limited to the basal nodes of the plants, either just above or beneath the soil. A number of possible factors determining rhizome development in this region might be postulated, e.g. proximity to roots, distance from the aerial shoot apices, or high humidity and low light intensity in the case of rhizomes developing below soil level. That roots are not essential for rhizome development is shown by the fact that if cuttings of potato shoots are suspended in a moist atmosphere, rhizomes may develop from the basal nodes even though roots are not formed (Kumar and Wareing, unpub.). A number of other similar experiments also point to the conclusion that roots are not essential for the development of stolons in cuttings. However, it is noteworthy that it is primarily the basal nodes which develop stolons in cuttings, as in the normal plant. There seem to be certain conditions prevailing in the basal region of a shoot which are favourable to stolon development.

There is evidence that the production of runners in strawberry under long days is also hormonally regulated. Thus, runners may be induced to develop under short days by applying gibberellic acid to the plants (Thompson and Guttridge, 1959) and there is evidence that in certain other species greater amounts of gibberellins are produced under long days than under short-days. Thus it seems likely that the effect of photoperiod on runner production is mediated through changes in endogenous gibberellins.

Plants spreading by creeping roots

Another very important group of weeds is constituted by those spreading by creeping roots, on which shoots are developed from adventitious buds. Sheep's sorrel (Rumex acetosella) and creeping thistle (Cirsium arvense) provide two very common examples of this type of weed. The capacity for regenerating adventitious buds from roots is not uncommon and is exhibited not only by certain plants with creeping roots, but also by others with rootstocks, e.g. dandelions and docks, and also by various woody plants, e.g. common elm (Ulmus procera), aspen (Populus tremula) and false acacia (Robinia pseudoacacia). The bindweeds (Convolvulus and Calystegia spp.) are also able to spread both by rhizomes and creeping roots.

It is not known why the roots of certain species readily produce adventitious shoots, whereas others lack this capacity. It appears from the work of Skoog (Skoog and Miller, 1957), and others, that hormonal factors are important in regeneration of shoots, and that the balance between the levels of kinins and auxins plays an important role. Little appears to be known regarding the developmental physiology of this type of weed; for example, it is not known whether creeping roots show dormancy, or whether environmental factors play a role in seasonal periodicity in the formation of adventitious buds. The biology of the creeping thistle has been described by Bakker (1960) and further studies on this species are described in the paper by Dr. Sagar at this Conference.

Conclusions

It will be clear from the foregoing account that our knowledge regarding the developmental physiology of rhizomatous and creeping plants is very fragmentary and information of a basic nature is lacking for many important weed species.

Detailed morphological and growth studies under field conditions have been carried out on certain species, such as Agropyron repens and bracken, but often these observations have not been supplemented by physiological studies on the role of environmental and hormonal factors in the growth and development of the plant. A useful start has been made for Agropyron repens, but even with this species there are still important gaps in our knowledge. Perennial weeds of this type present a number of fascinating problems to the plant physiologist, and a better understanding of their developmental physiology must form an essential basis for scientific weed control.

References

ANDERSON, L. E., APPLEBY, A. P. and WESELOH, J. W. (1960). Characteristics of Johnsongrass rhizomes. Weeds, 8, (3), 402-6.

BAKKER, D. (1960). A comparative life-history study of Cirsium arvense and Tussilago farfara, in "The Biology of Weeds" (Ed. J. Harper), Blackwells, Oxford.

BENNET-CLARK, T. A. and BALL, N. G. (1951). The diageotropic behaviour of rhizomes. Journ. of Exp. Bot., II, 5, 169-203.

BOOTH, A. (1959). Some factors concerned in the growth of stolons in potato. J. Linn. Soc. 16, 166-169.

BOOTH, A. (1963). The role of growth substances in the development of stolons, in "The Growth of the Potato", Butterworths, London.

BRAID, K. W. (1959). Bracken: a review of the literature. Mimeo. Publ. Commonw. Bur. Past., Fld Crops, (3), pp.69

BUCHHOLTZ, K. P. (1962). Some characteristics of quackgrass and their relation to control. Proc. N. East Weed Control Conf., 16, 16-22.

CLAPHAM, A. R. (1945). Studies on the depth adjustment of subterranean plant organs. 1. Raunkiaer's experiment on depth perception in Polygonatum. New Phytol., 44, 105.

CONWAY, E. (1959). The Bracken Problem. Outlook on Agriculture, 11, 158-167.

CZAPEK, F. (1895). Uber die Richtungsursachen der Seitenwurzeln und einiger anderen plagiotropen Pflanzenteile. Sitzber. Akad. Will. Wien. Math.-Naturwiss. Kl., 104, 1197.

DASANAYAKE, M. D. (1960. Aspects of morphogenesis in a dorsiventral fern, Pteridium aquilinum (L.) Kuhn. Ann. Bot., N.S., 24, 318.

EVANS, L. T. WARDLAW, C. N., and WILLIAMS, C.N. (1964). Environmental control and growth in "Grasses and Grasslands", (Ed. C. Barnard), Macmillan, London, 102-125.

HARTSEMA, A.M. (1961). Influence of temperatures on flower formation and flowering of bulbous and tuberous plants. Enc. Plant Phys., 16, 123-167

HAY, J. R. (1962). Biology of quackgrass and some thoughts on its control. Down to Earth, 18, (1), 14-16.

JOHNSON, B.G. and BUCHHOLTZ, K. P. (1962). The natural dormancy of vegetative buds in the rhizomes of quackgrass. Weeds, 10, 53-57.

LIDFORSS, B. (1903). Über den geotropismus einiger Frühjahrspflanzen. J. wiss. Bot., 48, 343.

MAIGE, M. B. (1900). Recherches biologique sur les plantes rampantes. Ann. Sci. Nat., Ser. 8, 11, 249.

MEYER, R. E. (1961). A study of factors affecting the bud of quackgrass (Agropyron repens (L.) Beauv.) Ph.D. Thesis, Univ. Wisconsin, pp. 141.

MEYER, R. E. and BUCHHOLTZ, K. P. (1960). Some factors affecting the activity and growth of buds on quackgrass rhizomes. Proc. 17th N. Cent. Weed Control Conf., 1960, 37.

MAYER, R. E. and BUCHHOLTZ, K. P. (1963). Effect of chemicals on buds of quackgrass rhizomes. Weeds, 11, 4-7.

O'BRIEN, T. P. (1963). The morphology and growth of Pteridium aquilinium var. Esculentum (Forst.) Kuhn. Ann. Bot., 27, (106), 253-267.

OYER, E. B., GRIES, G. A. and ROGERS, B. J. (1959). The seasonal development of Johnsongrass plants. Weeds, 7, (1) 13-19.

PALMER, J. H. (1956). The nature of the growth response to sunlight shown by certain stoloniferous and prostrate tropical plants. New Phytol., 55, 346-355.

PALMER, J. H. (1958). Studies in the behaviour of the rhizome of *Agropyron repens* (L.) Beauv. 2. Effect of soil factors on the orientation of the rhizome. Physiol. Plant. 15 (3), 445-451

PINCKNEY, A. J. (1945). Composition and vitality of quackgrass roots. North Dakota Agr. Exp. Sta. Bull., 334 (Tech)

RAUNKIAER, C. (1934). "The Life Forms of Plants", Clarendon Press, Oxford

SALISBURY, E. (1961). "Weeds and Aliens", Collins, London

SCHIRMAN, R. and BUCHHOLTZ, K. P. (1960). The effect of atrazine on the carbohydrate levels in rhizomes of quackgrass. Proc. N. East Weed Control Conf. 17, 19.

SCHWABE, W. W. (1950). Factors controlling flowering in chrysanthemum. I. The effects of photoperiod and temporary chilling. J. Exp. Bot., 1, 329-343.

SCHWABE, W. W. (1962). Effects of daylength and gibberellic acid on morphogenesis and flowering of *Epilobium hirsutum* and *E. Parviflorum*. Indian Journal of Plant Phys., V, 73-87.

SKOOG, F. and MILLER, C. O. (1957). Chemical regulation of growth and organ formation in plant tissues cultured *in vitro*. Symp. Soc. Exp. Biol., 11, 118-131

THOMPSON, P. A. and GUTTRIDGE, C. G. (1959). Effect of gibberellic acid on the initiation of flowers and runners in the strawberry. Nature, 184, 72-73.

VÖCHTING, H. (1898). Über den Einfluss niederer Temperaturen auf die Sprossrichtung. Ber. d. d. bot. Ges., 16, 37.

WATT, A. S. (1940). Contributions to the ecology of bracken (*Pteridium aquilinium*). I. The rhizome. New Phyt., 39, 401-422.

WEBSTER, B. D., and STEEVES, T. A. (1958). Morphogenesis in *Pteridium aquilinium* (L) Kuhn.- General Morphology and Growth Habit. Phytomorphology, 8, 30.

AN INTRODUCTION TO THE SURVEY OF MAINCROP POTATOES 1963

prepared by C. de B. Codrington, Potato Marketing Board.

In 1963 the Potato Marketing Board in collaboration with the National Institute of Agricultural Engineering and Rothamsted Experimental Station undertook a survey of Maincrop Potato production, similar in most respects to that which was carried out in 1958.

The Board wishes to acknowledge the help and assistance given by the following who have prepared the report: Dr. D. A. Boyd, Mr. B. M. Church and Miss M. G. Hills of the Statistical Department, Rothamsted Experimental Station, and Mr. J. K. W. Slater and Mr. M. P. Jones of the National Institute of Agricultural Engineering.

Introduction

The 905 farms in England, Scotland and Wales were chosen at random and visited by the Potato Marketing Board's staff. Two visits were made in the main - one in the Spring and the other in the Autumn. On a one tenth sub-sample, a third visit was made to estimate the weight of tubers in the ground after harvesting. Attention is drawn to the alteration in the regions as given in the 1958 survey compared with those in the 1963 survey. Unfortunately, in undertaking a crop survey of this sort, the possibility of carrying out the work in an atypical season has always to be contended with. 1958, for instance, proved to be an unusually severe blight year with a difficult harvest and again, in 1963, planting was delayed by rain in March and April.

Cultivation

It would appear that there has been little change in the depth of ploughing since 1958, after the substantial increase shown in the period 1948 to 1958. After planting was completed, to some extent there was a reduction in the number of harrowings but otherwise there was little change in post-planting operations. Weed control was carried out in the main by conventional mechanical methods. Herbicides were used infrequently, 1% of the crops being treated with pre-emergence weed killers based on diquat salts, and another 1% with D.N.B.P. and M.C.P.A. Of the crops visited, 10% were irrigated and this practice occurred among growers with the larger acreages. 20% of the crops visited had systemic organo-phosphorus compounds applied for aphid control.

Fertilizer Practice

The survey confirmed the general decrease in the quantities of farmyard manure applied to the crop with a significant decrease in the peat and silt farms in East Anglia. As regards inorganic fertilizers, it would appear that there has been an increase in the last five years. 10% increase for nitrogen and about 5% increase for phosphorus and potassium. The survey suggests that farmers are showing greater awareness in possible economies in fertilizer use, particularly in so far as potassium is concerned. It was interesting to note that fertilizers consisting of aldrin were used on 12% of the acreages and in Scotland it was shown that no seed crop was reported receiving this treatment. A further 2% of crops had aldrin sprayed on the soil prior to planting.

Planting

The report indicates that there has been a small increase in the acreage planted with certified seed in the East and West Midlands, Yorkshire and Lancashire regions.

Since 1958, there has been a slight increase in the use of chitted seed, mainly confined to the Eastern and East Midlands, Yorkshire and Lancashire regions. It is interesting to note that the practice of chitting was more common with the larger growers and again specialised buildings were more likely to be used by the larger growers. Seed rates increased by about 10%, the average planting rate being 22 cwts per acre for certified seed and 20 cwts. per acre for uncertified seed. It is suggested that the increase in seed rate was due to the increase in tuber weight. There has again been a further reduction in the amount of hand planting which possibly reflects the difficulty in obtaining adequate labour.

Spraying and Dusting

There was an increase of about 10% in both acreage and the number of times a crop was sprayed for blight control. The increase would appear to be uniform for the whole of the country. There has been a reduction in the use of copper based chemicals and an increase in organic fungicides mainly based on dithiocarbamates of zinc and manganese. The percentage of acreage sprayed by air has remained constant.

As regards the use of chemicals for burning down haulm, sodium arsenite has been replaced in part by sulphuric acid (40% of the acreage), diquat (25% of the acreage) and D.N.B.P. in oil (17% of the acreage) but mechanical means of destruction are still employed on about one tenth of the acreage.

Harvesting

The potato spinner still remains the most important implement used in potato harvesting but its use has decreased considerably since 1958. It will be seen that the use of the complete harvester has increased from 4% in 1958 to 18% in 1963. Handling techniques would appear to have remained comparatively constant but with great variation in the use of different methods from one part of the country to another.

Storage

There has been some increase in the use of buildings since 1958 and, at the present time, just over half of the crop is stored in this manner. It is significant that only 5% of the farms had stores fitted with ducts and only 2.7% of the farms had stores fitted with fans. The use of sprout inhibitors was reported on only 12 of the 905 farms.

Yields

The report gives a useful comparison on the different methods of sampling yields and compares the P.M.B. crop check weighing procedure with the "Dyke" method. The report indicates that both methods of sampling give comparable results but it should be borne in mind that the "Dyke" method is based on only 100 samples which is a far lower number of samples than that used by P.M.B. crop check weighing. Crop yield samples show that there was a wide variation in the ware yield from one farm to another in the same region. A high figure of 1.5 tons per acre of leavings, of which 1 ton was of ware size, indicates the seriousness of this loss. There was an indication that the average losses were greater on fields harvested by a spinner.

Note Report published in December 1964 by Potato Marketing Board, 50 Hans Crescent, Knightsbridge, London S.W.1. at a price of 1/6 post free.

THE EUROPEAN WEED RESEARCH COUNCIL - A PROGRESS REPORT

Prof. Dr. J.M.T. Stryckers
State Agricultural University, Ghent, Belgium.
Vice-President of the E.W.R.C.

At the sixth British Weed Control Conference at Brighton the then President of the European Weed Research Council Dr. R. Longchamp addressed the Conference. He gave a picture of the first steps in the development of contacts in weed research in Europe. It is now a great honour and pleasure for me to be called upon and to have this opportunity of addressing the members of the seventh British Weed Control Conference in order to give a progress report. Unfortunately the President of the E.W.R.C. Dr. T. Vidme from Vollebekk, Norway, cannot be with us today, but he and the other members of the Council join me in offering to the Conference their best wishes for an interesting and fruitful meeting.

In his address Dr. Longchamp described the activities of the Council up to 1962. Consequently I should like to report on our progress since that date.

Before doing so, however, I may again mention briefly the main ideas behind the Council.

The European Weed Research Council is a scientific organisation with the object of promoting the exchange of scientific information relating to all phases of the control of undesirable vegetation, between the countries of Europe and to encourage and assist common endeavours in this field.

In order to reach this object the Council has
- established a net of representatives all over Europe
- established committees working on special problems
- organized international meetings on selected topics
- started the publication of a journal
- established contacts with international organisations

Membership in the E.W.R.C.

As to the membership of the E.W.R.C. I would like to recall that the countries taking part in its activities are each represented by one member.

Since the last report the Council lost one of its outstanding first members, Prof. Raffaele Ciferri. Prof. Ciferri was the member for Italy on the European Weed Research Council and also a member of the Editorial Board of the journal Weed Research. His death occurred unexpectedly on 12th February 1964. Presently Italy is represented on the Council by Dr. Luigi Chiapparini. from Milan. After the retirement of Prof. B.D. Krimbas, Prof. U.X. Davidis has become the representative of Greece, and in Spain after the retirement of Prof. M. Benlloch the representative is Dr. F. Lopez de Sagredo. In Ireland Dr. M. Neenan has replaced Dr. B. Crombie. We are pleased to announce the addition of one more country to the list of participating countries. In 1964 Iceland has accepted our invitation to establish contacts with the Council and Mr. A. Gudnasson will be the representative.

For the United Kingdom Mr. J. Fryer has replaced Dr. E.K. Woodford. The E.W.R.C. cannot sufficiently express its appreciation to Dr. Woodford for all his contributions to the development of the E.W.R.C. in its crucial first years, and our thanks to the British Agricultural Research Council for allowing Dr. Woodford to spend so much of his time on international cooperation in weed research. We feel sure that in his new post as Director of the Grassland Research Institute Dr. Woodford will show continued interest in the activities of the E.W.R.C. Like ours, it will be his great satisfaction that Mr. Fryer has been appointed by the British Weed Control Council to represent from now on the United Kingdom.

Meetings of the E.W.R.C. in 1963 and 1964

In 1963 the Council had a brief meeting at the premises of the Weed Research Organisation at Oxford. In 1964 the Council met at Vollebekk (Norway), where the Norwegian Ministry of Agriculture and the Norwegian Plant Protection Institute acted as hosts. At this occasion I should like to combine the results of both meetings in one summary.

In discussing the adoption of a name for the study of weeds and their control, the Council was informed that the Weed Society of America has now approved the name "weed science". However, in several European countries the name "herbology" has been suggested and the Council has agreed to come to a decision at its next meeting as to whether the use of this name should be encouraged or not.

It was also agreed that there is a need for greater uniformity in national and international weed research terminology, and, presently ways to achieve this greater uniformity are being studied.

Also the publication of a multilingual list or small dictionary of technical terms in the field of weed research is being studied.

The preparation of a list of persons engaged in weed research is finished and the distribution of this list is about to start. This is a project in which the E.W.R.C. is cooperating with several other organisations, e.g. the International Union of Forest Research Organisation and the Weed Society of America, but also with Canadian, Latin- and South American colleagues and the New Zealand Weed Control Conference.

At its meeting at Vollebekk the Council started a discussion on international exchange of information and cooperation in research on undesirable side effects, related to the use of herbicides. The Council agreed that effects of herbicides on soil fertility will have to be considered first and for its next meeting a preliminary report advising on future actions of the Council will be prepared.

In several European countries weed flora inventories were or are being carried out and in this respect the Council agreed to make a comparative study of the systems followed. Dr. Heenan, who took the initiative in this study, will be leading this programme.

In 1965 the Council will meet in Paris and it can be officially announced now that on that occasion a second "Symposium on New Herbicides" will be organised in cooperation with the French Weed Control Committee, the COLUMA. The date for this Symposium has been fixed for the 3rd week of December and pertinent information as to presentation of contributions to the programme will be available in the near future from the secretary.

For 1966 the Council has gladly accepted the invitation of our Portuguese colleagues and at this occasion a meeting with limited attendance on mediterranean weed problems will be held, probably with the main emphasis on ecological approaches. In 1967 the organisation in Austria of the International Plant Protection Congress opens interesting possibilities for our meeting there.

Concluding this rather sketchy summary of the activities of the Council I should like to say that gradually a more programmatic approach is emerging in the activities of the Council. Unfortunately progress is retarded because of difficulties related to the setting up of any international activity and especially to those related to the insufficient number of research workers in most European countries in this relatively young field of activity.

With the Weed Society of America and particularly with its International Affairs Commitee the E.W.R.C. cooperation is excellent. Last February our Secretary. Dr. W. van der Zweep, attended the meeting of the W.S.A. and its Committee at Chicago. These contacts make it possible that in future developments in the organisation of weed research in the world, all international aspects can be sufficiently taken into consideration.

<u>Committees of the E.W.R.C.</u>

At the constitution of the EWRC it was decided that it would support groups of specialists in the formation of Committees with the object of studying specific and well defined problems.

Following five committees are now officially affiliated :
the Committee on Methods
the Committee on <u>Pteridium aquilinum</u>
the Committee on <u>Avena fatua</u> (and related species)
the Committee on Aquatic Weed Control
the Committee on Weed Problems in Mountain Areas.

At its fourth meeting in Lausanne, Switzerland, in 1963 and at the fifth in Vienna, Austria, in 1964 the <u>Committee on Methods</u> further discussed standardisation of experimental techniques. Under its secretary, Dr. H. Johannes (Braunschweig, Germany), the Committee is particularly concerned with techniques useful to organisations administering approval schemes. This year tentative recommendations were prepared for weed control studies in strawberries, for grass control experiments in cut forest areas and for <u>Pteridium</u> experiments. The members of the group carry out experiments according to the recommended methods and are requested to discuss the proposals in their home countries with their specialist colleagues. A publication of all recommendations can be envisaged.

The Committee has also agreed on a common evaluation scheme for rating the results of field experiments. This proposal has been sent to the member countries for consideration.

Discussion on the description of growth stages of crop plants has resulted in accepting the Feekes-Keller-Baggiolini scale for describing growth stages in cereals. Presently attention is being paid to the stages of development of weed seedlings.

Further activities will include the compilation of bio-assay techniques with which herbicides can be determined in soil, water and organic material; the preparation of a multilingual list of names and weeds, the preparation of a list of recommendations concerning application equipment for field experiments in the approval services.

No special meetings of the Wild Oats Committee have been held since the last meeting at Versailles (France) in 1961, due to the illness of the secretary, but a review of research on the biology and control of wild Avena species carried out in 1963 by members of the Committee and their programme planning for 1964 have been made.

At the Council Meeting in Vollebekk, it has been suggested to include the ecology and control of all annual arable weedy grasses in the activities of this Committee. Especially in Western Europe Alopecurus myosuroides Huds. is important; in other countries it can be e.g. Setaria spp. The secretary Mr. P. Zonderwijk (Wageningen, the Netherlands) has been asked to make an urgency list and to collect information in the different countries.

After the 1st successful meeting of the Aquatic Weed Control Committee held in Brussels (Belgium) on the 29th August 1962 and a most useful tour of experimental sites the next day in the Netherlands, this Committee held a new two-day meeting at La Rochelle, France, on 24th-25th September 1964, under the guidance of Dr. J. Lhoste (Neuilly s/Seine, France). This meeting became an International Symposium with more than 100 participants, with many lectures in the morning and field trips through the Charente Maritime in the afternoon.

A report of the 1st Meeting of this Committee has been published in "Weed Research" (1963),3,(1),69-70.

In most European countries, chemical control of aquatic vegetation has progressed beyond the research phase.

With the introduction of chemical control of emergent weeds however a replacement can occur of an existing plant community following herbicide treatment by another consisting of different plant species with possibly a shift in the balance of emergent and submerged species.

At present there is insufficient knowledge to enable changes in vegetation to be predicted. Ecological studies on this subject are required.

Furthermore, there is a great need for better spraying equipment specially adapted for use in canals and ditches and in several countries developments are under way.

Again it was emphasised that the techniques used to determine the toxicity of herbicides to fish show much variation. In addition to laboratory tests, experiments under actual field conditions are necessary. It was agreed that one of the Committee's aims should be to consider a more uniform testing procedure.

The next meeting of this committee has been planned for 1967 in Oldenburg, Germany; the secretary will be Dr. W. Holz (Oldenburg).

The Committee on Weed Problems in Mountain Areas met for the 1st time at Lausanne, Switzerland, in May 1963. Dr. [illegible] Würgler (Lausanne), Chairman of the Committee, gave a detailed account of this meeting in "Weed Research" (1964),4,(1),80-81. A second meeting has been arranged in Norway in July 1964.

Common experiments have been set up in 1963 for the control of 2 species: Nardus stricta und Rumex alpinus.

The Committee on Bracken Fern has had great difficulties owing to the temporary absence of Dr. E. Rohrig. At present Dr. G.L. Hodgson from Oxford has kindly agreed to be the convenor of the Committee and his elaborate report on many British experiments has been presented to members on the European continent. It is hoped that in the near future the results of some 23 common experiments (carried out by the members since 1960 in 7 different countries) will be studied in relation to the results obtained in the United Kingdom.

Further planning of the activities of the Committee may result in separate activities in forest and pasture areas, where the solution of the bracken problem will probably come from different approaches.

The Journal "Weed Research"

When the European Weed Research Council was formed in April 1960, the decision was taken to sponsor in 1961 a new journal, which would bring together from all parts of the world papers in English, French or German concerned with the science and technology of herbicides and other methods of weed control. The scope of the journal "Weed Research", the official publication of the Council, is wide, and the sole criteria for publication are the intrinsic interest and value of the work described, and the quality of its presentation.

This year "Weed Research" is in its 4th year. The total circulation is still increasing. The subscriptions are well distributed geographically amongst more than 50 countries all over the world (155 in the U.S.A.; 111 in Great Britain; Japan : 64; Germany : 40).

The number of organisations contributing to the Guarantee Fund is now 36; their support and especially that of the British Weed Control Council is gratefully acknowledged.

The Council's journal continues to make satisfactory progress. The standard and number of contributions have been maintained at a high level. With the increasing number of papers available, it has become possible to implement the desirable practice of refereeing manuscripts by appropriate authorities prior to publication.

In 1963-1964 a special series of short articles was published in "Weed Research", each describing briefly the organisation of weed research in a European country. A limited number of copies of the complete series will be available in the near future.

With the publication of "Weed Research" a valuable contribution has been made to the field of weed research in general and it can be stated that the journal has greatly improved the official status of the Council.

His recent appointment to Director of the A.R.C. Weed Research Organisation makes it increasingly difficult for Mr. Fryer, to be the Editor of "Weed Research". The Council, therefore, had to consider the resignation of Mr. Fryer from this post. Starting with Vol. 6, that will be published in 1966, a change in editorship will take place. The Council is very pleased to announce that Mr. H.A. Roberts has been willing to accept our invitation to be the new editor of "Weed Research" and we are grateful to the Director of the National Vegetable Research Station (Wellesbourne-Warwick,England) for allowing Mr. Roberts to do so.

To conclude, it can be stated that the fundamental structure of the European cooperation in weed research has been developed.

It has on the other hand become more and more apparent that the further development of the E.W.R.C. depends on a spreading of its activities over the various member countries. The national research groups of the member countries are gradually accepting part of this work as a more or less regular activity in their programmes. Unfortunately because of the many problems with which weed research workers in all countries concerned are faced and also because of the difficulties encountered in establishing and maintaining international contacts, it remains at present impossible to expand the activities of the Council much beyond the present level. With the members of the Council I want to stress however the increasing importance of the European contribution to the field of weed research, justifying continued efforts on behalf of all concerned.

SIDE EFFECTS OF PESTICIDES ON PLANT GROWTH

W. E. Ripper
Docking Manor, Kings Lynn

Summary Side effects of pesticides on the crop plant i.e. phytotoxic effects appearing some time after treatments, effects arising from interactions of different pesticides or effects influencing the infection by plant diseases or the infestation by pests are reviewed. The economic importance of some of these side effects would seem to call for more plant physiological and biochemical work on the effect of new pesticides, to enable the development of quantitative correlations which could be used to exclude dangerous application conditions, to develop methods for avoiding undesirable side effects and for exploiting beneficial side effects. The interdependance of measures for the application of weed science, entomology, mycology and virology requires a new type of biologist, who can combine sufficient knowledge of the above mentioned disciplines with a sound grounding in plant physiology to advise the farmer to maximise crop production.

Side effects of pesticides on the crop plant and through the plant on pathogens and insect pests of the crop plant merit a review, because most of the scientist's attentions have hitherto been focused on the effect of pesticides on the organism to be controlled, on their residues, the toxic effects to man, beast, fish and bees, and on the effect on the soil flora and fauna. It is obvious that the highly biocidal substances, which are used to kill weeds, insects and fungi, are also taken up by the crop plant and affect it in various ways. Phytotoxic effects which appear soon after spraying, are always noticed, but there are other sequels. Side effects of pesticides on crop plants are here defined as phenomena which manifest themselves on the crop plant only some time after application or are not directly obvious, arise from the interaction of different pesticides or are effects on diseases and pests of the crop plant caused by pesticide induced changes of the plant. Where these side effects are biologically significant, they can be harmful or favourable to the crop; they merit in either case the attentions of the research worker concerned with the control of weeds and pest and the manufacturer of the pesticide.

In the practice of crop protection these side effects have presented themselves occasionally in a catastrophic way and are often alarming in their economic consequences.

The side effects of pesticides on the plant can be grouped as:-

1) delayed or hidden phytotoxic effects on the crop plant itself.

2) effects on the disease of the crop plant through pesticide-induced changes in the plant.

3) effects on the insect pests of the crop plant through pesticide induced changes in the plant.

Dealing first with side effect on the crop plant itself, we can organise the considerable literature into:-

1.a morphogenetic effects of pesticides, chiefly herbicides.

1.b abscission responses to pesticides.

1.c effects of pesticides on the chemical composition and the metabolism of the crop plant.

1.d the stimulating effect of low doses of pesticides on plant growth.

1.a Morphogenetic Effects:

These are side effects which alter the shape of the crop plants and its organs. As far as herbicides are concerned there is a good review by Gorter and van der Zweep(1964).

The shape of a plant is determined by events in the meristematic tissues (the growing points) and it is not surprising that systemic herbicides and insecticides which penetrate or are taken up into the plant, can affect the thin walled cells of the meristematic tissues, which are made up of cells which are capable of multiplying and differentiating and which during differentiation are in an active state of division.

Out of the numerous morphogenetic side effects only a few examples must suffice.

The effect of auxin herbicide on the growing point

The auxin damage on the ears of cereals are well known. Cereals are very susceptible in the early growth stages and a close correlation has been established between the degree of abnormality observed in leaf and inflorescence development and the stage of development of the growing point at the time of applications of the herbicide. Damage during spikelet initiations and its early development of cereals and pasture grasses result in serious damage. The phenomenon has been well investigated and is a delayed direct effect of the herbicide, which can be easily avoided. In this category belongs also the dalapon damage to tulips, which manifests itself in the following year as deformed inflorescence (Wood 1959). When dalapon was sprayed on cotton at a time of heavy boll development it had little effect, but delayed seed germination and caused seed abnormalities (Foy and Miller 1963).

Auxin herbicide influence the meristematic leaf primordia already present on the growing point, but also leaf primordia laid down after treatment. For cotton this was shown by Gifford (1953) and McIlrath and Ergle (1953), who found that the 2,4-D side effects persisted for periods in excess of six months.

Roark et al (1963 and 1964) who found after the applications of methylparathion and parathion an increase of the number of vegetative buds on cotton and an inhibition of fruiting branches so that the ratio of vegetative buds to fruiting buds was increased by methyl-parathion, and resulting in later-set fruiting buds as compared with the untreated plants.

DDT induces greater foliage development and formation of more vegetative growth (Chapman and Allen 1949). Allen and Cassida (1951) deduced that DDT had an auxin like effect. Cotton, in the Sudan, sprayed fortnightly with low concentrations of DDT (0.2%) produced a higher number of flowers than the unsprayed control plants, as described by Goodman (1955).

The abnormalities of flowers produced by pesticides can be of great importance. In the flowering apex the parts of the flower, i.e. the sepals, petals, stamens and carpels arise in this sequence but in quick succession. The way in which a pesticide may interfere with these very complex events in the growing points depends on the way in which the compound reaches the young initials, from outside or after transport through the plant from some other point of entry, i.e. through systemic action. In the latter case the changes in the growing point are usually uniformly distributed, the same irregularities showing up in all organs originating on the same level on the apex.

Another example is the non-opening of cotton bolls which had disastrous effects on the Egyptian cotton crop in the Nile Delta in 1961 (Kamel 1964).

At low and medium volume (16-40 gal/ac) an application of 1.75 Kg/ac carbaryl caused reddish discolouration of the foliage, dry bolls and non-opening of bolls in batches.

Chemical analysis of the plants and soil profiles showed that the protein content of the affected plants was half that of healthy plants and that the affected plants were high in sugar content. Spraying with nitrogen solution to increase the protein content prevented the phytotoxic effects of carbaryl (Hamawi, 1965). Soil profiles revealed that affected plants had grown on saline and alkaline subsoil. After carbaryl treatment the soluble nitrogen is higher by approximately 5% even if no phytotoxic effects are noticed, hence carbaryl accelerates maturity.

In my logarithmic experiments 1000 miles south in the Nile Valley in 1963, applications of above 6 lb/ac of carbaryl induced phenomena similar to the red leaf disease.

Apart from direct influence on the growth and shape of the plant organs, growth regulators and other pesticides, presumably functioning as growth regulators can affect the timing of the physiological process of flowering.

As early as 1936 such effects were demonstrated by soaking oat and wheat seed in IAA and inducing earlier flowering (Choldny 1936). This was also shown for tomatoes (Stier and du Buy 1938).

Low concentrations of NAA and 2,4-D are used commercially to initiate flowering of the pineapple plant. More prolific flowering is often caused by growth-inhibitors, like TIBA (2,3,5-tri-iodo benzoic acid) for instance by treating tomatoes in the cotelydon stage.

On the contrary, many organophosphorus insecticides delay flowering and the maturity of cotton and other plants because the content of ether soluble phosphates is increased which affects the hormone balance. Organophosphorus insecticide sprayed plants are often greener, but the vegetative growth must lose its dominancy for fruits to mature. The delay in maturity of cotton was first noticed by Hacskaylo and Ergle (1955), Hackaylo and Scales (1959), Walker et al (1964). Disulfaton, phorate and dimethoate adversely affected the rate of bloom of cotton in the U.S.A. (Leigh and Walhood, 1960). Dimethoate has been found to delay the flowering and boll formations of the cotton crop in the Sudan, and thus in some years gives rise to a lower grade of cotton (Proctor & Tigani, 1962).

As the early bolls give the higher weight of lint and the growing season can be short in some years, this phenomenon can be of great economic importance. I have in progress experiments on cotton in the Sudan in which the retardations of maturity induced by organophosphorus pesticides is counteracted in the spray programme by carbaryl which accelerates the maturity, and thus brings the plants back to normal maturity dates.

<u>1.b Abscission responses to pesticides</u> are well known and of course exploited by some methods of defoliation. Since

many plants respond to adverse conditions by shedding of all or part of their leaves and fruit, it is not surprising that pesticides frequently accelerate abscission. Although the process of abscission is normally controlled by a balance of growth regulators and ageing factors, it is also affected by other internal and external factors, such as metabolic processes and is apparently dependent on respirations and inhibited by respiratory poisons.

There is a review of abscission responses by herbicides by Addicott and Carns (1964). As we have in this country an apple variety in Essex which responds to many pesticidal sprays by abscission of fruits and leaves, I will not deal further with this side effect of pesticides because it is so well known.

1.c. Effects of pesticides on the chemical composition of the plant and its metabolism

There are a number of reviews on this side effect as far as herbicides are concerned (Wain and Whightman 1956), (Woodford et al 1958), (Wort 1961), and a short review on side effects of insecticides (Ripper and George 1965).

Increases of up to 80% in the CO_2 evolutions or oxygen consumption following the application of 2,4-D have been measured, while high concentrations of the herbicide may depress the rate of respiration.

2,4-dinitrophenol has been shown to act like 2,4-D on the respiration of intact tissue. Concentrations of 2,4-D and 2,4-DNP inhibited the incorporation of radioactive P^{32} into nucleotides and stimulated the uptake of oxygen probably uncoupling the phosphorylations.

Turning to insecticides, Bogdanov (1964) showed that parathion and morphotion cause considerable changes in transpiration and respiration of sprayed bean plants.

The wax exuded onto the leaves and stems of peas and brassicas is strikingly reduced after spraying with TCA (Dewey et al 1962) as is the case with dalapon and other chlorinated aliphatic acids. Juniper (1959) has studied this phenomenon under the electron microscope in 1957. Thus the retention and the uptake of other pesticides is affected by the previous treatment with chlorinated aliphatic acids.

A further side effect of this group of herbicides is the reduction in winter-hardiness. After TCA and dalapon treatment a great number of crop plants (cereals, lucerne and fruit trees) show much less resistance to frost.

Prior or simultaneous applications of certain pesticides lead to serious damage when the herbicide propanil is applied, without it yet being clear that morphogenetic effects are involved (Unger et al, 1964) (McRae et al, 1964). But as there is a certain analogue in pathology, it might be mentioned here, that after the application of the insecticidal carbamate carbaryl or the organophosphorus insecticides azinophos - methyl or disulfaton propanil seriously damages potatoes, tomatoes and rice. In the absence of other agricultural chemicals propanil is safe on a number of potato, tomato and rice varieties on which it has been tried. It is also safe if applied with or after DDT and maneb. The damage after carbaryl is increased by higher temperature (Unger et al, 1964) McRae et al (1964) suggest that the interaction by certain insecticides eliminates or inhibits hydrolysis of the propanil by the crop plant, on which the selectivity of this herbicide is based.

Nitrogen metabolism is profoundly affected by herbicides and insecticides.

In a large number of instances the application of 2,4-D to a plant brings about an increase in protein and free amino acids in the stem and simultaneous decrease of these compounds in the leaves and roots (Freiberg and Clarke, 1955) (Yazuda et al, 1956). The character of the proteins is altered by a change in their composition expressed in terms of percentage of the amino acids (Sell et al, 1949).

While careful studies have shown that the nitrogen content of the grain of barley and wheat is not affected by MCPA and 2,4-D spraying, no such work seems to be available for grasses, where the nitrogen content matters greatly to the dairy farmer and the crop is harvested much sooner after spraying than cereals.

The application of $\frac{1}{2}$ lb/ac of 2,4-D to potatoes reduced the content of eleven amino acids in the potato tubers but increased their content of free glutamic acid, while the protein content was increased by 25% or more. Wort (1964) also reports that yearly analyses of potato tubers after foliar applications of 2,4-D mineral dusts have shown a rather consistent reduction in amino acids, and of glucose and fructose in the tubers of 2,4-D mineral-treated potato plants; sucrose is unaffected or increased; the RNA content is increased, while DNA decreases. As a high content of glucose and fructose in potato tubers results in darkening of chips or crisps during deep-fat frying, a smaller content of glucose and fructose is desirable for potatoes which are processed into potato crisps.

The nitrogen content of plants treated with the herbicidal and insecticidal carbamates is also increased over that of controls (Freed, 1953), and to a much lesser degree this is also true of DDT.

Simazine has a direct effect on nitrogen metabolism, perhaps by increasing the plant's ability to take nitrogen up from the soil, as Ries et al (1963) has shown. Gast and Grob (1964) discussed the changes in nitrogen metabolism during this Weed Control Conference. Amitrole affects the protein status of treated plants.

Phosphorus metabolism

The ubiquitous role of phosphate and of the phosphorylations in a multitude of metabolic processes such as photosynthesis, nucleotide formation respiration and generation of high energy bonds, protein synthesis and carbohydrate interconversion, makes it of importance that some herbicide treatments alter the P intake and metabolism of sprayed crop plants in most cases. The picture is complex and too involved to be discussed here in detail.

Enzymes

The dependance of metabolic processes on individual enzymes suggests that metabolic responses to pesticides stem from altered enzymatic activity. The effects of herbicides on various enzyme systems have been reviewed by Freed (1953), Freed et al (1961), Weintraub (1953), Woodford et al (1958), and Wort (1961).

From studies with 2,4-D, generally on susceptible plants, we know of the qualitative and quantitative changes in protein and free amino acid following 2,4-D applications which suggest that the herbicide may act directly on the protein portions of an enzyme (Sell et al,1949), (Yazuda et al, 1956). Freed (1953) believes that 2,4-D is absorbed by physical forces on the surface of enzyme protein. Unfortunately very little has been done on the 2,4-D resistant crop plants.

Changes of the protein and the non-protein nitrogen of bean plants after parathion applications were demonstrated by Bogdanov (1964), who also showed great changes in the enzyme and vitamin content of the parathion treated bean plants and seeds.

Buckwheat plants show a higher vitamin C content after treatment with low concentrations of 2,4-D (Wort, 1964).

A chlorophenoxy acetic acid spray (440 ppm) applied to snap beans four days before picking, retarded vitamin C degradation in the detached pods; when picked four days after treatment the pods contained 40% more ascorbic acid than those from untreated plants (Wort, 1964).

Polish scientists according to Wort (1964) hope, by use of chlorinated phenoxy acetic acids, to decrease the poisonous alkali found in white lupins used as cattle food and

Hungarian workers plan to use such formulations in an attempt to increase the stereo - glycoside content of the tomato.

In plants grown for drug extraction there seems to be room for a research programme designed to affect the yield of the desired drug by the judicious use of the side effects of pesticides.

1.d The stimulating effect of low doses of pesticides on plant growth

There are numerous reports of the stimulation of growth by low concentrations of 2,4-D, DNOC (Bruinsma, 1962), and lately of simazine (Gast and Grob, 1964). DNOC treatment increased the leaf blade area, the chlorophyll content of leaves and culms and delayed chlorophyll breakdown at ripening (Bruinsma, 1962). Simazine stimulates the nitrogen metabolism or nitrogen uptake.

2. Effects on diseases of the crop plant, induced through side effects of pesticides on the plant

The effect of pesticides on the composition and the metabolism of crop plants induces in some cases an increased resistance to some diseases; in others it increases the susceptibility to infection.

Limmasett et al (1948) found that dilute solutions of MCPA and 2,4-D inhibit virus multiplications so that the symptoms of virus x disappeared on white barley, tobacco, and virus y was similarly suppressed, and Kutzki and Rowlins (1950) found 1 ppm NAA decreases the virus concentrations by one third in tobacco tissue culture.

Simazine at a rate of 0.33 or 0.5 mg per plant killed tobacco plants infected by A1 strain of the tobacco mosaic virus, while non-virus-infected tobacco plants survived (Ulrychova and Blatny, 1961). Similar studies were carried out in Missouri with cherry root stocks infected with ring spot (Virus G) and prune dwarf (Virus B) singly and in combination. The trees were sprayed with 5 ml of 10,000 ppm atrazine. At the end of one month the initial leaf tissue on all trees was dead, but 75% of the B inoculated and 75% of the virus free trees initiated new growth. All G and G + B infected trees were dead (Millikan and Hemphill, 1964). Sesone killed strawberry plants (Royal Sovereign) infested with strawberry virus.

A deleterious effect of simazine on mosaic infected sugar cane has been reported by Adsour,(1961).

Unfavourable side effects on crop plants i.e. increased susceptibility to fungus diseases have been reported by a number of investigators (Miller, 1956), (Mostafa and Gayed, 1960), (Rademacher, 1958), (Richards, 1949). For example 2,4-dichlorophenoxyethyl sulfate (sesone) can have an unfavourable effect on peanut seedlings infected by root rot (Boyle et al, 1958 and 1962) and effects of 2,4-D on several physiological strains of potato scab organism (*Actinomyces scabes*), were reported (Michaelson et al, 1948). Köhler (1955), and Erickson et al (1958) found effects of 2,4-D on pathogenetic fungi infecting citrus. TCA appeared to render peas more susceptible to downy mildew (Proctor and Armsby, 1958), 2,4-D made wheat more susceptible to take-all (Anonymous, 1961-62). Dinitro herbicides made cereals more susceptible to *Mayeticola avena* (Thellot, 1959), and Grümmer (1963) observed an increased severity of *Bothrytis* on beans after simazine application.

Diquat when applied to water deficient potatoes and onion plants, is translocated to the tubers and onions and causes rots.

Wound Healing

The use of propham as a sprouting inhibitor on potatoes caused widespread outbreaks of tuber infections in the late forties, because propham inhibited the cork layer formations by which the plant seals off infections.

On the positive side Wort (1964) has shown that 2,4-D micro-nutrient combinations which were applied to cut potato tubers initiated a faster and more complete healing of wounds in tubers than on untreated plants.

3. Effects on the infestation of the crop plant by insects and mites induced by side effects of pesticides on the plant

When we discussed the effect of pesticides on the composition of plants, we mentioned abnormalities, for instance increases in nitrogen content of crop plants; relatively small increase in nitrogen content of the crop plant increase infestation by pests (Henneberry and Schriver, 1964), (Joyce, 1961), (Hamawi, 1965).

2,4-D is widely used in Japan to control broad leaved weeds in rice. This however causes an increased attack of the rice stem borer (*Chilo suppressalis*), the larva of a small moth. The growth of the rice borer was much faster in stems of 2,4-D treated rice, because the protein content of the stem of 2,4-D treated plants is 25% higher than of untreated plants (Ishii and Miramo, 1963).

Probably for the same reason 2,4-D increases also the incidence of the sugar cane borer, which develops more rapidly on 2,4-D sprayed sugar cane, (*Diatraea saccharalis*).

When carbamates such as carbaryl or zectran (Proctor 1964) are applied to cotton, outbreaks of the Whitefly (Bemisia tabaci) occur which exceed the untreated population by 2000 or 3000% respectively (Proctor and Tigani, 1962). It is known that a higher nitrogen content in the plant favours the reproduction of Bemisia spp. Carbamates, as we have seen, induce an increase of the nitrogen content in treated plants.

The build-up of spider mite and aphid populations after applications of a number of insecticides has been noted frequently (Hueck et al, 1952), (Hassan et al, 1962), (Ivy and Scales, 1950), (Salem Hassan et al, 1959), (Young and Gaines, 1953), (Löcher, 1958), and was at first attributed to an adverse effect on the predacious mites and other natural enemies of the spider mites and the aphids. While there is ample evidence of the destruction of predators by many of the insecticides in common use today, Hueck et al (1952) have shown as long ago as 1952 that DDT has an effect on the fecundity of the spider mite and it is thought that this effect is via the plant. This has been confirmed by Löcher (1958); it has further been shown that the fecundity of the spider mite Tetranychus telarius is positively correlated with the level of nitrogen supplied to plants and the nitrogen content of the leaves (Henneberry & Schriver, 1964). Against this others have been unable to demonstrate an increase of the fecundity of red spider after DDT treatment (Attiah & Boudreaux, 1964), explaining the red spider outbreaks by removal of natural enemies by the pesticide or by the pesticide causing dispersion indirectly through removal of natural enemies, which in turn allows dense local populations to develop.

This brief review shows that there is need for more work to study all the phytotoxic effects and to expand the investigations to probe for possible side effects of pesticides which do not fall within the definition of phytotoxicity, but nevertheless can have great economic importance.

It would be ideal if standard tests for phytotoxicity and side effects could be agreed for all the major crop plants. This would call for more plant physiological and biochemical work on the important crop plants without and after treatment by a pesticide in order to ascertain, under various environmental conditions and several levels of sorptive capacities of the soil, the quantitative relationship between the amount of the pesticide applied and the side effects, as defined in this paper, particularly the morphogenetic effects, the chemical composition of the treated crop plant and their metabolism, the time of flowering and ripening. Such standard test for each crop would also have to include the determination of the important qualities of the crop plant for which it is grown, degree of susceptibility to pests and plant diseases, and the effect of the pesticide on critical undesirable phenomena to which the plant tends, for instance, susceptibility to frost damage of winter cereals, bolting in sugar beet, non-opening of bolls in cotton etc. An extensive study on these lines would yield enough data to establish quantitative correlations which could be used to exclude application conditions which are dangerous.

The crop losses incurred by the side effects on the crop plants, which can be measured as damage to the grower or claims against the pesticide manufacturer, would seem to justify an investigation by the research stations to develop such standard tests for the important crop plants. New pesticides could then be tested under controlled conditions instead of obtaining knowledge of the unsafe conditions by damage experienced in the field.

The task involved would be formidable, but it follows from this review that there are four types of reward which might justify the expense:-

a) Avoidance of extensive crop damage such as were experienced through outbreaks of pests and plant diseases following pesticide induced side effects and through hidden or delayed direct effect of herbicides such as occurred in England when TBA-MCPA mixtures and dalapon were introduced as weed killers on cereals, cotton etc.

b) Greater confidence in formulating preliminary recommendations for new markets of the pesticide. The budget of agricultural research in developing countries overseas can often not afford erudite investigations; thus side effect of pesticides cause damage, where they can be least afforded.

c) Development of methods to offset the side effects or of antagonists to the side effects.

d) The exploitation of beneficial side effects of pesticides on plant growth, flowering and harvesting time which would benefit agriculture and widen the market for the sale of agricultural chemicals.

But not only research and more information on the effect of pesticides is called for on the crop plant; we should also give thought to a reform of pesticide applications.

I hope this review has also underlined the interdependance of measures for the application of entomology, weed science, mycology, and virology. Is it not high time that we gave thought to training of a new profession of experts in chemical control, to assist the farmer to select the right chemical treatment? Our biological sciences have made too much progress to leave advice on its application to the agricultural merchants or the salesman of the pesticide manufacturer. Our N.A.A.S. specialist officers today have not enough knowledge of the whole field and are narrow specialists confronted with a much wider task.

Let me quote Dr. Warren Shaw, whom many of you remember from the Second British Weed Control Conference in 1954. Dr. Shaw said in his Presidential address to last winter's Weed Conference in Chicago:-

"There is increasing evidence that research on the control of weeds must also consider the interrelation of herbicides and their effects on plant growth when used as soil or as foliage treatments along with insecticides, fungicides, nematocides, and other pesticides. A better understanding on the interacting effects of the multiple use of pesticides on crop growth and soils would insure safer use. For example, the use of certain pre-emergence herbicides is known to predispose plants to increased susceptibility to certain root diseases. Recent information also indicates that the interaction of the uses of pre-emergence herbicides and insecticides and fungicides increases the susceptibility of crop plants to injury. The multiple and interacting effects of pesticides applied to soils on weed and crop seed germination and the establishment and growth of crop plants must be more fully investigated."

It seems to me that we require a syllabus for a new type of applied biologist with a good training in plant physiology, plant biochemistry, and sufficient entomology, virology, plant pathology and weed science, as is required by the type of agriculture which the expert is to serve.

In fact the University College of North Wales has already such a Post Graduate course in Crop Protection, which might have to be further expanded; and in Germany there is an association of "Plant Doctors". To introduce in the training of biologists specialising as experts in chemical control, more plant physiology of crop plants would advance the practice of crop protection and lift it from application by narrow specialists such as entomologists or by laymen into the hands of professional people in a similar way as the treatment of animal diseases has been advanced since the establishment of veterinary schools in the late 18th century and the beginning of the 19th century.

The experts in chemical control might then be on the staff of the N.A.A.S., the pesticide manufacturers and spraying contractors and might even practice in the intensively cultivated areas on their own in private practice.

The nett gain to agriculture and to the crop protection industry arising from such a holistic approach would be great. Thus more consideration could be given to the maximum development of our crop plants; side effects of pesticides on the crop plants of an undesirable type could be reduced to an insignificant level, while desirable side effects could be more fully exploited.

Acknowledgement

The writer is indebted to Dr. E. K. Woodford for his encouragement to write this review, and to Dr. Woodford and Mr. C. Parker for help in collecting some of the relevant references, and for criticism of the manuscript.

References

ADDICOTT, F.T. & CARNS, H.R. (1964) Abscission Responses to Herbicides in Andus, "The Physiology and Biochemistry of Herbicides". Academic Press, London, pp.235-273.

ADSOUR, J. (1961) Deleterious effect of simazine on mosaic-infested sugar cane. J. Agric. Univ. P.R. 45, 191.

ALLEN, T.C. and CASSIDA J.E. (1951) Criteria for evaluating insecticidal toxicity. Aerial growth. J. Econ. Entomol. 44, 737-746.

ANONYMOUS (1961-62) Rep. Rothamstead Exptl. Stat. 1961-62 pp. 296.

ATTIAH, H.H. and BOUDREAUX H.B. (1964) Population Dynamics of spider mites influenced by DDT. J. Econ. Entomol. 57, (1), 53-57.

ATTIAH, H.H. and BOUDREAUX H.B. (1964) Influence of DDT on Egg-laying in spider mites. J. Econ. Entom. 57 (1) 50-53.

BOGDANOV, V. (1964) Investigations on the changes in vitamins and enzymes in bean plants sprayed with some insecticides. Proc. XII. Int. Ent. Congress 1964 (in press).

BOYLE, L.W., HAUSER, E.W., and THOMPSON, J.T. (1958) The combined effect of a herbicide and disease on the emergence of peanut seedlings. Weeds 6 (1), 461-464.

BOYLE, L.W. and HAUSER, E.W. (1962) Response to Sesone and development of Root Rot in peanuts. Weeds 2 (10), 106-111.

BRUINSMA, J. (1962) The effect of 4,6-dinitro-o-cresol (DNOC) on growth, development and yield of winter rye (Secale cereal L.). Weed Res. 2, 73-89.

CHAPMAN, R.K. and ALLEN, T.C. (1949) Stimulation and suppression of some vegetable plants by DDT. J. Econ. Entomol. 41, 616-623.

CHOLDNY, N.G. (1936) C. R. Acad. Sci. URSS (N.S.12), 439-442.

DEWEY, O.R., HARTLEY, G.S., and McLOUGHLIN, J.W.G. (1962) External leaf waxes and their modification by root-treatment of plants with Trichloroacetate. Proc. Roy. Soc (13) 155, 432-450.

ERICKSON, L.C., de WOLFE, T.A., and BRANNEMAN, B.L. (1958) Growth of some citrus-fruit pathogens as affected by 2,4-D and 2,4,5-T. Bot. Gaz. 120 (1) 31-36.

FOY, C.L., and MILLER J.H. (1963) Influence of dalapon on maturity, yield and seed and fibre properties of cotton. Weeds 11 (1) 37.

FREED, V.H. (1953) Mode of action other than aryl oxyalkyl acids. J. Agric. Food. Chems. 1 (1), 47-51.

FREED, V.H., REITHEL, F.J., and REMMERT, L.F. (1961) In "Plant Growth Regulators" pp.289-368. Iowa State Univ. Press Ames.

FREIBERG, S.R., and CLARKE K.E. (1955) Changes in nitrogen fractions and proteolytic enzymes of soybean plants treated with 2,4-Dichloro-phenoxyacetic acid. Plant Physiol. 30, 39-46.

GAST, A., and GROB, J. (1964) Triazines in top fruit and viticulture. 7th Brit. Weed Control Conf. 1, 217-226.

GIFFORD, E.M. (1953) Effect of 2,4-D upon the development of the cotton leaf. Hilgardia 21 (18), 607-644.

GOODMAN, A. (1955) Apparent stimulation of the growth of X17304 cotton by an insecticide. Emp. Cotton Grow. Rev. 32, 93-101.

GORTER, C.J. and VAN DER ZWEEP, W. (1964) Morphogenetic effects of herbicides. In Andus, "The Physiology and Biochemistry of Herbicides" Academic Press, London, 235-273.

GRÜMMER, G. (1963) [Increased severity of Botrytis attack on Vicia faba after herbicidal treatment]. Naturwissenschaften 50 ( ), 360-361.

HACSKAYLO, J. and ERGLE, D.R. (1955) Compositional and physiological responses of the cotton plant to the systemic insecticides schradan and demeton. Texas Agric. Exp. Stat. Bull. 821.

HACSKAYLO, J. and SCALES, A.L. (1959) Some effects on Guthion alone and in combination with DDT and of dieldrin -DDT mixture on growth and fruiting of cotton plant. J. Econ. Ent. 52 396-398.

HAMAWI, H.D. (1965) The red leaf disease on cotton. Bull. Min. Agric. (U.A.R.) in press.

HASSAN, A.G., HASSANEIN, M.H., and KAMEL, A.A.M. (1962) Studies on the build-up of red spider mite and aphid populations after the application of certain insecticides on cotton. Bull. Soc. Entom. Egypt. 46, 23-29.

HENNEBERRY, T.J. and SCHRIVER, D. (1964) Two-spotted spider mite feeding in bean leaf tissue of plants supplied various levens of nitrogen. J. Econ. Entomol. 57 (3) 377-379.

HUECK, H.J., KUENEN, D.J. den BOER, P.J., and JAEGER-DRAAFSEL, E. (1952) The increase of egg production of the fruit tree red spider mite (Metatetranychus ulmi Koch) under the influence of DDT. Physiol. Comp. Ecol. 2, 371-377 .

ISHII, S., and MIRAMO, C. (1963) Entomologia experimentalis and applicata. 6, 251.

IVY, E.E. and SCALES A.L. (1950) Dieldrin for cotton insect control. J. Econ. Entomol. 43, 590-592.

JOYCE, R.J.V. (1961) Some factors affecting numbers of Empoasca lybica (de Berge) (Homoptera: Cicadellidae) infesting cotton in the Gezira. Bull. Ent. Res. 52 (1) 191-232.

JUNIPER, B.E. (1959) The effect of pre-emergent treatment of peas with trichloroacetic acid on the submicroscopic structure of the leaf surface. New Phytol. 58, 1-4.

KAMEL, A.A. (1964) Personal communications.

KÖHLER, E. (1955) [The relationship between the treatment of plants with growth regulating herbicides and infection by pathogenic fungi] . Diss.Landwirtschaftliche Hochschule, Hohenheim, pp.94.

KUTZKI, R.J., and ROWLINS, T.E. (1950) J. Bact. 60, 763-768.

LEIGH, T.F., and WALHOOD, V.T. (1960) Effects of the systemic pesticides studied in field tests. California. Agric. 14, 10.

LIMMASETT, P., LEVIEIL, F., and SECHET, M. (1948) Influence d'une phytohormone de synthèse sur le dévelopment des virus x and y de la pomme de terre chez le tabac. C.R. Acad. Sci. Paris, 227, 643-695.

LÖCHER, F.J. (1958) [The effect of DDT on several red spiders (Acari Tetronychidae)] . Z. angew. Zool. 45, 201-248.

McILRATH, W.J., and ERGLE, D.R. (1953) Further evidence of the 2,4-D stimulus in cotton. Plant Phys. 28 (4), 693-702.

McRAE, D.H., YIH, R.Y., and WILSON, H.F. (1964) A biochemical mechanism for the selective action of amilides. Abstracts 1964 Meeting of the Weed Society of America, Chicago, Illinois, Feb. 10-13 1964 pp.87. Rohm & Haas Co., Philadelphia, P.A.

MICHAELSON, M.E., SCHAAL, L.A. and FULTS, J.L. (1948) Some effects of 2,4-dichlorophenoxy acetic acid, its salts and esters on several physiologic strains of the potato scab organism, Actinomyces scabies (Thaxt) Guss. Proc. Soil Sci. Soc. Amer. 13, 267-270.

MILLER, P.R. (1956) Effects of certain herbicides on incidence of plant pathogens. Agric. Chemic. 11 (6), 67-68, 135 and 137.

MILLIKAN, D.F., and HEMPHILL, D.D. (1964) Preliminary observations on the synergy between latent virus infection and atrizine in cherry root stocks.

MOSTAFA, M.A.K., and GAYED, S.K. (1960) A comparative study of the effect of cotton dust and 2,4-D on three pathogenic fungi. Mycopath. et Mycol. Appl. 13, 198-214.

PROCTOR, J.H., and ARMSBY, W.A. (1958) Experiments on the control of wild oats in peas. Progress report 1957/58. Proc. 4th Brit. Weed Control Conf. pp.12.

PROCTOR, J.H. (1964) Personal communication.

PROCTOR, J.H. and TIGANI el Amin. (1962) Spraying experiments 1961/62. Ann. Report, Gezira Agric. Res. Stat. 1961/62.

RADEMACHER, B. (1958) Some examples of chain effects after applying herbicides. Nachr. Bl. dtsch. Pfl. Sch. Dienst Braunschweig, 11, 155-156.

RANNEY, C.D. (1964) A deleterious interaction between a fungicide and systemic insecticides on cotton. Pla. Dis. Reptr. 48, 241-245.

RICHARDS, R.R. (1949) Responses of representative fungi to certain growth regulating substances. Bot. Gaz. 110, 523-550.

RIES, S.K. et al (1963) The apparent influence of simazine in nitrogen nutrition of peach and apple trees. Weeds 11, 270-273.

RIPPER, W.E. and GEORGE, L. (1965) Cotton Pests of the Sudan. Blackwell Scientific Public., Oxford.

ROARK, B., PFRIMMER, T.R., and MERKL, M.E. (1963) Effects of some formulations of methyl parathion, toxaphene and DDT on the cotton plant. Crop Science 3, 338-341.

ROARK et al (1964) Effects of some insecticide formulation on fruiting of the cotton plant. Crop Science 4 (1) 97.

ROBINSON, A.G. (1961) Effects of amitrole, zytron and other herbicides and plant growth regulators on the pea aphid, Acyrtosiphon pisum (Harris) caged on broad bean, Vicia faba L. Canad. J. Pl. Sci. 41 (2), 413-417.

SALEM HASSAN et al (1959) Infestation of cotton with spider mites. Bull. Soc. Entom. Egypt. 43, 357-400.

SELL, H.M., LUECKE, R.W., TAYLOR, B.M., and HAMMER, C.L. (1949) Changes in the chemical composition of the stems of red kidney bean plants treated with 2,4-dichloro-phenoxyacetic acid. Plant Physiol. 24, 295-299.

STIER, H.L., and de BUY, H.G. (1938) The influence of certain phytohormone treatments on the time of flowering and fruit production of tomato plants under field conditions. Proc. Amer. Soc. Hort. Sci. 36, 723-731.

THELLOT, B. (1959) The practice of selective weed control in cereals with dinitro herbicides. Phytoma, 107, 18-23.

ULRYCHOVA, M., and BLATNY, C. (1961) Synergic action of simazine and of plant viruses as a method for the possible detection of viral diseases. Biologia Plantarium (Prague) 3, 122-125.

UNGER, V.H., McRAE, D.H., and WILSON H.F. (1964) Crop tolerance to 3,4-dichloropropionanilide as affected by the concurrent use of other pesticides. Abstracts, 1964 Meeting of the Weed Society of America, Chicago, Illinois, Feb. 10-13 1964 pp.86. Rohm & Haas Co., Philadelphia, Pa.

UPCHURCH, R.P. (1964) The behaviour of herbicides in Soil. Seventh Brit. Weed Control Conf. Vol.3.

WAIN, R.L. and WHIGHTMAN, F. (1956) in "Chemistry and mode of action of plant growth substances." Butterworth Scientific Publications, London.

WALKER, J.K., HACSKAYLO, J., and PIRES, E.G. (1964) Observations on response of greenhouse grown cotton to excessive dosages of phosphate insecticides. J. Econ. Ent. 57 (5), 782-783.

WEINTRAUB, R.L. (1953) 2,4-D mechanisms of action. J. Agric. Food Chem. 1, (3) 250-254.

WOOD, J. (1959) Control of grasses in bulb growing. Proc. Dalapon Symposium p.25.

WOODFORD, E.K., HOLLY, K., and McCREADY, C.C. (1958) Herbicides. Ann. Rev. Pl. Physiol. 9, 311-358.

WORT, D.J. (1961) in "Handbuch der Pflanzen-Physiologie" edited by W. Ruhland Vol.14, pp. 1110-1136. Springer Verlag, Berlin.

WORT, D.J. (1964) Stimulating crop yields, New Scientist 24 (418), 525-527.

WORT, D.J. (1964) Responses of plant to sublethal concentrations of 2,4-D without and with added minerals in "The Physiology and Biochemistry of Herbicides" edited by L.J. Andus, Academic Press 1964.

YAZUDA, A.K., PAYNE, M.G., and FULTS, J.L. (1956) Effect of 2,4-dichlorophenoxyacetic acid and maleic hydrazide on potato proteins as shown by paper Electrophoresis. Nature, Lond. 176, 1029-1030.

YOUNG, M.T. and GAINS, R.C. (1953) Control of insects and spider mites on cotton in 1952. J. Econ. Entom. 46, 693-696.

Discussion on preceding paper

Dr. W.W. Fletcher   In the latter part of his paper Dr. Ripper has mentioned the need for a degree in Applied Biology which would incorporate many of the aspects of the science of pesticides. I am happy to tell him, and this I think may be of interest to many others in the audience, that such a cause is already in being in the University of Strathclyde. The B.Sc. in Applied Biology incorporates such topics as Weeds and Herbicides, Insects and Insecticides, Plant diseases and Fungicides, Parasitology, and Animal Pathology. The cornerstone of the course is Biochemistry. We hope that students graduating from such a course will be of interest to manufacturers of pesticides. At present there are 5 students in the 2nd year and 9 students in the 1st year of the Four Year Course.

OFFICIAL REQUIREMENTS UNDER THE PESTICIDE SAFETY PRECAUTIONS SCHEME

Dr. E.J. Miller
Plant Pathology Laboratory
Harpenden.

10 years ago two important events occurred in the pesticide regulatory field in this country. Both arose from recommendations in the 2nd report of the Zuckerman Working Party on Toxic Chemicals in Agriculture.

The first was the formation of an official committee to advise the Government on all risks arising from the use of poisonous substances in agriculture and foot storage. This Advisory Commitee and its Scientific Subcommittee have been very active in the intervening years. In fact the Advisory Committee celebrated its 10th anniversary earlier this year by publishing a report on a review of certain persistent organochlorine pesticides. This led to the Committee's terms of reference being widened and its title changed so that it is now known as the Advisory Committee on Pesticides and Other Toxic Chemicals. Its Scientific Subcommittee still retains its original title as it is still concerned solely with pesticides used in agriculture and food storage. There is another Subcommittee, which deals with veterinary products and therefore is appropriately known as the Veterinary Subcommittee, and which is of quite recent origin.

The second important event was the initiation of a voluntary scheme whereby industry undertook to inform the Government of its intentions regarding the marketing of new pesticide products and to obtain clearance for their safe use. Both parties met to work out the rules which Industry would follow and the Government would enforce. In this way a scheme was evolved and eventually published in 1957 under the title of the Notification of Pesticides Scheme. Later it was issued as a printed booklet in 1960. Under the scheme Industry was able to exercise a certain amount of discretion as to which products they had to notify. At the same time the onus was upon Industry to provide all the information needed to support their claims for the safe use of their products.

With increased public interest in pesticides, and experience gained over the years, it became clear that the scheme required revision and so in 1961 Industry and Government again met. These consultations took time but eventually a revised version, agreed by both sides, was issued early this year, under the new title of the Pesticides Safety Precautions Scheme.

It differs from its predecessor in a number of ways. Distributors are now expected to notify all new products and uses except for minor changes in formulation such that no change of hazard could reasonably be expected. This almost complete withdrawal of discretion was made at Industry's request. The Scheme now gives a far more detailed description of its purpose and defines more adequately the term "food storage practice". It gives fuller examples of the uses that require notification and advises on how to proceed on "fringe" uses.

The Scheme calls upon distributors to state the name of the active ingredient on the label and has had written into it the procedure, which has been followed from some time, for reviewing chemicals when additional data become available and also the steps to be taken if necessary to withdraw a product from the market.

Finally, as before, it gives industry the necessary assurances that the confidentiality of the information, received in support of a notification, will be respected at all times.

I mentioned earlier that another Subcommittee advises on veterinary matters. This relates to notifications made under the parallel Veterinary Products Safety Precautions Scheme, which was also issued earlier this year.

Having devised a scheme, Industry and Government representatives next jointly drew up a number of guides on the information required in support of notifications and on how to present that information. These were issued as Appendices to the Scheme and the first three appears in the 1960 printed issue. Since then more have been issued and they now total seven.

Arising from requests for detailed guidance on specific points, a number of Working Documents have been prepared, each relating to a Guide or Appendix. Currently there are nine Working Documents issued with the Scheme and others are in the course of preparation particularly those concerning labelling phrases for products used in food storage practice.

The relationship between the Pesticides Safety Precautions Scheme and the Agricultural Chemicals Approval Scheme remains unaltered. Until a product has been cleared for safety under the Pesticides Safety Precautions Scheme it cannot be approved for efficiency under the Agricultural Chemicals Approval Scheme.

To assess fully the hazards likely to arise from the use of a pesticide, it is necessary to know, amongst other things, its inherent toxicity, how it is used, its persistence on a treated foodstuff and its acute and long term effects on wild life.

As experience has grown over the years so has the demand for greater detail in toxicological and residue data, as well as for new types of information such as on persistence and wild life effects.

A combination of two factors, namely the agreement to notify all new pesticides and new uses on foodstuffs, and the undertaking that any official recommendations on safe use will, as far as possible, include guidance on the residue levels likely to occur on foodstuffs following recommended uses, has led to considerably increased demands for residue data.

Later speakers in this session will enlarge on certain of the requirements I have mentioned and give their purpose.

What is the future of the scheme? This question must be in the minds of many of you here today who are aware that, following the publication of the report on a review of the persistent organochlorine pesticides, the Minister for Agriculture, Fisheries and Food requested the Advisory Committee to review the safety arrangements for pesticides used in agriculture and food storage in this country. This review is about to begin and all organisations known or believed to be interested in pesticides in one way or another have been invited to submit their views. This review will take some time to complete. Meanwhile, we shall continue to follow the Pesticides Safety Precautions Scheme.

TOXICOLOGICAL INFORMATION - ITS REQUIREMENT AND PURPOSE IN INDUSTRY

Dr. A.A.B Swan,
I.C.I. Industrial Hygiene Research Laboratory.

Essentially the purpose of toxicological information is no different in industry than anywhere else. The information is necessary to ensure that we know how to handle and apply a chemical at all stages of development without risk to man or beast and that if it does pass beyond the development stage the information enables us to send it out into the world with a set of simple agreed instructions to make it safe to use. The requirement for information in industry depends on the stage of development. As development of any new pesticide proceeds the circle of people and animals at risk steadily widens and we have to make certain that the knowledge of its potentially harmful effects keep pace with this development.

As experience in the use and properties of pesticides has grown, our ideas of what we need to know about their side effects has changed considerably. There is no rigid schedule of investigation that can be followed for every new chemical and this continual change is one of the principal reasons behind the periodic meetings and exchange of views that takes place between the Advisors and several Govt. Depts. responsible for agricultural safety and those responsible for toxicological work in industry. This exchange of views has been an extremely important factor in the effective operation of the Pesticides Safety Scheme.

Initially the information on toxicity needed for the development of a new herbicide is modest enough. We want to know the order of acute oral toxicity in some laboratory mammal and its local effects on the skin and whether it will penetrate and cause general poisoning. Many of the papers presented on new herbicides at this Conference illustrate just this stage of development. We want to know enough to know that the people handling the compound experimentally are not at risk and also to know whether it is worth proceeding with development. A new herbicide with toxic properties of the alkali arsenites for example would have to show some really outstanding technical advantage before any further developments would be considered. In the early stage of development of a new herbicide there is no very sophisticated information on toxicity required. We want to know its acute toxicity, some indication of how well it is absorbed in the gut by comparison of its acute oral toxicity with its toxicity by parental administration, some notion of its pharmacological action if this can be gained by observations of the symptoms produced by large doses, and some indication as to whether it may be cumulative.

When development is proceeding to the field trial stage, then, of course, we need to know how the range of effect may vary from one species to another. Toxicity for birds, and for domestic stock of the kinds likely to come in contact is particularly important, for it does quite often happen that compounds with relatively low toxicity for laboratory animals have a much greater toxicity for the larger domestic animals, and may be as much as 10 - 20 times greater. It is essential to discover this beforehand rather than have it brought to one's notice by a mishap in the field.

If the development has gone to the stage of more extensive field trials, then we have to define the range of pathological effects that a chemical can produce in greater detail, and many specific requirements have been drawn up in the Working Documents of the Pesticides Safety Precautions Scheme. For organo phosphorus compounds, for example, we want to examine for possible neurological damage. We are looking now for effects which may not be lethal but which it is important to know about; cataract production, interference with thyroid function, production of liver hypertrophy, we want to know whether the changes are reversible when we stop giving the compound, what the most sensitive measure of an effect is and the level that can be tolerated without producing any effect at all. We would at this stage investigate the pharmacological effects in the hope of getting some clue to the mode of action and exploring the possibility of treatment for accidental poisoning. We would also study the routes of excretion, to see if the urine for instance is an important route of excretion and if possible to identify a major metabolite. We want to have enough information, in fact, to be able to know whether urine analysis offers a useful means of monitoring exposure. If the uses are such that the substance will not be used on food crops or persist on soil then this range of toxicological information is almost enough: to know the risks of operators, to have some means of monitoring their exposure, to know the order of risk to stock and also to have some indication, as to whether there is a possible risk to wild life, and to what extent there is a need for field experiments, such as Dr. Moore will be discussing. We are then in a position to collect field information from the operators during field trials, to look for skin effects such as sensitisation not suspected from the animal experiments, for nasal or eye irritation from the spray and for indications of absorption which may indicate either unsuitable equipment or unsuitable practices. With this information we can then go with more confidence to wider scale tests.

But other aspects have come more to our attention in recent years, particularly we have been more concerned with the subsequent fate in soil, if the compound is persistent and may be washed out into watercourses or streams there is the question of toxicity to fish. If, in fact, the herbicide, as with diquat has applications in aquatic weed control toxicity to fish is of major importance. There are also effects on the soil fauna and micro flora which we are coming more and more to regard as essential information in the assessment of toxicity. While we are only now really beginning to investigate in detail the consequences of great chemical stability, it is only fair to say that many herbicides have been in widespread and trouble-free use over many years with no more toxicological information than I have already outlined.

The more versatile and useful a herbicide is, the more likely it is to give rise to residues in food. It is then that a whole new vista of work opens, both for the residue analyst and for the pharmacologist. If it is an entirely new chemical type, the question of demonstrating the absence of a carcinogenic action at once arises, and we are fortunate to be able to consult with the acknowledged expert advisers of Govt. on these matters. In the present state of knowledge its really rather an unfortunate situation that the best result to be hoped for from the long and labour consuming experiments necessary to demonstrate lack of carcinogenic action is to be able to say at the end of the time that nothing happened. Both in this field and in the problem of teratogenesis it is to be hoped that ultimately when we have a better understanding of the fundamental processes we shall be able to investigate this whole question of carcenogenic effect and teratogenic action in a more constructive and understanding way.

When a herbicide is present as a residue in food we must have a great deal more detailed information about its metabolism in the animal. We want a more direct measure of its absorption in the gut, a knowledge of its distribution in the body, what metabolites are produced, whether they are more or less toxic than the original chemical, and the routes and time course of excretion as well as the extent of storage and the chemical form in which it is stored. With this information we end up with a better notion of how likely it is for the compound or metabolite to accumulate and whether it becomes more or less toxic as a result of transformations in the body. As a result of knowing the particular enzyme systems involved in metabolism, when these can be identified, it may be possible eventually to make some prediction as to how the presence of one chemical residue may affect the metabolic fate and hence perhaps the toxicity of another different residue present in the diet at the same time. It is becoming apparent that some chemicals have the effect of stimulating the activity of particular enzyme systems dealing with them and this may well facilitate the metabolism of other compounds. It is important to realise that some interactions may result in reducing the toxicity of a second residue present. It is still to be determined, however, whether any such effect can be shown to occur at the levels of dosage that pesticide residues in food would involve. The enhancement of effect produced by some combinations of organo phosphorus compounds occurs only at levels too high to be of practical consequence. It isn't always, in fact, appreciated just how low the residues in food are in relation to the levels causing, or rather the levels not causing effect, when fed continuously in animals. With the dipyridyl herbicides, the maximum residues in potatoes found last season nowhere exceeded 0.02 ppm and if you allow a 70 kg. man to eat a pound of potatoes daily this would amount to about a 12 thousandth of the no effect level fed daily to dogs for four years. This is an outline of the requirements of toxicology in industry. A great deal has been developed through discussion and interchange of ideas with official colleagues but I think its clear that industry is, in fact, continuously and actively investigating and defining the toxicological problems set by new pesticide developments, it is not just being prodded reluctantly on the way but is responsibly and properly dealing with the problems.

TOXICOLOGICAL INFORMATION, ITS REQUIREMENT AND PURPOSE FOR GOVERNMENT

H.B. Stoner
Medical Research Council Toxicology Research Unit
Woodmansterne Road, Carshalton, Surrey

I do not want to add very much to what Dr. Swan has just said. There is very rarely any disagreement between the toxicologists of industry and Government. As he has said, both are aiming at the same thing, namely, the safe use of these compounds in agriculture.

To the toxicologist the herbicides form a very interesting and diverse collection of compounds. Some are very toxic like dinitro-o-cresol, others have a very low acute toxicity. Their activities range over a very wide number of tissues in the body and they may show a number of different pharmacological effects. I think it would be possible for a toxicologist to spend his life studying herbicides without ever getting bored simply because they would lead him into such enormously varied and fascinating areas of toxicology. With dinitro-o-cresol he would be studying the chemical reactions in the mitochondria of the cell, with others he would be studying such phenomena as co-carcinogenesis, and hormonal inter-relationships.

Now from the regulatory point of view, when one deals with herbicides, one must start from the assumption that they are potentially dangerous. The very fact that you use them to kill weeds or destroy haulm indicates that they are active, and usually very active, in at least one biological system. This means that we have to know a good deal about their toxicological properties if we are going to assess the possible hazards to the people who apply them and the people who may consume any residue left on the final crop. The major hazard is always to the user, the man who applies the material and who may come into contact with significant amounts of it. The consumer of the crop as Dr. Swan said, meets very, very tiny amounts of these materials, if any at all. The emphasis which is put on the hazard to these two groups differs a bit from country to country so that we see differences in the practice in different countries. For instance, I think there are differences in outlook and practice between this country and the USA. In this country the hazards to both groups are considered by the same Committee, the Advisory Committee, with its Scientific Sub-Committee. In the USA the hazards to the consumer are considered by the Federal Food and Drug Administration of the Department of Health, Education and Welfare, whereas the hazards to the worker are considered by the U.S. Department of Agriculture and any precautions implemented by State legislatures. This seems to lead to a greater emphasis on consumer hazards. The Americans certainly do not ignor user hazards but it always seems that in America if you can show that there is no residue of the herbicide left in the final product, then a relatively small amount of toxicological research on that compound is required. In this country, I think it is fair to say that the emphasis is put fairly and squarely on user hazards and manufacturers should realise this. To assess the possible user hazards, the hazards to people coming into contact with quite large amounts of the pesticide, we do demand a fairly detailed toxicological investigation of the compound and this, as Dr. Swan has shown, can take you into detailed scientific study of its pharmacological properties. One needs to know a great deal about its effects, not only in the rat, the usual species, but other species, necessary from the 'wild-life' point of view. One needs to know the ease with which this material goes through the skin because that is usually the main portal of entry into the user. One needs to know its effect on the skin and on skin structures, does it cause sensitisation, for instance. Questions may be raised about its possible carcinogenicity and what happens if it is absorbed into the body over long periods and, of course, the question of absorption over long periods becomes particularly important if the herbicide is used in such a way that there is a residue on the crop when it comes to be eaten.

As Dr. Swan indicated, no toxicologist is very satisfied with this long-term feeding to animals as a way of deciding the effect of long-term consumption by human beings. However, until we know a good deal more about the way in which these compounds act we are more or less stuck with these long-term feeding experiments although they are not very satisfactory, either from the point of view of assessing what happens if the material is consumed for long periods, or from the point of view of carcinogenicity testing. This is, of course, a subject which is being considered a good deal in toxicological circles and I think it is hoped that the newly-created British Industrial Biological Research Association will try to find new ways of examining compounds, particularly from the point of view of their long-term effects.

As already mentioned we also want to know a good deal about the metabolism of these compounds, both in animals and in plants. It may be very helpful to know why the compound is a weed-killer. It may be because it interferes with a biochemical reaction in the plant which does not occur in mammals and this is obviously very helpful in assessing the hazards due to the material. But, no matter how much we can find out by animal experimentation in the laboratory, and we do not want to under-estimate the value of this, there comes a time when we have to apply our findings to man, and this is, of course, always a jump. When the material comes to be used, on a large scale, when the people who are starting to use it are just ordinary people, not the more highly trained workmen and spray teams employed by firms, and particularly when it is going into home-garden use, then there is always the possibility that some unexpected property may make its appearance. This should not surprise us too much. We are used to seeing species differences between animals and between plants. Man, after all, is another species so the fact that he occasionally produces species differences should not surprise us; but we must take care about it. For this reason I would make a plea for the gradual introduction of new compounds onto the market. When a new compound is being developed to the point of going out into wide-scale use, I do not think it is a very good plan to introduce it broadcast during the first season. These things want introducing on a small scale with some surveillance of the people using it, in order to be sure that nothing out of the ordinary is happening.

What we are aiming at is the safe use of a potentially valuable material which can increase crop yields and increase the efficiency of agriculture, not only in this country but abroad where pesticides and herbicides are much more important to successful agriculture. I think that by the slow introduction of new chemicals we can avoid disappointment and the possibility of a chemical getting a 'bad name' through being widely distributed and then producing some unexpected effect on man.

WILD LIFE INFORMATION - ITS REQUIREMENT AND PURPOSE

N. Moore
Nature Conservancy, Monkswood Experimental Station
Abbots Ripton, Huntingdon

I should perhaps start by defining wildlife. I take it to include all wild animals; but we are particularly concerned with pollinating insects, predacious insects which eat pest species, with game birds, fish and mammals, and all those economically neutral species which, by reason of their size, are of aesthetic and educational value to the general public. In Britain we are mainly concerned with birds and fish. Increasingly wildlife is thought of in terms of a natural resource which should be used wisely and conserved for posterity, and I think it is fair to say that the obligation to do this is becoming increasingly recognised throughout the world.

The purpose behind the wildlife requirements of the British Pesticides Safety Precautions Scheme is to prevent gross destruction of wildlife and all avoidable damage. The immediate aim is to obtain data which, when other factors on use, persistence, etc. are taken into account can be used as the basis for an assessment of the risks involved. Of course, no amount of testing before clearance can give absolute certainty; this point has already been made clear by previous speakers. We want the best information which it is practicable to obtain. Three types of information can be required. First of all there are the data from testing laboratory animals. In general, we want as much information as possible of the types mentioned by Dr. Swan and Dr. Stoner; tests on acute toxicity on mammals are essential in the case of all pesticides from the human point of view; for all pesticides which are used in the field, data should also be obtained from at least one species of bird, a species of fish and of an insect. It should be noted that there is very considerable variation in response within these taxonomic groups. In general there is less variation within the mammals than in the birds, less within the birds than within the invertebrates. Therefore, the representative value of experimental animals varies between these different groups. When analytical methods allow, indication should be made of the relationship between the residue levels present in bodies and the lethal dose. This information has not always been asked for in the past but I am sure that it will greatly help the assessment of risk if it is done in the future. In other words, chemical analysis should be made of organs of animals used in LD50 tests. If wildlife is likely to be subjected to lengthy exposure to a herbicide or other pesticide in the field, studies on chronic toxicity should be made. In the case of chemicals which are highly persistent and so are likely to become disseminated in the environment and to become re-concentrated in the bodies of animals, much more rigorous testing is required. The testing of persistent chemicals should include studies on sub-lethal effects on reproduction. So far difficulties arising from persistence have all come from the use of insecticides, but it is conceivable that a similar problem could occur with regard to herbicides.

Wild animals do not live in isolation. They exist as members of ecosystems and as links in food chains. Ecosystems and food chains cannot be defined precisely but they are none the less real for that, and it is most important to bear their existence in mind. In other words an ecological approach to the problem is essential. The value of laboratory testing is necessarily limited. (This is even true as regards experimental procedure, for example, pheasants will feed readily on BHC dressed corn in the field but not in the laboratory.) A second type of testing is therefore required to back up the laboratory work. For pesticides of moderate and high toxicity, field tests should be carried out to check up on gross effects unforeseen in the laboratory. As Dr. Miller pointed out, there is a Working Document on this in which we suggest the type of research which should be carried out. The main points are these. It is most important that the field testing area selected should be suitable - that before treatment it has a good bird population, the experimental area should not be less than 20 acres and it should be surrounded by thick hedges which are the main habitat for birds in agricultural land. Then a count is made of the birds before spraying, or other treatment, and at least once afterwards. A rigorous search for corpses is made in the crop of surrounding hedges at different times after spraying, and finally the corpses should be analysed for residues of the chemical used. It is very difficult to do this sort of work on a large enough scale but 20 acres is absolutely minimal and so it can normally only be done on one or two occasions. Therefore this type of work, though important, also has only limited value. For pesticides which are highly toxic, or persistent, or in the case of any chemical about which serious and responsible doubts have been expressed, post-clearance surveys should be carried out. I do very much support Dr. Stoner's remarks on the gradual introduction of chemicals. This certainly applies to wildlife as much as to human beings. By post-clearance work I do not mean the 'no damage has been seen' type of observation, a comment which is sometimes made after a chemical has been used and sometimes means nothing more than that nobody happened to notice a dead bird! We have got to think in terms of systematic searches in sample areas rigorously carried out. The results of field surveys, both pre- and post-clearance, may make it necessary to go back to the laboratory to carry out further laboratory tests.

To conclude, I do not think it is possible to lay down hard and fast rules which can be applied to every case. It is largely a matter of taking a commonsense synthetic view considering the likely hazards resulting from normal use, and then carrying out the necessary tests.

RESIDUE INFORMATION - ITS REQUIREMENT AND PURPOSE

J.A.R. Bates
Ministry of Agriculture, Fisheries and Food, Plant Pathology Laboratory, Harpenden.

Prof. Truhaut at the Vth International Pesticides Congress last year paraphrased Andre Gide a famous French author as follows 'When all seems to have been said it is always useful to repeat it for the benefit of those who have not heard, or for those who, though they have heard, have not understood'. While it is realised that there is little really new to be said on the subject of residues the current interest and concern justifies a re-iteration of some of the important factors involved.

The ever increasing problem of pesticide residues is one of the most disturbing features of present day chemical control of pests and diseases and probably one of the least understood by the public. Basic philosophies change as new information is made available and this is true with residues. The old philosophy that all residues should be unacceptable has been modified, and to-day, in the United Kingdom as in many other countries, we subscribe to the basic philosophy that - "The presence of some pesticide residues in selected foodstuffs is allowed in amounts demonstrated to be no higher than those resulting from 'good agricultural practice', provided that the final amount of residue in the daily food is no greater than the amount accepted as safe for the long term consumption of man". Decision-making in predicting the safety of a residue in a foodstuff is largely a consideration for the pharmacologist. The determination of the size of the residue following good agricultural practice is a question the chemist must resolve from analysis of samples reflecting pesticide usage under representative conditions. The chemist must accept the responsibility not only of developing the compound but also for providing the analytical method whereby traces of the chemical can be measured in a food crop. This is not a simple matter since many analytical procedures commonly used for relatively pure samples are dismal failures when applied to biological materials. But, however accurate the analytical method may be and however conscientious the chemist is, all his time and effort can be wasted unless there is full co-operation between him and all the scientists involved in the crop residue studies. <u>A prime requirement of the analytical data is that they be properly related to both toxicity considerations and to the practical use of the pesticide.</u>

In designing the residues experiment, early consideration must be given to the intended use of the residue data. If the data are to support a notification under the Pesticides Safety Precautions Scheme, results from a number of replicated experiments in several geographical areas are often required and one or more pesticide disappearance curves are needed. Such considerations influence the location and size of the test plots. In addition knowledge of the toxicity of the chemical may have a marked effect on the lower limit of determination required of the analytical method. The limit of determination decides the size of the sample which must be taken from each plot and this in turn determines the size of the experimental plots. Too many residue programmes are the result of a last minute decision to collect samples from plots set up for efficiency trials without giving proper thought to the design needed for a residue programme. This often results in the use of very small plots, insufficient replicates and control samples, etc. and usually leads to residue data that are of little real value. On the other hand, with proper planning, certain economies can be achieved and both residue data and efficiency data obtained from the same plots. When a pesticide disappearance curve is required then it is important that the size of the plot is sufficiently large to allow for taking proper samples at a regular intervals, a factor often overlooked.

Since, in most cases, it is not practical to harvest for analysis all the crop from an experimental plot a sampling method has to be devised. The best approach for any particular experiment can only be determined by someone capable of recognising and interpreting the usefulness of the residue data sought. The field sample must be truly representative of the plots and can be taken randomly, systematically or selectively depending on the circumstances. It must be remembered, however, that the field sample will usually be much too large for a so-called laboratory sample and most of it will be discarded during the normal mixing and quartering procedures used to reduce the field sample to size suitable for storage or direct submission to the laboratory. A further consideration, often overlooked, is the adequate sampling of controls or untreated crops, particularly if the residues in the treated crop are likely to be less than 1 p.p.m.

Careful experimental design and conscientious sampling are of no avail if the sample is allowed to spoil before analysis. Arrangements should be made in advance if the samples have to be stored for any length of time, or, as frequently happens, the sample is transported elsewhere for analysis. In general, if there is any doubt about the storage quality of the crop or loss of residue with time, freezing to -10°C (approximately 0°F) or below and storage in individual containers is a satisfactory way of storing or transporting a sample. It is necessary for the analyst to have full confidence in his colleagues in the field, for his residue data although precisely determined could be quite misleading because of poor experimental design, inadequate field sampling or bad sample storage. As in most analyses, an erroneous result is worse than no result at all.

The residues analyst is working in a relatively new field of chemistry which incorporates features of classical trace analysis in that he is concerned with minute amounts of compounds. In addition, he is quantitatively following these compounds along complex biological pathways in soil, plants and animals. With few exceptions the molecules of interest are organic chemicals, distributed in great dilution throughout biological tissue. Sometimes, there may be only a few microgrammes of the chemical being looked for in a kilogramme of the substrate.

There are two limits to the detection of small quantities of residues in plants -

1. the lower detectability threshold of the chemical itself which is frequently represented by the sensitivity of the instrument used for the final measurement, and

2. the influence of the interfering plant materials the 'plant blank'.

There are cases when the blank is zero, that is either when the method of measurement is specific and there is no background contribution or when any background is compensated for in the method. These cases are, however, usually rarer than some analystswould like to believe.

In the majority of cases there is a 'blank value' to be subtracted from the 'treated sample value' to obtain the residue.

The plant blanks may vary according to the method of analysis and the type of plants and usually range from one to several tenths of a p.p.m. Since residues in crops at harvest are often less than 1 p.p.m. and for herbicides are usually less than 0.1 p.p.m. then analytical values can be the same order as those of the blank. Due to the technical difficulties in residue analysis which is carried out on biological material, the results must be allowed a margin of variation of about ± 20% for values of less than 1 p.p.m. In general, the actual size of the blank is of less importance than its variation. If the blank has a large variability, it is not possible to determine such small amounts in the sample as when the blank is constant. When an apparent amount of impurity is found the probability that this is a real residue obviously increases with the increase in magnitude of the impurity found. For small amounts, say less than the standard deviation of the blank there can be considerable doubt as to whether or not the figure represents a true residue.

Again, since analysis is a tool of science designed to demonstrate the presence of a substance it is impossible, regardless of analytical method, to show the complete absence of a residue. Reporting a 'zero residue' when none can be detected is clearly unjustified. Today's analytical methods may respond consistently to 10 µg of a chemical but tomorrow's improvements may lower this to 1 or 2 µg.

To conclude I would like to emphasise again the need for the full co-operation of all workers involved in residue trials, particularly field staff engaged in design and sampling, so that the residue data really mean something to those who have to interpret these data whether the aim is to extend our knowledge on the mode of action of a chemical or to protect consumers from undesirable residues in foodstuffs.

Safety Forum - Discussion on preceding five papers

DR. W.W. FLETCHER. One topic that has not been covered in this session is the question of herbicides and soil micro-organisms. I would like to comment, if I may, pointing out some of the difficulties involved in a study of this kind. The first and most obvious one is the number of organisms in the soil. The number of species and varieties must run into tens of thousands and looking through the Research Reports of this Conference it looks as if there are as many herbicides as there are micro-organisms. That is probably an exaggeration but when one allies the number of micro-organisms with the number of herbicides, in all their formulations and mixtures, then one realises that there is enough work here to keep a regiment of Rip van Winkles, with Methuselah as technical assistant, working day and night! Add to this the variability in soil type, soil moisture, soil pH, etc., all of which affect the distribution and activities of the micro-organisms, and perhaps more important, the distribution and activity of the herbicide and the problem becomes almost insuperable. Then multiply the whole thing by at least two, for one can look at the effect of the herbicides on the micro-organisms or the effect of the micro-organisms on the herbicides. And yet there are few workers in the United Kingdom looking at the problems involved.

One cannot look into the soil and see what is happening there so the next best thing is to isolate some of the organisms and grow them in petri dishes in the laboratory. Has one chosen the 'right' organisms? I am afraid that very often we select the ones that are most easily grown in nutrient medium and raise them to an importance which may be out of all proportion to their importance or occurrence in the soil. Some time ago I did a survey of the literature on the effect of herbicides on soil micro-organisms and it was obvious that although many workers (particularly in the United States) had looked at a wide spectrum of bacteria and fungi, few had looked at the effect on the nitrifying bacteria, presumably because they are a bit more difficult to grow.

And then one asks the question. Do the results that we get in petri dish culture bear any relationship to what happens in the soil? Can one relate parts per million in agar to pounds per acre in the field? Some of us, including myself, have been brave enough to attempt this and looking back I think that we have often been more brave than scientific. Having said this, however, I think that there is merit in looking at the effect of herbicides on micro-organisms on two counts:-

(1) Such investigations may throw some light on the mode of action of some herbicides. Micro-organisms are easy to work with, they do not take up much space and they multiply rapidly. Bearing in mind that it may be dangerous to relate findings with micro-organisms to what happens in higher plants, may I say that one of our experiments has shown that MCPB is more toxic to micro-organisms than is MCPA and that this may point to MCPB having an inherent toxicity in its own right apart from its β-oxidation to MCPA.

(2) I think that manufacturers have a moral obligation to examine the effects of any given herbicide on soil micro-

organisms before it is put on the market. The great majority of herbicides, at the rates used in agricultural practice, do no permanent harm to the soil micro-flora. This is a tribute to the versatility and adaptability of these organisms, rather than to the foresight of manufacturers. Whether this good luck will continue remains to be seen. We have heard in the past day or two about some pretty potent herbicides. One firm in the south of England has set a good example in this matter by encouraging us to look at the effect of the hydroxybenzonitriles on soil microbes before these herbicides are put on the market. Do the gentlemen on the panel consider that the effect of herbicides on soil micro-organisms is a matter of urgency and importance?

DR. N. MOORE. I am not really competent to answer this question because I am not a microbiologist but I should have thought there is no doubt whatever that the effect of pesticides on micro-organisms ought to be studied, though the question of who should study them is a very difficult one. There is, of course, a certain amount of work being done on this and I should perhaps mention that there is a built-in safety factor here that anybody producing a chemical which greatly reduced the fertility of the land would presumably do himself out of business.

DR. H. MARTIN. My question arises from a statement made by Dr. Miller to the effect that information submitted to the Pesticides Safety Precautions Scheme shall remain confidential at all times. We have seen in the past six years misrepresentation of quasi-scientific evidence made by propagandists and the important significance given to their conclusions by the general public. In no other subject is correct, factual, scientific evidence more important than in this particular field. I therefore hope, Sir, that the Minister will be advised to secure as prompt as possible the publication of the scientific evidence upon which the conclusions of this Committee are based. He should encourage the manufacturers in the case of those products which are cleared to publish, in a scientific manner, the evidence which they submitted and I would go further and say that the evidence upon which the non-clearance is based should likewise be published. I therefore hope, Sir, that I have mis-interpreted the statement that this information will be held confidential at all times.

DR. E.J. MILLER. Perhaps my statement was not clear on this point. We have made a pledge to manufacturers that, if they supply us with information in confidence, we will respect that confidence. This is often a prime requirement for getting information from industry. Nevertheless we have always done our best to persuade those who originate this information to publish it. This is a constant plea on our part, and it is made elsewhere, for there is a vast amount of extremely valuable information, sitting in the files of manufacturing companies in other parts of the world, remaining unpublished. This is understandable because manufacturers carry out a research programme with the end in view of providing the necessary information to satisfy the Authorities that the product can be used safely. To round off that information in a form suitable for publication can often involve a lot more work and industry is hard pressed these days to do so when they have so much work to do on other compounds which they are developing. Whether or not it can be published in rather an incomplete form must remain in the hands of those who produce the information. I agree with Dr. Martin that there is a need for a lot more information, which we know exists, to be published openly. On occasions we ask manufacturers if we can pass their information to other official sources. But at all times we must respect the right of the person who produced the information to publish it in his own way.

MR. H.J. TERRY. I should like to take up a point of Dr. Stoners on the safety to users and operators. We know that the hazard to operators is based largely on experiments on laboratory animals, and on the dermal and oral toxicity of the chemicals in question. I think a lot of us know only too well that the safety precautions which are advised by the Committee for the use of these chemicals in the field are not strictly adhered to and, in fact, a lot of operators, and tractor drivers, must get spray deposits on their face and hands. Is there, in fact, any work being done to determine the levels of actual residues which might fall on operators in practice? This could be considerable in some cases, more especially in fruit spraying. Could anyone say whether such work is being done to determine the actual risk under field conditions?

DR. H.B. STONER. There is a certain amount of work being done on this problem, not only in this country but in others. Most of the work comes from America. We are always hoping, of course, that manufacturers will work on this problem and provide us with more information. Of course when the Ministry makes these regulations it does appreciate this point that not all regulations are strictly observed. There is a small group in this country, based on the Plant Pathology Laboratory, which perhaps Dr. Miller can tell you more about, concerned with this type of work in the field, determining the sort of contamination which occurs when somebody sprays a particular compound.

DR. E.J. MILLER. To supplement Dr. Stoner's reply, we have a small team at the Plant Pathology Laboratory whose task it is to determine the actual hazards faced by an operator when applying pesticides in the field. Over the past year they have been involved with granular formulations containing the more toxic organo phosphorus pesticides. This work has been done in conjunction with the manufacturers of those particular formulations. Their main work is to determine the risks to operators using pesticides scheduled under the Agricultural Poisonous Substances Regulations, to see whether, in fact, the requirements under those Regulations are possibly too onerous or possibly not strict enough. Their findings go to the Official Committee I mentioned and eventually recommendations are made to the Ministry of Agriculture, Fisheries and Food to amend the Regulations. Resulting from the work of this team on granular formulations, changes will be made in the Agricultural Poisonous Substances Regulations fairly soon.

MR. J.G. ELLIOTT. A question for Dr. Miller. Is it now illegal to sell to farmers a pesticide that has not been cleared?

DR. E.J. MILLER. No, Mr. Chairman, what I said was that the relationship between the Safety Scheme and the Scheme for efficiency, that is, the Approval Scheme, remains unaltered. Until a product containing a new chemical has been cleared under Safety Scheme it cannot be approved for efficiency under the Approval Scheme. The sale of the more poisonous pesticides is controlled under the Poisons regulations.

DR. G.W. IVENS. I should like to ask if any estimate can be made of the actual proportion of herbicides on the market which have been cleared to date?

DR. E.J. MILLER. It is a fair question, Mr. Chairman, but I am sorry I do not know the answer.

MINUTES OF THE CONFERENCE DELEGATES' MEETING HELD AT 3.30 P.M. ON THURSDAY, 26TH NOVEMBER, 1964 AT THE METROPOLE HOTEL, BRIGHTON

Present:	Mr. M. N. Gladstone	(Chairman)
	Mr. H. S. Leech	(Treasurer)
	Miss C. Bloemink	(Secretary)

together with about 57 members of the Conference.

Mr. Gladstone expressed apologies for absence on behalf of the President, Sir Harold Sanders, who was unable to be present.

1. MINUTES OF THE DELEGATES' MEETING OF THE 1962 CONFERENCE

The Minutes of the meeting held at Brighton on 8th November, 1962, having been circulated to each Conference member, were taken as read and signed as a true record.

2. MATTERS ARISING FROM THE MINUTES

Timing of Conference

Mr. Gladstone pointed out that although at the meeting of delegates after the 1962 Conference, a Resolution was passed in favour of holding the Conference either during mid-December or January, the Council, in coming to a decision, had not found it possible, owing to the many interests involved, to agree to either of these dates and, as a compromise, the week commencing Monday, 23rd November, 1964 had been the date chosen.

There was now before the meeting a Resolution proposed by Mr. M. Bradford of the N.A.C.A.M. and seconded by Mr. J. S. W. Simonds and five other signatories in accordance with item 13(d) of the Council's Constitution.

This Resolution read as follows:

"(a) The B.W.C.C. should hold its Conference every other year.

(b) The Conference should always commence on the third Monday in November, provided that at least ten days elapse between the last day of the Conference and the beginning of the Smithfield Show"

Speaking in favour of the Resolution, Mr. Leech explained that by always holding the Conference biennially, and always choosing the same week, i.e., starting on the third Monday in November, a pattern would be set which would enable delegates and other organisations to arrange their time-tables accordingly. Moreover this date appeared to offer the best possible compromise between the research and commercial interests.

Although there was general support for holding the Conference biennially, there was considerable discussion on the advantages and disadvantages of the date proposed in the Resolution. It was again pointed out from the research angle that there was great difficulty in submitting papers in time to allow for inclusion of the season-end results. In spite of this Conference having

2. MATTERS ARISING FROM THE MINUTES (Contd.)

Timing of Conference (Contd.)

been held two weeks later, with the present system of producing the research reports and summaries in the form of bound volumes prior to the Conference, papers had to be submitted even earlier than before, thereby making it impossible to maintain the high standard and the very full detail of papers. Some delegates were of the opinion that if the date proposed in the Resolution were to be adopted, some simpler procedure for presentation of the papers would be desirable. Mr. Terry of May & Baker suggested that the research reports and summaries should be summarised beforehand by an expert on the subject in consultation with contributors and a more comprehensive summary presented. Mr. Fryer of the Weed Research Organisation suggested that no research reports and summaries in the form of Proceedings should be made available to delegates before the Conference, authors producing their papers in draft form merely for presentation at the Conference and then afterwards finalising their papers for the purpose of publication. It was generally agreed, however, that the availability of bound copies of the research reports and summaries before the Conference was very much appreciated, particularly by overseas delegates because of language difficulties. One or two delegates again put forward January as a suitable date but, apart from the fact that there were other Conferences held in this month, there would be considerable administrative difficulties and this date was not considered suitable.

Mr. Terry, while supporting the concept of a biennial Conference, then proposed an amendment to Mr. Bradford's Resolution that the date should be mid-December, allowing a full week after the Smithfield Show. Mr. Fletcher of Boots Pure Drug Co. Ltd. supported this amendment. Mr. Billitt, a member of the Council, pointed out, however, that it was worth noting that at this Conference, commencing two weeks later than previous Conferences, there had been a record attendance of nearly 700 delegates and the standard of the papers had been higher than ever before.

The amendment to the Resolution was defeated and the main Resolution was carried.

Mr. Gladstone stated that he would put before Council the views expressed by Conference delegates on this question of timing and Council would take these into consideration when deciding finally on the date of the next Conference.

3. ELECTION OF PRESIDENT

Mr. Gladstone stated that, in accordance with the Council's Constitution, Sir Harold Sanders, the President, retired from office after the Conference. It was with regret that he had to report that Sir Harold was not willing to stand for re-election. In accepting Sir Harold's resignation, Mr. Gladstone expressed the appreciation and thanks of the Council and all Conference delegates for the valuable services Sir Harold Sanders had rendered during his eight years' of office as President of the Council, and these sentiments were endorsed with acclamation. The office of President was therefore open for nomination. Mr. A. W. Billitt proposed the name of Mr. Emrys Jones, Director of the N.A.A.S., who had indicated his willingness to stand, as the

3. ELECTION OF PRESIDENT (Contd.)

new President. The proposal was seconded by Mr. N. E. Williams and, in the absence of any other nominations, Mr. Emrys Jones was declared duly elected.

4. SECRETARY'S REPORT

The Secretary's Report covering the activities of the Council since the 1962 Conference had been circulated to all Conference members and Mr. Gladstone invited comments. There were none, and Mr. Gladstone therefore moved the adoption of the Report, and the proposal was carried unanimously.

5. FUTURE ACTIVITIES OF THE COUNCIL

Mr. Gladstone invited suggestions as to ways in which the Council should direct its future activities.

Mr. R. E. Adams of the Royal Horticultural Society said that in addition to the official Approval List there was a need for a list of herbicides suitable for use by gardeners and growers. The list should state, inter alia, the proprietary name of the herbicide, the active ingredient, by whom manufactured, date of introduction, whether or not approved and whether available in small packs. Mr. Gladstone said the suggestion would be put forward to the Council; he pointed out, however, that all weedkillers sold in the U.K. did, in fact, indicate the active ingredient on the label.

Mr. T. H. E. Kelly, National Association of Groundsmen, asked that the Council should draw attention of manufacturers to the need for clearer instructions for use and safety precautions on the labels of herbicides.

Mr. G. B. Lush of Boots Pure Drug Co. Ltd. emphasised the importance of the application aspect and the need to improve spray machinery design. Mr. K. V. Cramp of the N.A.A.S. endorsed this and considered there was a case for a special session at the next Conference on application techniques of herbicides. This problem was particularly acute in the horticultural field. Mr. Gladstone agreed that progress in products had outstripped progress in methods of their application. The Council was taking steps in an attempt to remedy this need and there had already been some liaison on the question of improving the design of spray machinery. The Council was considering the possibility of setting up a special sub-Committee to consider this very important aspect.

Mr. J. Selby-Link of Link Industries, Melbourne, Australia, suggested that the Council should bring pressure on manufacturers to give a better after sales service particularly with regard to new products. He also asked for an improvement in the size of delegates' badges for the next Conference. He felt it important that not only the delegate's name, but also the organisation he or she represented and the country from which he or she came should be indicated.

Mr. K. W. Hole of Velsicol International Corporation, C.A. referred to the use of mixtures of herbicides and, whilst recognising that these might present some difficulties with regard to approval owing to the very large number of possible mixtures, felt that the Council should recognise that this was one direction in which the herbicide industry was tending.

5. FUTURE ACTIVITIES OF THE COUNCIL (Contd.)

One delegate raised the point that it was very difficult to obtain statistics of the usage of herbicides and he suggested that this information could be obtained by asking farmers to include it in their June returns. Mr. Billitt pointed out, however, that A.B.M.A.C. had already suggested this to the Ministry of Agriculture who had stated that there were practical difficulties in the proposal.

Dr. E. C. S. Little of the Weed Research Organisation stated that the standard of slide-projection at this Conference had not been good. The trouble was largely due to unsuitable slides being used and he suggested that for future Conferences, contributors should be given clear instructions regarding the correct type of slides required. He also raised the point that there had been inadequate time allowed at the Conference for discussion of the papers. A third point raised was consideration at the next Conference of a session on tropical weed control. There was increasing interest in weed control in tropical countries. Mr. K. W. Hole supported this point and also mentioned the importance of aquatic weed control.

Miss H. M. Hughes of the N.A.A.S. emphasised the importance of concurrent sessions and Dr. Little supported the case for more concurrent sessions. There should be more of these at the next Conference and Miss Hughes suggested they should be broken down in such a way that the time could be spent more usefully. She felt that the time for discussion had been inadequate and thought this was partly due to the fact that delegates had not had sufficient time to read their research reports and summaries. There was a need for these to be distributed well in time before the Conference. Another method was to reduce the number of papers by being more selective, putting emphasis on the good papers and sectionalising into smaller groups thus allowing better discussion. Council should have more regard to the type of audience at the Conference. A large number of delegates were technical representatives. Good reviews would be far better than several papers on the same subject; in such reviews chemical details could for example be omitted and the 10% or so who understood the chemical details should have the opportunity for detailed discussion on these while the other 90% could then follow the general background information without great detail.

Dr. B. J. Heywood of May & Baker Ltd. supported the need for better discussion and suggested evening sessions with informal discussion groups. This had in fact been done at a previous Conference and had been very successful.

Dr. H. P. Allen of Plant Protection Ltd., as a Session Organizer at this Conference, said that papers had been selected from a wide area in an effort to provide as much information on a subject as possible. In view of the previous comments, however, he wondered whether too many papers had in fact been packed into a session; there was, perhaps, a case for accepting fewer papers and dealing with subjects in greater depth by means of special Symposia.

Mr. J. G. Elliott of the Weed Research Organisation referred to the excellent review papers given in the plenary sessions and wondered if consideration could be given to handling some of the other sessions in a similar manner. He suggested the appointment of a summariser who would receive research reports, extract from them the salient points and then put these forward for approval by the authors of the papers, say, at a meeting on the Monday night before the Conference; at the relevant session he could then give, say, a thirty-minute review of the literature and information on the subject, the weed situation in a particular crop, the factual results and conclusions as to the adequacy or inadequacy of control and give pointers where further research was needed. This could be followed by a thirty-minute discussion and would, in his opinion, result in a more interesting session. Mr. Lush supported this proposal but emphasised the need for screening the summariser as well as the authors. The summariser should be an expert if this method was to be a success.

Dr. van der Zweep of I.B.S., Wageningen, Holland made a plea, on behalf of overseas delegates, for Council to re-consider its decision not to post Proceedings abroad to reach delegates before the Conference, and emphasised the need for foreign delegates to have an opportunity of going through the papers beforehand particularly in view of their language difficulties. Mr. Gladstone pointed out the difficulties, involving both time and expense but noted the request.

Mr. Gladstone then thanked Conference delegates for their presence and for the various suggestions put forward and said that due note would be taken of the points raised.

There being no further business, Mr. Gladstone then closed the Conference by expressing his thanks and appreciation to all those who had helped to make the Conference such a great success and particularly thanked Dr. Woodford and Dr. Davison of the Programme Committee and all Session Chairmen and Session Organizers who had worked so hard and enthusiastically.

The meeting closed at 4.45 p.m.

SECRETARY'S REPORT

ACTIVITIES OF THE COUNCIL SINCE THE 6TH BRITISH WEED CONTROL CONFERENCE

MEMBERSHIP OF THE COUNCIL

Changes in membership of the Council that have occurred are as follows:

Ministry of Agriculture, Fisheries & Food

Mr. W. S. Rayfield has resigned as headquarters representative.
Mr. D. J. Columbus Jones, Mr. C. V. Dadd and Mr. J. S. Rhodes have resigned as N.A.A.S. representatives. Mr. Rayfield has not been replaced and the Ministry have nominated 2 N.A.A.S. representatives instead of the 3 allowed for in the Council's Constitution - Mr. S. A. Evans and Mr. O. W. Shill (Horticultural). Due to the death of Mr. Shill, however, the Ministry nominated Mr. J. Rhodes to resume temporary N.A.A.S. membership of the Council. Mr. R. Clements was subsequently nominated as the official N.A.A.S. (Horticultural) representative and Mr. Rhodes resigned his temporary membership.

It was with deep regret that we heard of the death of Dr. E. Holmes

Royal Agricultural Society of England

The R.A.S.E. accepted Council's invitation to become a member organisation and Mr. C. V. Dadd, their Secretary and Technical Director, has been nominated as their representative. The Council's Constitution has been amended accordingly.

National Farmers' Union

Dr. R. E. Slade has resigned as an N.F.U. representative; the N.F.U. have not yet nominated his successor.

Ministry of Agriculture, Northern Ireland

Mr. D. J. Allott has replaced Dr. D. W. Robinson as representative of the Ministry of Agriculture, Northern Ireland.

Agricultural Research Council

Mr. J. D. Fryer and Dr. D. Rudd Jones have replaced Dr. E. K. Woodford and Dr. E. E. Cheesman respectively as the A.R.C. representatives.

The period of co-option of Col. J. F. Cramphorn (N.A.C.A.M.) and Mr. W. F. P. Bishop (N.A.A.C.) as members of the Council in their respective capacities of Chairman and Secretary of the 1962 Conference Organising Committee terminated on 31st December, 1962. Mr. W. F. P. Bishop has agreed to the extension of this period to 31st December, 1964, to cover similar duties as Conference Secretary in connection with the 1964 Weed Control Conference.

Mr. M. N. Gladstone and Miss C. Bloemink have been re-elected as Chairman and Secretary respectively of the Council for a further period of two years. Mr. H. S. Leech has been re-elected as Treasurer of the Council for a further period of two years.

Mr. W. A. Williams, Secretary of A.B.M.A.C., has been in attendance at meetings of the Council during the past two years.

Details are given of the member organisations of the Council, the number of representatives allocated to each organisation according to the Council's Constitution, and the full existing membership of the Council.

The President

The Chairman

The Treasurer

	Representatives
N.A.A.S., Ministry of Agriculture, Fisheries & Food	3
Plant Pathology Laboratory, Ministry of Agriculture, Fisheries & Food	1
Department of Agriculture for Scotland	1
Ministry of Agriculture for Northern Ireland	1
Agricultural Research Council	2
Department of Technical Co-operation	1
National Farmers' Union	2
Association of Applied Biologists	1
Society of Chemical Industry	1
National Association of Agricultural Contractors	2
Association of British Manufacturers of Agricultural Chemicals	3
National Association of Corn & Agricultural Merchants	1
Royal Agricultural Society of England	1

Existing Membership as at 23rd November, 1964:

President: Sir Harold Sanders
Chairman : Mr. M. N. Gladstone
Treasurer: Mr. H. S. Leech

Members

Mr. D. J. Allott	Ministry of Agriculture for Northern Ireland
Dr. R. de B. Ashworth	M.A.F.F., Plant Pathology Laboratory
Mr. A. W. Billitt	A.B.M.A.C.
Mr. W. F. P. Bishop	N.A.A.C. (co-opted)
Mr. M. S. Bradford	N.A.C.A.M.
Mr. R. Clements	M.A.F.F., N.A.A.S.
Mr. C. V. Dadd	R.A.S.E.
Mr. S. A. Evans	M.A.F.F., N.A.A.S.
Mr. J. D. Fryer	A.R.C.
Mr. D. J. S. Hartt	A.B.M.A.C.
Mr. R. G. Heddle	Department of Agriculture for Scotland
Mr. R. E. Longmate	N.A.A.C.
Mr. H. C. Mason	N.F.U.
Dr. H. Martin	S.C.I.
Mr. H. C. Mellor	A.B.M.A.C.
Mr. F. W. Morris	N.A.A.C.
Mr. D. Rhind	Department of Technical Co-operation

Dr. D. Rudd Jones	A.R.C.
Mr. W. A. Williams	A.B.M.A.C. (co-opted)
Dr. E. K. Woodford	A.A.B
Miss C. Bloemink	Secretary

Full meetings of the Council have been held quarterly and, in addition, the various Committees of the Council appointed to deal with special aspects of the Council's work, have met at intervals during the past two years. Membershipsof these Committees are as follows:

Research and Development Committee

Dr. E. K. Woodford	(Chairman)
Mr. S. A. Evans	(Secretary)
Dr. R. de B. Ashworth	
Mr. M. N. Gladstone	
Mr. R. E. Longmate	
Mr. J. S. W. Simonds	
Dr. R. E. Slade	

Recommendations Committee

Dr. E. K. Woodford	(Chairman)
Mr. S. A. Evans	(Secretary)
Mr. J. D. Fryer	A.R.C. Weed Research Organisation
Mr. D. J. S. Hartt	Association of British Manufacturers of Agricultural Chemicals
Mr. D. S. C. Erskine	Department of Agriculture for Scotland
Mr. J. R. Aldhous	Forestry Commission
Mr. J. V. Spalding	M.A.F.F. Drainage Department
Mr. R. G. Hughes	M.A.F.F. National Agricultural Advisory Service
Dr. R. de B. Ashworth	M.A.F.F. Plant Pathology Laboratory
Mr. D. J. Allott	Ministry of Agriculture for Northern Ireland
Mr. R. E. Longmate	National Association of Agricultural Contractors
Mr. M. S. Bradford (deputy:Mr.J.S.Simonds)	National Association of Corn & Agricultural Merchants
Dr. P. S. Wellington	National Institute of Agricultural Botany
Mr. R. J. Courshee	National Institute of Agricultural Engineering
Mr. H. A. Roberts	National Vegetable Research Station

Publications Committee

Mr. A. W. Billitt	(Chairman)
Mr. H. S. Leech	(Secretary)
Mr. F. W. Morris	
Dr. E. K. Woodford	

Finance Committee

Mr. F. W. Morris	(Chairman)
Mr. H. S. Leech	(Secretary)
Mr. M. S. Bradford	
Mr. H. C. Mason	

1964 Conference Organising Committee

Mr. F. W. Morris (Chairman)
Mr. W. F. P. Bishop (Secretary)
Mr. A. W. Billitt
Mr. C. V. Dadd
Mr. M. N. Gladstone
Mr. D. J. S. Hartt
Mr. H. S. Leech
Mr. H. C. Mason
Dr. E. K. Woodford

1964 Conference Programme Committee

Dr. E. K. Woodford (Chairman)
Dr. J. G. Davison (Co-ordinating Secretary)
Dr. H. P. Allen
Mr. A. W. Billitt
Mr. G. W. Cussans
Mr. J. D. Fryer
Dr. B. J. Heywood
Mr. R. G. Hughes
Dr. G. W. Ivens
Dr. E. L. Leafe
Mr. H. C. Mason
Mr. C. Parker
Dr. R. K. Pfeiffer
Mr. H. A. Roberts
Mr. J. P. Shildrick

REGISTRATION OF BRITISH WEED CONTROL COUNCIL AS A CHARITY

The British Weed Control Council has been formally registered as a Charity in the Central Register of Charities (9th April, 1964).

FURTHER REPRESENTATION ON THE BRITISH WEED CONTROL COUNCIL OF OTHER INTERESTED ORGANISATIONS

In 1964, an application for Council membership from the Horticultural Trades Association raised the more general issue of whether the Council should not review the whole question of representation so as to include those organisations, not yet members, the nature of whose interests made it desirable for them to become members. Existing member organisations of the Council were therefore invited to give their views and suggestions in this respect.

As a result of the views and suggestions received, certain bodies were listed as potential candidates for Council membership.

Council members agreed, however, that although there were certain interests which were not represented on the Council, it was impossible to admit all the bodies listed. A Sub-Committee was therefore appointed to review the whole subject and make appropriate recommendations for Council's consideration. They have completed their task, and Council in deciding this difficult problem, will take account of the fact that thirteen organisations are at present members of the British Weed Control Council with a total of twenty-two representatives, a number considered by many members to be already large enough for effective working.

CONFERENCES, SYMPOSIA AND TECHNICAL MEETINGS

6th British Weed Control Conference, 1962

The Conference, organised by the British Weed Control Council, took place from 5th to 8th November, 1962, at the Grand Hotel, Brighton. 481 delegates attended, 110 from overseas, and the Conference was generally thought to have been very successful.

1964 Weed Control Conference and Future Conferences

Two considerations emerged from the 1962 Conference Business Meeting. These were:

(a) The question of timing of the next and future Conferences. It was the opinion of many delegates that the date of the Conference was set too early (first week of November) to enable experimental results to be properly analysed and collated for presentation at the Conference, and often important research information regarding certain crops could not be included because of the time factor. It was considered that, as a result, there was a general lowering of the standard of research reports and, therefore, a danger to the national and international reputation of British Weed Control Conferences. It was suggested that the date should be after the end of November, mid-December being the most favourable time.

(b) The question of concurrent sessions. It was considered that, with the increasingly scientific nature and content of the Conferences, there was a need for interested scientists to get detailed discussions on specialised scientific topics, and concurrent sessions on these subjects would enable the appropriate people to attend. Concurrent sessions should therefore be provided for at the next and future Conferences.

The British Weed Control Council have taken into consideration the views expressed by Conference delegates and also their member organisations on these two aspects and, as a compromise, have arranged for the 7th British Weed Control Conference to be held from 23rd to 26th November, 1964, and to give concurrent sessions a trial, these being limited to two afternoon sessions. The Council is not, however, committed in either respect for future Conferences but will be guided by the results of the 1964 Conference and the view of 1964 Conference delegates on these two aspects.

One-day Symposium - "Annual Review of Herbicide Usage"

The Council considered that it would be most valuable to hold an annual one-day Symposium at the end of each season with the object of: (1) exchanging experiences of happenings during the current year relating to the practical use of herbicides, and (2) to indicate practical problems, relating to the efficiency of herbicides, methods of application and side effects, that need attention. Accordingly, a Symposium was arranged for Thursday, 22nd October, 1964, in London at the offices of the National Association of Corn & Agricultural Merchants. Seven organisations participated - A.B.M.A.C., A.C.A.C., N.A.A.C., N.A.A.S., N.A.C.A.M., N.F.U. and W.R.O. The day's discussions were based on a draft paper submitted beforehand by each participating organisation, giving details of their own experiences on this subject.

The Symposium proved both interesting and valuable and will, it is hoped, provide a well-documented report giving a picture of weed control obtained during the season, and drawing attention to any abnormalities or unusual results. This report will be made available to all member organisations of the Council.

European Weed Research Council

Dr. Woodford attended the special two-day meeting of the Council's Committee on "Aquatic Weed Control" in August 1962, which was briefly noted in the previous Secretary's Report. The meeting was interesting and most useful and included a tour of experimental sites in Holland on the second day. A further meeting of this Committee was arranged at La Rochelle, France for 24th/25th September, 1964.

The 4th meeting of the E.W.R.C. took place in Oxford in July 1963, and the 5th in Vollebek, Norway, in July 1964. It is planned to hold the 6th meeting in Paris in December 1965 in conjunction with a Symposium on Herbicides.

The E.W.R.C. maintains contacts with countries in Europe not represented in their organisation and with such other bodies as the W.S.A. and F.A.O.

The Council's journal, "Weed Research", continues to make satisfactory progress. The standard and number of contributions have been maintained at a very high level.

The British Weed Control Council has paid a further £20 against their guarantee of £100 leaving them still liable for a sum of £53.

PUBLICATIONS

Weed Control Handbook 1963 (3rd Edition)

The 3rd edition was published on 28th February, 1963 by Blackwell Scientific Publications Ltd. and is sold at 21/- per copy. It is generally considered to be an excellent publication both from the point of view of content and presentation, the dust jacket designed and executed by May & Baker Ltd. being particularly attractive. To date, approximately 5,000 copies have been sold.

Weed Control Handbook 1965 (4th Edition)

The Council's Recommendations Committee have the work in connection with the fourth edition of the Handbook well in hand. It will again be printed and published by Blackwell Scientific Publications Ltd. The art work for the dust jacket has been undertaken by Plant Protection Ltd. and has been approved and accepted.

Future Editions of Weed Control Handbooks

The Recommendations Committee has a proposal for the next edition of the Handbook to be a two-volume edition. The Committee considers that the Handbook in its present form is getting too large. The idea is, briefly: one volume to contain more general and more or less static information which could be expanded to produce an extremely good and comprehensive text book which could be revised periodically; one volume to contain the recommendations which would be subject to frequent revision.

Council considers the idea basically a sound one, and the Recommendations Committee are outlining their ideas and proposals for a two-volume Handbook in some detail and, in conjunction with the Council's Publications Committee, will study the proposal from the point of view of presentation, saleability, economics. It is hoped that the two Committees will then put forward to Council joint concrete proposals for the production of the Handbook in the new form.

Proceedings of Symposium on "Crop Production in a Weed Free Environment"

These Proceedings were printed and published in July, 1963, by Blackwell Scientific Publications Ltd., and are being sold at 25/- per copy.

To date, approximately 700 copies have been sold.

Proceedings, 6th British Weed Control Conference, 1962

The Proceedings of the 6th British Weed Control Conference held at Brighton in November, 1962 were printed and published by the British Weed Control Council in October, 1963. Delegates to the Conference each received a copy. Copies are still available from the Secretary, British Weed Control Council, 95 Wigmore Street, London, W.1. at a cost of £2-15s. per copy.

Proceedings, 7th British Weed Control Conference, 1964

The Proceedings of the 7th British Weed Control Conference held at Brighton in November, 1964, will be printed and published by a different procedure from that adopted previously. Volume I of the Proceedings will consist of a bound copy of the Research Reports and Summaries presented at the Conference, and will be available to all Conference delegates before the Conference. This will be the larger of the two volumes of Proceedings as it will contain the main body of the material presented. Volume II will be a bound copy consisting of main papers and discussions. Copies of both Volume I and II will be available for subsequent sale to non-delegates.

GENERAL

Hazards in the use of Herbicides

The Council has always had very much before it the problem of keeping the public informed of the real facts of this matter and, towards this end, gave their full support, along with other interested bodies, to the R.A.S.E.'s exhibit at the 1963 Royal Show. This was in the form of a demonstration of the benefits etc. of using agricultural chemicals and of the steps taken to ensure their safe use. It was felt important to put over the story of the value of agricultural chemicals and the tremendous amount of time, effort and research that goes into making them as safe as possible, particularly in view of the late Miss Rachel Carson's book "Silent Spring" which was published in the U.K. in February 1963 and contained a bitter attack on the use of chemicals in agriculture. The exhibit was very well done, but it did not get the public support it deserved.

Joint B.W.C.C./B.I.F.C. Study Group

In late 1963 the British Weed Control Council, in conjunction with the British Insecticide and Fungicide Council, decided to set up a small Joint Study Group to consider how to further education on the important subject of herbicides, insecticides and fungicides. Two members were accordingly nominated by each Council, Mr. C. V. Dadd (Chairman) and Dr. E. K. Woodford being the Council's representatives.

The Joint Study Group's Terms of Reference are to "make recommendations as to the activities which both Councils should be undertaking in the field of education". It is free to seek specialist views and therefore to co-opt as and when necessary.

Two meetings of the Joint Study Group have been held and its recommendations have been submitted to both Councils.

The Group considers there is need for taking vigorous action to induce and encourage farm operators in particular, to be better informed on the general philosophy of crop protection as well as the practical aspects. To this end the Group has recommended to the two Councils three practical courses of action:

1. The preparation and publication of a popular style booklet outlining both the philosophical and practical aspects of crop protection and drawing attention to the possibilities of training courses and the sources of information on such courses.

The idea is to stimulate the demand for formal instruction which it would then be the direct responsibility of the Local Education Authority to provide.

2. Representation by the two Councils to the appropriate education authority for the provision of advanced training courses for the more skilled operator.

3. Provision of sets of colour slides with accompanying tape-recording on various aspects of crop protection to provide material of the right kind for the many organisations who require such information and to whom it is impossible to send a qualified and fully competent speaker.

The British Weed Control Council considers the recommendations of the Joint Study Group both sound and practical. However, it is thought that the first practical step should be co-ordination of action with all the other bodies working on similar lines and towards the same objective, e.g., A.B.M.A.C., Nature Conservancy, Department of Education and Science, leading to co-ordinated implementation of everybody's ideas and efforts in this direction.

Liaison with Machinery Manufacturers

The importance of this subject was high-lighted in the previous Secretary's Report. Since then a new user testing service for farm machinery has been inaugurated by the N.I.A.E. and the Council, through their Research

& Development Committee, asked and received the N.I.A.E.'s assistance in arranging to carry out series testing on ground spraying machines. A number of manufacturers were invited to submit their machines to the very thorough scheme of testing (including nozzle performance), devised by the N.I.A.E. Five manufacturers submitted their machines, which were tested not only in the workshop but also in operation in the field.

The N.I.A.E. have now published their test reports.

It is hoped that this exercise will result in the laying down of a series of minimum standards which will measure the efficiency of a machine, perhaps leading eventually to farmers refusing to buy a machine unless it has a 'cachet' on it - in short an approval scheme for spraying machines which will discourage the marketing of inefficient machinery.

Long Term Effects of Herbicides

With the object of assessing the results of long term herbicide experiments, the A.R.C. Weed Research Organisation in spring, 1963 laid down a long term experiment at Begbroke involving 4 types of herbicides - MCPA (phenoxyacetic acid growth regulators), simazine (triazines), tri-allate (carbamates) and linuron (substituted ureas). The experiment was designed to produce reliable soil and produce samples to allow the study of long, as well as short term, effects of these herbicide treatments on such aspects as (a) persistence of the herbicides and breakdown products in the soil, (b) seasonal breakdown pattern, (c) the performance of soil "conditioned" by regular applications of herbicide to break down the applied herbicide, as well as other agricultural chemicals, in comparison with soil that has not been regularly treated, (d) changes in micro-flora and fauna and in turn changes in measurable soil properties such as pH, organic matter and nutrient status, (e) herbicide residues in crop produce, (f) changes in crop 'quality' and productivity.

Through the Council, the W.R.O. asked for co-operation from member organisations in obtaining the maximum information from the experiment. Assistance was requested, particularly from industry, with routine chemical determinations and analyses of residues in plant material. The response from industry has been good and at least five firms have promised their support in carrying out chemical analysis.

Safe Use of Chemicals in Agriculture

The Council considers that the question of safe use of chemicals from the application aspect e.g. the problem of disposal of containers etc. has been neglected and that research into agricultural chemicals has gone ahead much faster than the knowledge of their application. This aspect should be given more attention and Council has asked their Research & Development Committee to study the present position and facts. After studying their report and recommendations, Council has in mind the holding of a one-day Conference to highlight the subject.

Survey of Herbicide Practice in Horticulture

Horticultural Officers of the N.A.A.S. carried out a pilot survey of herbicide practice on 52 horticultural holdings in East Kent during the winter of 1962-63. The method was similar to that used in the 1959-60 survey in arable farming districts and the information obtained related to horticultural crops grown during the calendar year 1962. The results briefly are as follows:

1. The holdings which had a large area of horticultural crops made the most use of herbicides.

2. The proportions of the horticultural acreage treated were less on holdings with 20 to 50 acres of horticultural crops than on the smaller or larger holdings. These differences appear to be related to the cropping patterns on holdings of different size.

3. The crops most frequently treated with herbicides were carrots and onions, and bush or cane fruit.

4. The largest treated acreages were under spring cabbage and collards, and under bush and cane fruit.

5. Apart from simazine, dalapon and paraquat used in orchards, pre-emergence herbicides were usually used.

6. Results of herbicide treatment were generally satisfactory.

Varietal Susceptibility of Crop Plants to Herbicides

Following an approach from the N.I.A.B., the Council's Recommendations Committee has undertaken the responsibility of collating and disseminating information received on this subject from the N.I.A.B. and other research organisations and industry.

Weed Society of America - International Affairs Committee

In 1963 the Weed Society of America formed an International Affairs Committee whose objectives basically are to encourage and foster international co-operative effort in the field of weed control. Two of the more important long term objectives of the Committee are:

1. To encourage the formation of scientific weed control organisations in other countries and to aid in whatever way possible in their establishment.

2. To encourage the development of weed surveys throughout the world and to publish the results of such surveys.

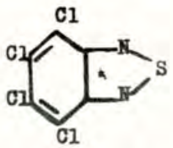
The British Weed Control Council will, through Dr. Woodford who has accepted membership of the International Affairs Committee, be kept informed of what the Weed Society of America are thinking internationally.

PRELIMINARY INVESTIGATIONS INTO THE HERBICIDAL PROPERTIES OF 4,5,7-TRICHLOROBENZTHIADIAZOLE 2,1,3.

J.Daams, H.Koopman, J.E.Dieperink en A.Kars
N.V. Philips-Duphar, Agrobiological Laboratory "Boekesteyn"
's-Graveland (Netherlands).

Summary: This paper reviews some of the herbicidal properties of 4,5,7-trichlorobenzthiadiazole-2,1,3, referred to in this paper as PH 40-21. This compound and its herbicidal properties were discovered by Philips-Duphar. It is active against many germinating weeds and possesses a pronounced selective effect on a number of crops. In field trials the selective properties have been confirmed by pre-emergence application in peas, wheat, barley, maize, cotton, beans, soybeans, tulips, hyacinths, daffodils and gladioli.
A pre-emergence application of 4-6 kgs a.i./ha was usually found to give a sufficient control of annual weeds.

Chemical structure.



4,5,7-trichlorobenzthiadiazole-2,1,3.
(code PH40-21)

Physical and chemical properties.

Molecular formula: $C_6HN_2Cl_3S$

Molecular weight: 239.53

Malting point: 130°C
Physical form: white crystalline
Vapour pressure: 0.16 mm Hg at 100° C.
Volatility: slightly volatile, liable to co-distillation with water.

Solubility in water

Table 1

	Temperature (centigrade)		
	10	20	30
ppm	1.5	2.5	4.3

Solubility in other solvents.
Slightly soluble in organic solvents most commonly used in pesticidal preparations (less than 5%).

Formulation.
For all field trials a 50% wettable powder formulation was used.

Toxicology
LD 50 orally for rats: 1500 mg/kg
" " " mice: 1500 mg/kg

Ld 50 intraperitoneally for rats: 600 mg/kg
" mice: 900 mg/kg

Biological properties.

Mode of action.

4,5,7-trichlorobenzthiadiazole-2,1,3 is mainly absorbed through the roots and by seeds. T a slight extent it is also taken up by leaves and stems, partly by absorption from the vapour phase. It is active against germinating weeds and young seedlings. Susceptibility of seedlings decreases strongly with increasing age. In most cases weeds are susceptible to practical rates of applications until the appearance of the first true leaves. Some exceptions have, however, been observed.
High dosages on susceptible plants produce a general growth inhibition, accompanied by browning and necrotic effects on young leaves and vegetation points. Swelling of meristematic tissues has also been observed.
In some cases the phytotoxic effects are remarkably similar to those caused by dichlobenil.

Range of action.

From the results of a number of greenhouse experiments the following lists of responses of crops (table 2) and weeds (table 3) after pre-emergence application has been compiled.

Table 2

kg/ha	1.5	3	6
Maize	T	T	T
Wheat	T	T	T
Barley	T	T	T
Oats	S	S	S
Rice	T	T	T
Peas	T	T	T
Beans	T	T	T
Soybeans	T	T	T
Potato	T	T	S
Sunflower	T	T	S
Cucumber	T	T	S
Groundnuts	T	T	T
Cotton	T	T	T

Response of crops to pre-emergence application of PH 40-21. Greenhouse experiments in sandy soil. T = tolerant. S = susceptible.

Table 3

	1.5	3	6
Avena fatua	R	S	S
Poa annua	S	S	S
Echinochloa crus-galli	R	R	S
Alopecurus myosuroides	S	S	S
Capsella bursa pastoris	S	S	S
Chenopodium album	S	S	S
Amaranthus retroflexus	S	S	S
Lamium purpureum	S	S	S
Galium aparine	S	S	S
Polygonum aviculare	S	S	S
Polygonum convolvulus	S	S	S
Senecio vulgaris	S	S	S
Sinapis arvensis	S	S	S
Stellaria media	S	S	S
Urtica urens	S	S	S
Veronica arvensis	S	S	S

Response of weeds to pre-emergence application of PH 40-21.
Pot trials in sandy soils. R = resistent. S = susceptible (100% control).

<u>Influence of soil types.</u>

In pot trials, the influence of three types of soil on the effect of PH 40-21 was investigated. The types chosen were a sandy soil. (4% org. matter), a clay soil and pot soil (22% organic matter). Sowing depth 2 cm. Pre-emergence application immediately after sowing. In this trial (3 replications) 2 weeks after emergence the plants were cut and weighed. The results in table 4 are expressed in percentage weight of treated, compared to untreated. Dosage rates 4 and 8 kg/ha.

Table 1

	Sandy soil		Clay soil		Pot soil	
	4	8	4	8	4	8
Maize	100	25	90	86	91	81
Rice	101	75	80	98	98	110
Broad beans	97	85	95	82	89	87
Chickweed	0	0	0	0	20	0
Annual blue-grass	0	0	0	0	5	0

The compound was applied in an acetonic solution.

The compound was applied in an acetonic solution

Persistence in the soil.

The persistence of PH 40-21 in soil was investigated on a sandy soil (3.5% organic matter content). Rates of application: 3-6-12 kg/a.i./ha Garden cress (Lepidum sativum) was sown, 2 days, 1 week, 3 weeks and 2 months after treatment. After 1 month the growth of garden cress was evaluated following a numbered scale (0-5) and expressed as percentages of untreated.

Table 5

Treatments	Dosage kg a.i./ha	S=T +2d	S=T + 1 week	S=T + 3 weeks	S=T + 2 months
Untreated	-	100	100	100	100
Surface treatments					
PH 40-21	3	100	90	100	90
"	6	95	90	95	90
"	12	60	90	80	80
Incorporation into the soil					
Untreated	-	100	100	100	100
PH 40-21	3	20	65	100	90
"	6	15	25	75	70
"	12	5	0	5	50

T = treatment
S = sowing

Incorporation into the soil took place by raking immediately after spraying. It can be concluded that in the case of surface treatment PH 40-21 at the dosages of 3 and 6 kg/ha is hardly persistent in the soil. In the case in to the incorporation soil however, the compound shows in the higher dosages a considerable residual action.

Field trials.

In all trials a 50% wettable powder was used. The herbicide was applied by means of a common knapsacksprayer or a logarithmic sprayer. Between 600-1000 liters of spraying liquid was used per hectare. The trials followed a randomized block design with 2-4 replications. The results were evaluated according to a visual assessment scale ranging from 0-to 10 where 10 represents the optimum result from the point of view of the grower. Figures of weed counts were obtained by throwing a frame many times at random. The results of a number of field trials are represented in tables. All dosages are in kilograms of active ingredient per hectare.

Table 6.

Log-trial on spring barley. (Herta) sown on clay soil

kg/ha	Crop Emergence		Crop Stand		Weed Control
	24/4	2/5	2/5	29/5	29/5
0.2	9.0	9.0	9.5	9.0	4.5
0.3	9.0	9.0	9.5	9.0	5.0
0.5	9.0	9.0	9.5	9.0	5.5
0.7	9.0	9.0	9.5	8.5	5.8
1.2	9.0	9.0	9.0	8.2	6.8
1.8	9.0	9.0	9.0	8.2	6.5
2.6	9.0	9.0	8.8	8.0	6.8
3.9	8.0	8.0	8.5	8.2	7.0
5.6	8.0	8.0	8.0	8.2	8.0
7.9	8.0	8.0	7.0	8.0	9.2
11.1	8.0	8.0	6.8	7.8	9.8
15.1	8.0	8.0	6.5	7.5	9.8
19.1	7.0	8.0	6.0	7.0	10.0

Pre-emergence Spraying
Sowing date 9/4-64
Treatment 18/4-64

Type of soil: clay
Weather conditions: weak S.W. wind, heavily clouded,
High rel.humidity
Soil moisture: high
Soil temperature: 13°C.

Table 7

Log-trials on spring barley (Herta)

kg/ha	Abbenes, spring barley						Nwe Krim, spring barley				
	Crop Emergence		Crop Stand		Weed Control		kg/ha	Crop Stand		Weed Control	
	3/5	27/5	3/5	27/5	9/5	27/5		4/6	27/6	4/6	27/6
0.1	10	10	9	10	4	1	0.1	8	7	0	0
0.2	10	10	9	10	4	1.5	0.2	8	7	0	0
0.4	9.8	10	9	10	4.2	2	0.3	8	7	0	0
0.7	9.5	10	9	9.5	4.5	2.5	0.4	8	7.5	0	0
1.1	9.2	10	9	9.5	4.8	3	0.6	8	7.5	0	0
1.7	9	10	9	9	5	3	1.0	7.5	7.0	0	0
2.6	8.8	10	9	9	6	4.5	1.5	7	6.5	0	0.2
3.8	8.5	10	9	9	6.5	6	2.9	6	6.5	1	0.2
5.6	8.2	10	9	8.5	7	7.5	3.3	7.5	7.5	2	1.5
8.2	8	10	8.5	8.5	8	9	4.8	7.5	7.5	5	3
11.5	8	10	8	8.5	9	9.2	6.7	7	7.5	8	4
16.0	7.5	10	8	8	10	9.5	9.2	7.5	7.5	9	5
20.5	7	10	8	8	10	9.8	11.8	7.5	7	9	

Type of soil: humic clay
Date of sowing: 13/4-1963
Date of treatment: 19/4-1963 present
Weather conditions: heavily clouded, weak N.W. wind, high humidity
Temperature: 13°C.
Soil moisture: high soil temp. 14°

Type of soil: peat soil
Date of sowing: 4-4-1963
Date of treatment: 29/4-63 (at emergence)
Weather conditions: heavily clouded, weak S.W. wind, high humidity;
Soil moisture: very high; before and after application rain (6 mm).
Some weed seedlings present

Table 8

Log trial on peas (Rondo)

kg act. ha	Crop Emergence	Crop Stand		Weed Control	
	24/4	29/5	26/6	29/5	26/6
0.2	10	9	9	5	3
0.3	10	8.5	9	4	2
0.5	10	8.5	9	4	3
0.9	10	9	9	5	4
1.4	10	9	9	5.5	5
2.1	10	9	9	6	6
3.1	10	8.5	8	7	6
4.6	10	8.5	8	8	8
6.6	10	8.5	8	9	7
9.4	10	8.5	8	9.5	7
13.2	9.5	8.5	8	9.5	7
18.0	9	8.5	7.5	9.5	9
22.8	9	7.5	7.5	9.8	9

Pre-emergence spraying.
Sowing date: 6-4-1963
Treatment: 9-4-1963
Type of soil: clay

Temp. 16° C, half clouded, weak S.E. wind, low humidity, no rainfall before application, rain during the night after spraying. No weeds

Table 9

Pre-emergent application in peas (Rondo)

Treatments	kg/ha	Crop Stand 20/5	Weed Counts Lam.purp. 15/5	Stell. 15/5	Total
Untreated		7.4	1500	45	1560
Simazin	1	3.6	45	3	52
PH40-21	4.5	6.9	108	4	130
"	4.5 inc.	6.2	36	0	44
"	6	7.4	36	3	47
"	6 inc	6.1	24	1	33
"	8	6.8	26	0	38

Date of sowing: 16-3-1964
" " treatment: 27-3-1964
Spray volume: 600 l/ha
Temperature 8°C.
Soil temperature 6°C.
Type of Soil: River clay
Incorporation by shallow harrowing

Weather conditions: heavily clouded, weak wind
Relative humidity: 60%
Soil humidity: high
After treatment cold and wet weather

Table 10

Pre-emergence application in spring wheat (ores.)

Treat-ments	kg/ha	Crop Emerg.	Crop Stand			Weed Control			Av. fat.	Weed Counts 5/5					Tot.	Yield
		22/4	22/4	5/5	6/7	22/4	5/5	6/7	6/7	P.a.	St.m.	Thl.a	G.a.	Sa		
Untr.	-	9.2	8.9	8.1	8.4	5.5	1.6	2.5	3.0	99	296	64	15	12	1131	11.4
Sima-zin	1	8.9	8.0	6.1	6.9	7.2	9.4	9.4	8.8	23	12	5	5	0	124	5.1
Ph40-21	4.5	8.9	7.8	7.8	7.9	9.7	8.4	8.2	7.4	3	11	27	11	4	86	10.9
"	6	8.5	8.1	7.8	8.5	9.3	8.8	9.0	7.8	2	23	7	1	13	83	10.0
"	8	8.5	7.8	7.2	8.9	9.8	9.2	9.2	7.5	17	17	7	4	6	69	10.9

Date of sowing: 18-3-1964
Date of treatment: 16-4-1964
Type of soil: river clay
Spray volume: 600 l/ha
Weed counts per 4 m²

Weather conditions: partially clouded; moderate S.W.wind, rel.hum.50%
Soil temperature 8.5. Soil humidity 0-5 cm: 13%
Temperature 9°C.
Weeds: P.a. = Polygonum aviculare
S.m. = Stellaria media
Thl.a. = Thlaspi arvensis
G.a. = Galium aparins
S.a. = Sinapis arvensis

Table 11

"At-emergence" application in snap beans.

Treatments	Dosage kg/ha	Crop Stand	Weed Control		Yield in kg
		30/6	30/6	18/8	18/8
Untreated	-	9.0	5.0	6.1	57.2
Simazin	1	6.8	9.1	8.1	52.3
Ph40-21	4	7.3	8.8	7.7	58.8
"	6	6.8	8.7	8.3	57.3
"	8	6.5	9.5	8.3	59.0

Date of sowing: 11-5-1964 Weather conditions: unsettled weather
Date of treatment: 4-6-1964 Temperature 26°C. Much rain after treatment
Type of soil;
The untreated plot was weeded after 30/6. Main weeds: Senecio vulgaris, Solanum nigrum, Chenopodium album, Stellaria media.

Table 12

Pre-emergence application on maize

Treatments	Dos. kg/ha	Crop Emerg.	Crop Stand		Weed Control		Weed Counts 5/6			
		5/6	18/6	23/7	18/6	18/9	Pol. conv.	Vicia sp.	Stell. med.	Chen. alb.
Untreated	–	7.6	6.8	6.7	1.5	2.6	110	6	13	26
PH40-21	1	84	8	6.5	4.2	6	75	8	5	0
"	2	67	7.5	6.5	5.2	7.8	92	6	0	0
"	4	76	7.8	6.6	7	7.8	35	0	0	0

Date of sowing: 5-5-1962
Date of treatment: 10-5-1962, about 2 days before emergence
Type of soil: sandy soil
Weather conditions: settled, moderate W.N.W. wind. Temperature 12-13°C. High relative humidity. Some showers between treatments. Soil temperature 12°C.
Soil moisture: high. Very few weed seedlings were present.

Table 13

Post-planting application on celeriac

Treatment	Dos. kg/ha	Crop Stand 21/8	Weed Control				Total number of Plants	Yield Tuber weight in gr
			10/7	30/7	21/8	3/9	19/7	7/11
untreated	–	7.1	1.3	2.5	6.3	5.0	68	535
propazin	1	7.3	7.7	8.1	8.0	7.7	66	520
PH40-21	3	7.8	6.0	6.5	5.3	6.1	65	545
"	5	7.3	7.5	7.7	7.6	7.7	61	506
"	8	8.0	7.9	8.5	8.0	8.3	64	525

Date of treatment: 4-7-1963, 7 days after planting
Type of soil; clay
Weather conditions: light cloud; weak S.O. wind. Temperature 22°C.
Relative humidity: low. Before and after spraying much rain. Untreated was weeded after 30/7
Main weeds: Stellaria media. Chenopodium album, Polygonum convolvulus. after 30/7 Cirsium arvense.

Discussion.

This paper deals with a restricted number of trials, and though it is not possible to draw definite and detailed conclusions from such relatively limited experimental work, PH 40-21 proved to be a compound capable of giving useful selective weed control in a number of crops. Based on the results of the logarithmic spraying experiments it can be concluded that the phytotoxic effects on the crops increase relatively slowly with increasing dosages, indicating a wide margin of selectivity.

Further work needs to be done to investigate the effects of various environmental factora on the activity of PH40-21 and to obtain more information on the range of weeds controlled.

PH40-21 offers good prospects of effective pre-emergence weed control in a number of agricultural crops and for post-planting application in some horticultural crops.

Supplementary Yield Data

WEED CONTROL AND PLANT POPULATION STUDIES IN POTATOES

Maurice Eddowes

Harper Adams College, Newport, Shropshire

(See Pages 520-523 - Volume 2 of Proceedings)

Final Yield data 1964 - Table 7. Weed Control Experiment

Mean yield of King Edward potatoes in ton per ac and relative yield expressed as per cent of mean

Treatment	Grading > 2 in.	$1\frac{1}{2}$-2 in.	1-$1\frac{1}{2}$ in.	Diseased	Total Tubers
1. Cultivated	15.17(102)	2.67(94)	0.43(96)	0.19	18.46(100)
2. Hand-weeded	15.83(106)	3.16(111)	0.51(113)	0.27	19.80(107)
3. DNBP in oil	15.24(102)	3.04(107)	0.48(107)	0.19	18.96(103)
4. Diquat + Paraquat	14.55(98)	2.88(101)	0.37(82)	0.29	18.11(98)
5. Prometryne + Simazine	14.51(97)	2.60(91)	0.38(84)	0.26	17.76(96)
6. Prometryne	14.91(100)	2.87(101)	0.45(100)	0.30	18.54(100)
7. Ametryne	14.88(100)	2.82(99)	0.41(91)	0.21	18.33(99)
8. Linuron	14.23(95)	2.75(96)	0.48(107)	0.26	17.71(96)
Mean	14.91(100)	2.85(100)	0.45(100)	0.24	18.46(100)
SE	± 0.87(5.8)	±0.18(6.2)	± 0.05(10.0)	± 0.04	± 0.82(4.4)
Signif.	n.s.	n.s.	n.s.	n.s.	n.s.

Differences between treatments were not significant. Hand-weeding resulted in the highest total, and ware yield, and the results suggest that simazine and linuron may have slightly depressed yield.

Data for experiment 1964b - Plant Population Study

Table 8. **Mean yield of King Edward potatoes in ton per ac., and relative yield expressed as per cent of mean.**

Treatment Plant/acre	> 2 in.	Grading 1½-2 in.	1-1½ in.	Diseased	Total Tubers
1. 12,446	16.50(103)	2.67(71)	0.29	0.35	19.86(95)
2. 24,892	15.93(99)	3.98(106)	0.51	0.28	20.73(99)
3. 16,594	19.08(119)	3.86(103)	0.77	0.58	24.35(117)
4. 33,188	15.15(94)	4.35 (116)	0.99	0.35	20.94(100)
5. 24,000	13.78(86)	3.82(102)	0.66	0.40	18.70(90)
Mean	16.09(100)	3.74(100)	0.64	0.39	20.87(100)
S.E.	± 1.03(6.4)	± 0.23(6.1)	± 0.11	± 0.01	± 1.03(4.9)
Sig.	LSD 3.15	0.72	0.33	n.s.	3.16

Unreplicated plots

1a. 8,000	11.12(74)	2.20(90)	0.41	0.23	13.95(74)
2a. 10,668	15.74(104)	1.74(71)	0.23	0.06	17.83(97)
3a. 10,668	16.05(106)	2.36(96)	0.58	0.46	19.49(106)
4a. 14,224	17.49(116)	2.83(115)	0.64	0.35	21.33(116)
5a. 24,000	15.16(100)	3.13(129)	0.41	0.12	18.89(100)
Mean	15.11(100)	2.45(100)	0.45	0.24	18.29(100)

Note 2a = 28 in row width 21 in spacing : 3a = 21 in row 28 in spacing
5a = Beds - 3 rows 14 x 14 in.

The first section of Table 8 shows that treatment 3 (21 in rows by 18 in spacing) gave significantly higher total and ware yield than the other treatments. Results from the replicated and unreplicated series of plots suggest that under conditions of high fertility a population of about 16,000 plants per acre may give the highest saleable yield of King Edwards.

CORRECTIONS TO VOLUMES 1 and 2

VOL.1.

page 158: The drawings of the growth stages of blackgrass are not drawn to the same scale as those for winterwheat on page 159. The drawings for blackgrass should be reduced to 2/3 to be on the same scale.

page 370, line 5: delete "4 lb/ac" insert "2 lb/ac".

VOL.2.

page ix: "The European Weed Research Council - a Progress Report" was presented by Prof. J.M.T. Strykers, State Agricultural University, Ghent, Belgium.

page 441: add footnote "*Patent rights by Farbwerke Hoechst AG."

page 442, line 24: delete "wild mustard" insert "charlock".

page 443, line 2: after Linuron insert "per hectare".
line 16: after kg insert "/ha".

page 445: add:- STRYKERS, J & BRAECKMAN, H.
Ervaringen met chloorphenylmethoxymethylureum verbindingen als selective herbiciden.
Mededel. Landbouwhogeschool Gent 1962, XXVII, 1231-1251.

page 446: Tab.1, - delete "0.5kg/ha" in columns 2 and 3, insert "0.75 kg/ha" and "1.0 kg/ha" respectively.
Galium aparine to read →

0.5 kg/ha		0.75 kg/ha		1.0 kg/ha	
M	L	M	L	M	L
4	4	3-4	3	3	2-3

page 473: 1963 - Aldroughty, the crop was planted on "17 April" not "17 May".

page 580, Figure 2: Owing to the method of reproduction the image of the autoradiograph indicating the presence of 14C in the hemiparisite has not been reproduced and this figure may therefore appear to be at variance with the text. This should only apply to copies of Volume 2 issued before and during the Conference.