PROCEEDINGS OF THE

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FIFTH

BRITISH WEED CONTROL CONFERENCE

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(78178)

NOTE

All doses of herbicides given in the proceedings are in terms of pounds of acid equivalent or pounds of active ingredient per acre, except if stated otherwise.

The following abbreviations have been adopted:

ac	acre(s)
a e	acid equivalent
a i	active ingredient
cm	centimetre(s)
dose	dosage, rate, dosage rate, rate of application, etc.
ft	foot or feet
g	gram(s)
gal	gallon(s)
ha	hectare(s)
in.	inch(es)
kg	kilogram
l	litre(s)
lb	pound(s)
m	metre(s)
ml	millilitre(s)
mph	miles per hour
oz	ounce(s)
ppm	parts per million
psi	pounds per square inch
sq	square
w/w	weight/weight
w/v	weight/volume
v/v	volume/volume
yd	yard
/	per
$>$	greater than
$<$	less than.

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SESSION 1

Chairman: Mr. M. N. Gladstone

THE IMPACT OF HERBICIDES ON CROP HUSBANDRY

THE IMPACT OF HERBICIDES ON CROP HUSBANDRY IN GREAT BRITAIN

H. G. Sanders
President, British Weed Control Council

At the outset I should make it clear that the title of President of the British Weed Control Council is purely honorific - it carries with it no implication that the holder is knowledgeable about weed killers. No doubt, in the U.S.A. things are different and Dr. Buchholtz will be able to speak learnedly on the subject of this Conference, but I am only one of those who strive, with little success, to keep in some sort of touch with the astonishing advances in herbicides which are taking place. These have certainly had a major impact on husbandry already; they are, of course, used very widely and our farmers are prepared, in increasing numbers, to make the radical alterations in their methods which chemical weed control makes possible. In farming, developments are determined by the sordid realities of economics. We have had some twenty years in which maximum production, at any reasonable cost, has been the all-important aim and now we are finding it difficult to concentrate first on low cost, even if it might entail some diminution in output. As things are today, the British farmer has to keep his unit cost down even to maintain his present share in the home market. Herbicides have to pass many tests in regard to safety, selectivity and effectiveness, but they will be judged more and more in the future by their cost in relation to the job they do.

We cannot think of the impact which herbicides, in isolation, have had on traditional farming because there have been concomitant changes and advances. Farming on a fixed rotation, with all that went with it, was clearly the proper course when labour was cheap and abundant and when little was known about the workings of plants and animals and of the ills which beset them; it was a proved system with every air of permanence. But it could not continue at present wage rates, for carrying on as before - save for employing less labour - would have meant yielding the mastery to weeds. Modern herbicides came to the farmer just at the right time, but they are only one of what I might term the triangle of forces acting upon him. The others are mechanisation and accelerated progress in biological knowledge. None would dare to set a limit to what the engineers will do in the future. They have displaced the horse and produced tractors and equipment which will do much that horse-drawn implements could never achieve. We already see the first application of automation to farming, the first steps to push button control. The engineer may even usurp part of the chemist's function in regard to selective weed control by placing the herbicide only on the intended victim rather than spreading it all over the land and on all vegetation growing thereon. The accumulation of knowledge in the biological field proceeds at such a pace that it is getting ever more difficult for a farmer to keep up. It is therefore argued that he must specialise, so that he may be really master of one narrow trade and, incidentally, so that he may equip himself fully for one type of production. Some move in this direction seems inevitable but there is still force in the arguments (and we must not forget the economic ones) used in the past to justify diversification in a farming business; I do not believe that future progress will entirely demolish these arguments. Specialisation versus diversification is, of course, an old contention but it is becoming more intense. It seems to me that the best solution is for the farmer to delegate more of his responsibilities, to get specialist services for what requires detailed specialist knowledge. There are several fields in which he can do this but none is more suitable than that of chemical weed control. By delegation of this nature a farmer can still hope to survive in these modern times and yet avoid monoculture with its threat of disaster sooner or later.

At this Conference we are unlikely to minimise the importance of weeds, but we must remember that cleanliness is only one facet of fertility. We could get the land in such a state that it would not even grow a decent weed. It is a thing with me never to mention the word fertility without immediately raising the subject of drainage for, despite our efforts over the last 20 years, roughly half of our farm land suffers to some degree from inadequate drainage. Correction of soil acidity is so easy for the farmer nowadays that it is not surprising that our record and progress in liming are satisfactory. The three major plant foods are cared for pretty well and the consumption of chemical fertilisers continues to rise; indeed, cases of waste through excessive application are encountered with increasing frequency. Starting with land in good condition it has proved possible to go on for a long time growing grain crops continuously or with occasional one-year breaks disposing of the straw quickly and easily by burning; herbicides control the weeds and chemical fertilisers supply the main plant nutrients. But can such a system be really permanent? None know the answer to this question. Fortunately stubble fires cannot reach roots in the soil so that some contribution is made to the organic matter in the land but this is not enough to prevent a slow fall in humus content. When humus was a major source of plant nutrients any fall in its level was bad but now the fertiliser bag can cover up a considerable drop in organic matter content. There remains, however, the physical effect of humus on soil structure and there is cause for apprehension on that account. Possibly it is no longer true that any fall in humus content of the soil is harmful but there comes a point when it fails as a builder of soil structure. How soon the point is reached and the possibilities of continuing with a system of corn growing thereafter will depend on the soil type. Continuous, or nearly continuous, corn growing may be profitable on some soils for many years but it is a brittle and precarious system. Herbicides have removed one of its limitations and it may be that the chemist will also provide the answer to the limitations hitherto imposed by pests and diseases. Perhaps the plant breeder will do this but breeding for resistance does not seem to be a very satisfactory job; generally it involves a never ending race in which the breeder must always keep one jump ahead of the pathogen. It may be that we shall get some quite new approach to this problem as some of these pathogens do not seem to read the text books - I am thinking of the fungi which cause Take-all and Eyespot in particular. There are so many cases where one or other of these two takes its toll and the farmer carries on with wheat or barley and escapes retribution entirely in the succeeding year; likewise there are cases of severe attack where there has been nothing blameworthy in the previous cropping.

Cultivation experiments are notorious for yielding results which are inconstant, often directly contradictory and generally untrustworthy. They have utterly failed to justify the cherished beliefs of the traditionalist who has been thrown back on his last defence that, anyway, good cultivation is necessary to control weeds. Now that line has gone. Clearly the seed has got to be covered up, if only to protect it from the birds, and clearly it must be in close contact with the soil. Thus some inch or two of tilth on top of the land must be obtained. Is this enough - especially as work with radioisotopes points to the very high contribution to feeding the plant which the surface roots make? Nothing could be more confusing than a study of the literature of deep cultivation. Some people have found great gain from it in early spring working of the land; some have dug down and found much deeper and better developed rooting systems; some have even talked of cleaner land, but in so many cases there has been no yield increment when the crop has been harvested. Nevertheless there have been experiments which showed a worthwhile return from deep cultivation. These successes, if I may so term them, have not been confined to one type of crop or to one sort of land so that one arrives at no useful generalisation. Just twenty five years ago I read a paper to the Farmers Club describing a series of cultivation experiments for which Frank Garner and I were responsible, the burden of my remarks being that so few of these experiments "came off". My erstwhile mentor Mr. Arthur Amos in the following discussion took the line that this was no matter for wonder, since experiments receive more care than is possible under practical farm conditions. His argument was that proper cultivation was the good farmer's insurance against unfavourable conditions, that they ensured a good start to the crop and a tilth in which plant roots could easily proliferate. Other things like available plant food and the weather, might have bigger effects on yield, often blotting out any influence of cultivation. If the seed was strong in germination, if the birds did not get it, if excess water could percolate down the soil profile, if the roots could get down reasonably far without encountering any pan or impenetrable blocks of soil, if there were plenty of plant nutrients in the soil, if there was no serious attack by a pest or disease, if weeds did not compete unduly, if the weather was good - if all these things were right then the cultivation which the ground received did not matter much. But the farmer cannot control all these. Good cultivation can help in some of them and the good start it provides a plant, which may be able to stand up to any of the others which may be adverse. It is noteworthy that advanced farmers untrammelled by tradition - as, for instance, those who concentrate on cereals - do not scamp their cultivations. On the contrary, their powerful tractors work the land thoroughly and at the proper time. A typical procedure with them is to finish combining a field one day, to burn the straw on the following day and to put the plough in on the day after that. With herbicides they can control annual weeds when they come, so there is no need for them to indulge in stubble cleaning, which the best of their fathers did as circumstances allowed; they get the land turned up to the weather months earlier than it could be done in the old days and I would claim that this is cultivation at its best, though the land may only be moved twice or thrice between crops.

Painful experience was the basis on which traditional rotational farming was based. The system was a protection against the ills which may befall a farmer, ensuring a reasonable yield level and, perhaps more important, maintaining the fertility of the land. Some of these ills can now be averted by scientific methods but we ought to remember that a good rotation, apart from its economic advantages, can lessen the incidence of these ills and hence the need for expensive control. Humus may be a low and insufficient provider of N, P and K but it gives a modicum of these and other elements, it favours the efficient application of power to the land, it helps in keeping plants supplied with water and in some cases it checks the onslaught of pathogens. Old time mixed farming gave these benefits at little or no real cost. The time may come when we shall be able to control eelworm chemically; the betting is that treatment will be expensive and it would certainly be better never to have eelworm present in harmful numbers, as can be assured by a proper rotation. I will not pretend that the same is true of weeds but a good cropping sequence can do a bit to keep some of them in check - I will not say all lest I be reminded of the yellow fields we used to see in May. What I am trying to say is that herbicides provide one of the aids which have come to the farmer in recent years. Of course they have had a considerable impact on farming systems but I see little point in using them as a child uses a hammer - to smash something to smithereens. There are enough problems in farming without our creating more just so that we can have the satisfaction of solving them - the solution is generally pretty costly. In the old days we had to try and work with Nature - we could do nothing else. Scientific controls empower us to meet some biological hazards but I cannot think it very sensible to ask for trouble. The impact of herbicides on farming methods has generally been complimentary to established practice. Therein lies their value, not, I suggest, in the building of an agriculture which is artificial in the sense that it disregards what Nature can do herself.

One very real problem that modern methods may not have created but which they have greatly magnified is that of the wild oat. This seems to me a menace to our cereal growing which looms larger every year. We have, of course, had them long enough, especially on certain farms, but in recent years there has been a marked deterioration. In parts of East Anglia the wild oat is rampant and it is spreading to the midlands and the south. Old fashioned good farming used to keep the wild oat in reasonable check but it is no use advocating a return to that, which would take a generation or two to clear up the mess. Already there are herbicides which, with some modification of cropping, will give a practical control and there are rumours of chemicals which will kill them in cereal crops, even, I gather, in some varieties of oats. This will be wonderful but I very much fear the cure will be long and costly. The wild oat's cunning tricks of variable and possibly prolonged delay in germination is going to cause real trouble. Assuming that the chemical gives a 99 per cent kill - and obviously anything less than that is useless - and that spraying is unfailingly followed up by hand roguing, the treatment will have to go on without intermission for ten years at the very least. Even then there may be the odd laggard germinator still capable of starting the curse again. All this is going to cost a lot of money. Sykes at Boxworth is finding that the number of viable seeds goes down very rapidly in the first five or six years of a ley and in a mixed farming system this may easily be the most economic way of reducing an infestation to the point where hand pulling is possible. Here, of course, I shall be accused of a nostalgic backward glance when I ought to be looking forward eagerly to the scientific solution of a scientifically produced problem.

Chemical control of the wild oat will require specificity to a degree we have not dreamt of until very recently. As knowledge of the mode of action of herbicides grows we shall, no doubt, find chemicals that control narrower and narrower ranges of species but I am not sure whether these are what we really want. With insecticides and fungicides high specificity is very desirable because crops do not often suffer simultaneously from serious attacks of several pests or several fungi. For them, spraying is nearly always against one enemy; the narrower the range of the chemical the better because there is danger of killing things that we want to live - in particular the predators of the one we are after. But with weeds it is different. Farmers suffer from a variety of them at the same time and to kill only one or a few gives much better chance for the rest to multiply. The success of MCPA and 2-4.D is largely due to the fact that each has a pretty wide spectrum. We could arrive at the position where we had a whole range of herbicides each deadly to one weed and to nothing else. In practice a farmer would make a survey of his field, decide which weeds were plentiful enough to justify chemical obliteration, and then make up a mixture which would kill all that qualify. In actual fact, some highly competent advisor would have to prescribe and I fear that this really scientific method would cost the earth. My dream of the future is quite different. What we must get is a pair of chemicals which between them will do the lot. Each must, of course, be completely safe in use, non-persistent in the soil, non-corrosive and very cheap to make. One or other of them must be completely effective (that is, give 100 per cent kill) against every known weed and every crop we grow must be resistant to one of the pair. When we reach that point I shall cease to bleat about other methods of weed control and, indeed, I think the B.W.C.C. may then cease to function.

All of us at this Conference realise that the chemist has made a great and opportune contribution to efficient agriculture. We know also something of the care taken in testing new chemicals before they get into general use and we should agree that, by and large, no dreadful price has been paid for the good which herbicides have done. There have unhappily been fatalities but they have been due to ignorance or carelessness, which exact their toll in the application of many other scientific advances. But we ought to respect the views of those who do not hold with using these substances and tolerate what may only be due to lack of knowledge. In a sense they are watch dogs in case we overstep the mark, because we cannot run any risk at all with human life and so if a herbicide leaves any toxic residue in or on a crop used for human food we should think of an individual who lived entirely on that commodity and who, moreover, had a gargantuan appetite. Nearly everyone uses toxic sprays with a due sense of responsibility, but there will always be the very occasional slap-happy chap who could be dangerous. I realise that up to the present this risk attaches to insecticides rather than herbicides but there are some of the latter which are dangerously toxic to humans. The protection of operators and of the farmer's livestock are our direct concern and apart from fortunately rare tragedies our record is satisfactory. But we ought not to forget the threat which some chemicals - even herbicides - may be to wild life, particularly through spray drift and water pollution. There are those who are very sensitive in this matter and no doubt these people often wrongfully ascribe deaths or diminution in numbers of certain species to the sprays used by farmers. I suggest that we ought not to brush these views aside as those of cranks and we must certainly avoid any suggestion of ruthlessness in the matter.

There are many problems still to be solved in the field of chemical weed control. In concluding I would like to refer once again to the economic one. The cost of applying a herbicide is only too clear to a farmer but the financial return to be expected is entirely conjectural. Experiments designed to measure the profitability of herbicide usage have given results varying from zero (a few have in fact been negative) to a yield increase of three or four fold - a gain which can easily be evaluated. A further gain, over and above that from the crop actually sprayed, lies in the improved cleanliness of the field in succeeding years. Farmers strive for low-cost production and herbicides have helped and will help more in future, especially if they are moderate in price. The intelligent use of cheap and efficient herbicides will be, if it is not already, recognised as a point of good husbandry, as are traditional practices such as proper cultivation.

THE IMPACT OF HERBICIDES ON CROP HUSBANDRY IN THE U.S.A.

K. P. Buchholtz

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It is a privilege to have this opportunity to participate in the Fifth British Weed Control Conference. In past years I have attempted to keep in touch with the work in progress in Britain through the Proceedings which you have prepared after each meeting. I have been impressed with the diversity of your interests in weed control. It has appeared as though you frequently conduct your investigations in greater detail than is commonly done in the United States. Weed workers in the United States have a high regard for the findings of investigators in Britain and in a number of instances have adapted them to their own use.

As an officer of the Weed Society of America I wish to extend official greetings from our organization. I am sure that I may also speak for the four weed conferences in the United States for they too wish you every success in your present meeting. The need to control weeds is truly international. Whether it be the control of weeds in rubber plantations in Liberia, the control of bracken (Pteridium aquilinum) in the hill pastures of Scotland, the control of sagebrush (Artemesia spp.) in the range lands of the United States, or the control of weeds in the sugar cane fields of India, the objective is the same. As workers interested in the control of weeds, we are developing methods to facilitate the production of food, feed or fibre for an ever-expanding population. We are attempting to control a group of plant pests so that crop plants will not be forced to share the limited supplies of nutrients, water and light. The methods and the locale may change but our objectives remain the same. Therefore, we have much in common and it is my hope that in the years ahead we may see increased exchange of workers, of ideas, and of research findings between the various nations.

The title of my paper is very broad and may mislead you. I cannot speak with assurance about the cropping practices and weed control measures employed in all parts of the United States. Many of you have travelled in the United States and know that a wide range of crops is produced. In some of the southern states sugar cane, pineapples and tung trees may be grown. At our nothern extreme in Alaska only a few spring grains will mature. My observations will be based chiefly on field crops grown in the northern states. I am more familiar with these and, while conditions are not identical to yours in Britain, they are more nearly so than are those in other areas of the United States. My own experience has been in the North Central area of the United States and naturally a number of examples will be drawn from this region.

Agricultural production practices are undergoing rapid change in the United States. In evaluating these changes, herbicide applications that have come into wide-scale commercial use in field crops will be described. The probable effects these applications have had, or will have, on our cropping practices will be examined. Some attention will be given to reasons why herbicide applications have been accepted by farmers on certain crops while on other crops only limited acreages have been treated. With your indulgence, I will speculate a little on developments that may occur in the years ahead. Some marked changes have already occurred in our methods of controlling weeds. Additional changes will occur when developments in the research stage come into general use. The changes in methods of weed control are almost certain to influence cropping practices such as seeding methods and rates, seed-bed preparation, crop varieties used, harvesting methods and indeed the whole series of operations that make up our cropping program.

TRENDS IN AGRICULTURE

In order to evaluate the significance of the newer methods used by farmers to control weeds some background information should be presented. You are no doubt aware of the slight but continuing over-production of most agricultural commodities in the United States. This is a perplexing problem and at the same time a source of satisfaction. The over-production in agriculture has political, economic and sociological implications and has had pronounced effects on agricultural practices.

In general, agricultural prices have been low during the past 15 years, although governmental action has prevented their reduction to disastrous levels in most cases. In an effort to maintain a suitable net income, progressive farmers have rapidly accepted more efficient and more economical methods of crop production. Farmers who have not been willing, or have been unable, to use more modern production practices have not been able to compete and are rapidly leaving the farm for other types of employment. There seems little doubt but that the "cost-price" squeeze, and the relatively high cost of labor, have been notable factors in the rapid change in production practices and in the acceptance of herbicides for wide-scale use.

Data in Table I show that during the past 20 years farm employment has declined from about 11 million to 7.5 million. The acreage of crop land harvested has fallen only sightly but the number of farms has declined about 30 per cent. The toal population of the United States has increased sharply from 132 million in 1940 to 180 million today. In 1940 one farm worker supported 12 persons. Today one farm worker supports 25 persons. There is no doubt but that, based on acreage harvested and on man-hours utilized, the production of field crops is much more efficient today than it was 20 years ago.

Table I. AGRICULTURAL STATISTICS

	1940	1960
Farm employed	11,000,000	7,500,000
Acres harvested	339,000,000	332,000,000
Farm number	6,100,000	4,250,000
Population U.S.A.	132,000,000	180,000,000
Supported per farm worker	12	25

FACTORS AFFECTING EFFICIENCY OF PRODUCTION

It will be useful to determine some of the factors that implemented this increase in efficiency of crop production. Part of the increase in efficiency resulted from increases in average crop yields. The index of production per acre rose 40 per cent from 1940 to 1959. During this period the use of plant nutrients increased 421 per cent and the use of lime increased 64 per cent. There is no doubt but that the marked increase in the use of plant nutrients during this period increased the average yields of crops substantially. The entire increase in crop yield should not be associated with increased use of fertilizer, however. Use of better varieties of agronomic crops has also increased yields. Hybrid corn is credited by Griliche (1960) with increasing the average yield of corn by from 15 to 20 per cent. We are sure that use of superior germ plasm in other crops has also increased yields. However, the increases are probably not as great as has been noted in the case of corn.

A third factor that has increased yields is the use of superior production practices. Better methods of planting and harvesting are being used. Seed treatment for the control of soil-borne diseases is more widely used today than ever before. Control of insect pests is more prevalent than formerly. And the control of weeds today is generally better than was the case 20 years ago.

There is no simple way of proportioning the total increase in yield among the factors mentioned. Individual examples of increases in yield are available for many of the newer production practices. However, the data from these examples are not fully reliable when efforts are made to apply them on a regional or national basis.

Increased crop yield is by no means the only way in which the use of herbicides may have contributed to agricultural production. Another measurement of change in agricultural practices is the index of crop production per man-hour. The data in Table II is from material assembled by U.S. Department of Agriculture workers (1960). The index rose 203 per cent in the 19-year period from 1940 to 1959. The increase was not uniform for all crops but was 379 per cent for feed grains, 236 per cent for food grains, 210 per cent for cotton and only 174 per cent for hay and forage. It seems significant that the two classes of crops on which herbicides have been used most extensively, namely food grains and feed grains, have shown the greatest efficiency of labour use. It is also of interest to note that the index for cotton has increased appreciably during the past five years. This is the period during which use of herbicides in this crop has developed into a commercial practice.

Table II. INDEX OF PRODUCTION PER MAN-HOUR

Crop	Year				
	1940	1945	1950	1955	1959
Feed grains	100	136	218	304	479
Food grains	100	139	195	242	336
Hay and Forage	100	126	192	224	274
Cotton	100	109	146	230	310

Source: U.S. Department of Agriculture (1960)

The data in Table III is from the material assembled by Strickler and Hines (1960). It can be seen that a considerable part of the increased productivity per man-hour was probably due to increased mechanization. The number of tractors on farms increased 3-fold, grain combines increased 5½-fold and corn pickers 7-fold in the 20-year period. The data on field sprayers is less reliable for no survey to determine the number of sprayers on farms has been attempted on a national basis. About 5,000 power sprayers were manufactured each year prior to 1945. If we assume a life of 10 years for these sprayers, about 50,000 sprayers were probably in use in 1940. Most of these were used to apply insecticides and fungicides to fruits and vegetables. Since 1945 about 70,000 power sprayers have been manufactured for domestic use each year. If the life of these machines is also 10 years, there should now be about 700,000 sprayers on farms in the United States. This would indicate a 14-fold increase in the number of sprayers on farms. Furthermore, since there are about 4¼ million farms, about one farm in six now has a sprayer.

Table III. MACHINES IN USE ON U.S. FARMS

Machine	1940	1950	1960
Tractors	1,545,000	3,609,000	4,770,000
Combines	190,000	714,000	1,065,000
Corn Pickers	110,000	456,000	780,000
Balers	---	196,000	650,000
Sprayers	50,000	235,000	700,000

Source: Strickler and Hines (1960)

During the past 20 years there has been a tremendous increase in mechanization on farms in the United States. Along with this mechanization has come a greater utilization of herbicides. This is not unexpected for an objective of mechanization is to reduce the need for hand labour. In recent years tedious hand labour for controlling weeds has been eliminated for many, and indeed nearly all, crops grown on the field scale. It appears that the use of herbicides and mechanization are complementary and that neither might have progressed as rapidly alone. In summary, it seems safe to say that the use of herbicides has contributed in some substantial but as yet undetermined degree to the increase in productivity per man-hour that we have noted in the past few years.

EXTENT OF HERBICIDE USE

Estimates of the extent of herbicide use in the United States are far from as complete as desired. Brodell et al (1955) estimated that weed and brush killers were applied to about 42,000,000 acres of land in 1952. Shepard (1958) states that in 1957 farmers in the state of North Dakota treated 7,200,000 acres of crop land and pasture. This was about 38 per cent of the crop land harvested in that year. In 1953 only 2,700,000 acres were treated. The data presented by Shepard indicates that about 30,000,000 lb of 2,4-D and about 5,000,000 lb of 2,4,5-T are used each year in the United States. Not all of this is used on crop land, however. In addition a large number of herbicides are used on small acreages. In some cases these may be applied to specialized crops or in other instances the herbicide is just coming into commercial use.

Bjerken and Coe (1959) have reported on a detailed survey of herbicide applications in the state of Minnesota. The data have been obtained during the past 10 years and include the major herbicide applications made in the state. Since the data illustrate the trends taking place in a typical state, it should be of interest to describe them in some detail. The data can probably be applied to other states in the North Central region without gross errors.

Minnesota borders on Canada. The state was originally partly prairie and partly wooded. The main crops grown in the state are maize, oats, wheat, barley, soybeans, flax and forage crops. Dairying is the predominant livestock enterprise. A considerable number of hogs are produced in the southern part of the state and beef animals are also fattened in some areas. The farms are generally well mechanized and are predominantly operated by the owners. The farms averaged 211 acres in size in 1955.

Trends on the use of herbicides in three crops grown in Minnesota are shown in Table IV. The use of herbicides first became prevalent in small grains. 2,4-D and later MCPA were used to control a variety of broad-leaved weeds. The data show that by 1950 approximately 25 per cent of the acreage in the state was being treated for the control of weeds. With the exception of one year, the percentage of acreage treated increased each year during the decade so that in 1959 over 55 per cent of the grain was treated. In certain counties in Minnesota, where small grains are grown extensively, as much as 80 to 85 per cent of the grain was treated for weed control in 1959.

Table IV. PERCENTAGE OF CROP ACREAGE TREATED WITH HERBICIDES IN MINNESOTA

Year	Crop		
	Small grains	Maize	Flax
1950	24.1	2.4	--
1951	27.4	1.8	--
1952	29.1	2.8	2.4
1953	32.0	3.2	7.6
1954	37.6	4.6	10.7
1955	43.2	12.8	13.1
1956	49.3	18.6	14.0
1957	46.9	23.6	18.6
1958	53.7	30.4	29.3
1959	57.6	32.6	43.0

Source: Bjerken and Coe (1959)

The data for maize show that the use of herbicides was slower in developing in this crop. Only a small acreage was treated each year until 1955. In that year a substantial increase in acreage treated occurred. Additional increases have been noted every year since. Applications are both pre-emergence and post-emergence but by far the greatest acreage results from the post-emergence treatment.

Flax is a crop that is grown in substantial acreages in Minnesota. Use of herbicides on this crop became significant in 1952 and has increased each year since that date. Marked increases in acreage treated were noted in both 1958 and 1959. The trend toward greater use of herbicides after 1956 appears to coincide with the widespread use of MCPA by farmers. Previously, 2,4-D had been the material used most widely for weed control in flax and injury to the crop had been too great to encourage widescale use.

Soybeans are grown extensively in Minnesota but no completely satisfactory herbicide is yet available for use on this crop. Small acreages are treated but data have not been published and it is unlikely that more than one or two per cent of the acreage planted is treated with herbicides. Minnesota also has extensive areas devoted to pasture. These are described as woodland pastures, improved pastures and unimproved permanent pastures. A survey made in 1959 indicated that 3.3 per cent of the pasture land was treated with herbicides in that year. Five years earlier a similar survey had shown that 2.6 per cent of the pasture land had been treated. It seems clear that only a small portion of the pasture land is being treated in this state.

The evidence is fairly clear, both on a national scale and in Minnesota, that farmers have accepted herbicides as a routine method of controlling weeds in small grains, maize and flax. The level of acceptance observed has occurred in 15 years or less, for the first use of 2,4-D on a field scale took place in 1946. The practice of herbicide application must have provided distinct benefits in order to have increased steadily during the past decade and at the rate shown.

FACTORS INFLUENCING ACCEPTANCE OF HERBICIDE APPLICATION

It should be of interest to examine the reasons why rapid acceptance of herbicide application has occurred. The small grain grown in Minnesota is almost exclusively of the spring type. The grain is grown close-drilled and no opportunity exists for tillage after planting. In Wisconsin each delay of one day of planting after April 20 reduces the yield of oats approximately one bushel per acre. As a result of the need for early planting, there is no opportunity for early tillage prior to seedling. Broadleaved weeds are prevalent and frequently reduce the yields of grain.

Data are difficult to obtain on a regional basis on the extent to which yields of grain are reduced by weeds present in the field. Perhaps the most applicable work is that of Canvin and Friesen (1956) who conducted a series of studies in Canada. These workers found that weeds reduced crop yields in fields selected at random by 15.9 per cent in 1956. It is unlikely that 2,4-D or MCPA would increase the yields to the maximum obtained on a hand-weeded plot. However, broadleaved weeds are the predominant ones in fields of small grains and appreciable increases in yield should result from the application of an herbicide.

Additional factors may also contribute to the rapid increase in the use of herbicides. Grain, free of broadleaved weeds, can be combined more readily than can grain in weed-infested fields. In the wheat-producing areas of Kansas and Nebraska an extra charge is made for combining weed-infested fields. The use of herbicides has facilitated the use of the combine. The combine requires less labour, is faster and is more economical than the use of the stationary thresher. As a result, fields of bound and shocked grain are becoming less common, even in areas where grain is grown less extensively. When broadleaved weeds are prevalent and are not controlled, the use of a combine offers less advantage for the machine must be operated slowly and the separation of the grain from the straw is less complete.

A third advantage from using herbicides in grain fields is the improvement in storage of the harvested grain. Grain from weed-infested fields is likely to have considerable quantities of moist weed seeds, leaves and fragments of weeds. This material increases the moisture content of the mass of grain to the point where the grain will not store well and may even mould. This is particularly serious when the grain is being grown for seed purposes. A fourth advantage, that probably is not regarded as highly by the farmer, is the reduction in weed seed production and infestation that occurs on treated fields.

In summary we can say that the use of herbicides in small grain adds a spray treatment to the normal procedures for grain production and increases the cost of production per acre moderately. However, the use of the herbicides has facilitated the use of the combine and has improved the storage of the harvested grain. Treatment of grain fields has increased yields. In the aggregate, it has reduced the costs of production and has increased the efficiency of labour on the farm. These responses must have been considered great enough by farmers to lead to widespread acceptance of the application.

The impact of herbicide use in the production of maize is somewhat different. This crop is planted in spaced rows and is normally cultivated several times subsequent to emergence. Tillage of maize by itself usually does not give complete control of weeds in the row. Tillage is required at the busiest season of the year, late spring and early summer. It cannot be postponed for to do so will greatly reduce the yield of the maize.

The use of herbicide gives evidence of a profound change in the culture of maize. Applications of 2,4-D as a post-emergence treatment are widely used to control broadleaved weeds remaining in the row in maize fields under tillage. Most maize fields are infested with both broadleaved and grassy weeds so this treatment does not eliminate the need for tillage. The control is certain to be better, however, than where only tillage is used. Use of pre-emergence applications appear to offer the greatest promise at present. Materials now available will control both broadleaved and grassy annual weeds when applied in this way. Ideally a treatment with atrazine or simazine may, and often does, control all weeds for the entire growing season without tillage.

As long ago as 1912, Cates and Cox (1912) reported that they could find no consistent advantage for the use of tillage to control weeds in maize fields. At that time the only method other than tillage that could be used to control the weeds was hand-pulling or scraping with a hoe. In recent years several studies have been conducted using herbicides for the control of weeds in an effort to determine the value of tillage in maize production. Meggitt (1960a) and Klingman (1958) both have presented data that shows that tillage is not necessary for maximum yields of maize in soils that have a good physical structure and are friable. Results of several years work in Wisconsin support this contention. At present, only a small acreage of maize is being produced without tillage. The practice will probably increase, for it is a decided convenience to the operator where it can be used.

Let us consider the advantages of using herbicides in maize. The most detailed studies on the effects of weeds on yields in maize appear to be those of Staniforth (1953). He estimated that maize yields averaged 11 per cent lower than optimum becuuse of competition from weeds, even though normal tillage practices were followed. Applications of triazine herbicides may eliminate the weedy growth and may thereby increase maize yields accordingly. Use of 2,4-D can be expected to increase maize yields if the infestation is of susceptible species. In most instances, the presence of weedy grasses will prevent the whole increase from being realized.

A factor of greater significance is the increased convenience of production. A successful pre-emergence application will reduce the need for tillage, especially during June. In most cases weed control by tillage requires three operations, the first of which is very slow because of the small size of the maize. If a post-emergence application of 2,4-D is used, two tillage operations will usually suffice. Use of a pre-emergence application may reduce tillage operations to only one or may eliminate the need for tillage completely. A reduction in the need for tillage during the month of June is of greater importance than the monetary cost might make it appear. In the diversified farming areas of the north-central states, the first cutting of hay must be harvested during June. The weather during this month is unsettled and showers are frequent. Consequently, the farmer is faced with the problem of both maize tillage and hay making during a relatively short period during which the weather is likely to be favorable. By eliminating or reducing the need for maize tillage he can divert more time to making hay. The result has been improved quality hay. By harvesting the hay at a more favourable stage of maturity, it tends to be of higher quality. By concentrating on the hay making operation, the farmer is more apt to get the hay baled and under cover before a shower interrupts the operation.

An additional advantage derived from successful herbicide application is the elimination of weeds in the field at harvest time. Maize is mostly picked or harvested by machine. A number of weedy plants handicap the harvest operation by tangling the harvesting equipment or by adhering to the snapping rolls of the picker. Freeing the equipment of weeds is a dangerous operation. Not infrequently the hand or arm of the operator is drawn into the machinery with serious consequences. Reducing or eliminating weed infestations in the field at harvest time not only speeds the harvest operation but increases the safety of the operation. As with small grains, the reduction in weed growth reduces the weed reseeding problem. The benefits of this may not be apparent immediately but continued over a period it would be certain to reduce the weed problem in crop land.

In summation, the use of herbicides in maize has provided for better control of weeds, particularly in the row. Maize yields have been increased by possibly 10 to 15 per cent. Reductions in time required for tillage has allowed the farmer to give greater attention to other farm operations particularly harvest of forage crops. Harvest of the maize has been facilitated and made less dangerous.

Control of weeds in soybeans by use of herbicides has been investigated in considerable detail. To date only a small percentage of the acreage has been treated each year. A successful herbicide for use in soybeans must control both broadleaved and grassy annual weeds without injury to the beans and it must be economical to use. Soybeans are not a high-value crop and production expenses must be kept low. To date, no material in commercial use is fully satisfactory on any of the three points of evaluation. The introduction of an effective, selective and economical herbicide is likely to change production practices with soybeans. At present this crop is grown in rows spaced 30 to 40 inches apart to allow cultivation. A satisfactory herbicide would reduce or would eliminate the need for tillage. Under these conditions the soybeans could be planted in close-drilled rows. The crop will soon shade the soil surface and is competitive enough to control weeds that germinate later in the season. It has been shown by Meggitt (1960b) that soybeans sown in this manner and kept weed-free will yield substantially more than beans planted in spaced rows. The result of such culture will be a reduction in the field work required to produce beans, an increase in yields and certainly an increase in the efficiency of the operator. Needless to say, a determined effort is being made by many concerns to develop a herbicide for widespread use on this crop.

I would now like to consider the control of weeds in cotton. This crop is grown extensively in the southern and southwestern states. Many of the observations cited are based on the data collected by Porter (1960). He has been active in weed control in cotton for many years in Louisiana. Progress in the control of weeds in cotton in states other than Louisiana may vary in degree but I believe that the conclusions he has reached can be applied in a general way throughout the cotton-producing area.

Cotton has been a crop that required a tremendous amount of hand labour. Weeds between the rows have been controlled by tillage, but hand labour has been required to remove the weeds in the row. Cotton has a long maturation period. The areas where it is grown have moderate to high temperatures. Rainfall is adequate for good plant growth or water is supplied by irrigation. Cotton is generally grown on fertile or heavily-fertilized soil. Needless to say, all of these factors tend to increase the weed problem. As a result, several hoeing operations may be necessary during the season. Porter et al (1957) summarized results from 42 experiments and found that an average of 33 hours of hoeing labour were required for each acre of cotton. Another point of significance was that the requirement for hoeing labour was extremely variable, varying from 129 hours per acre to as low as five hours in the different trials.

Hand labour for hoeing is poorly paid but the costs are substantial even so. Hoeing or chopping cotton is drudgery and only unskilled workers can be obtained for such work. The supply of labour is not elastic. In years when weeds are abundant, sufficient labour may not be available to get the job done. The work is seasonal and other employment during winter months is usually not available in the area. This leads to community problems because of unemployment, delinquency and low standards of living. It is obvious that there are many reasons why a determined effort has been made to develop a herbicide application programme in cotton that will eliminate, or at least drastically reduce, the need for hand labour in this crop.

Porter (1960) has estimated that 40 per cent of the cotton grown in Louisiana was treated with herbicides in 1959. In 1960 approximately 65 per cent was treated and he estimates that by 1963 up to 95 per cent of the cotton acreage will be treated. The largest share of the acreage is treated with diuron as a pre-emergence application but some post-emergence applications using herbicidal oils are used. The present herbicides used in cotton have some deficiencies and do not always eliminate the need for weed control during the entire season. However, the need for hand labour is greatly reduced by the use of herbicides. By using herbicides farmers can develop a work plan that will require the smallest possible permanent labour force. This labour can be employed the year around and seasonal employment is avoided. The control programme using herbicides may not reduce the cost of controlling weeds and the yields of cotton may not be increased, but the control obtained is more dependable and the labour force is used much more efficiently.

The introduction of herbicides into cotton production has accelerated the use of mechanical cotton pickers. As long as a large labour force was required for weed control, there was a strong inducement to employ them for picking the cotton at harvest. On farms where herbicide applications are made, this factor is no longer of importance and a considerable portion of the cotton acreage is now harvested mechanically. Considerable savings in the cost of harvest have resulted. This increased use of the cotton picker is a good example of the changes in cropping practices and techniques that may be expected as the use of herbicides becomes more widespread in our agricultural crops.

The control of weedy and brushy plants in pastures has not followed the pattern noted with the cultivated crops. Work by Klingman and McCarty (1958) in Nebraska has shown that control of herbaceous weeds can increase the yield of forage produced in permanent pastures as much as 50 per cent. The control of the weedy plants also facilitates the management of the pastures and reduces cases of mechanical injury to grazing animals. In areas where poisonous weeds are prevalent, losses from poisoning are reduced as a result of treatment. Notwithstanding these inducements, treatment of pasture lands in the northern states has not expanded as expected. The treatment entails an additional operation that must be done during an already busy season. The cost of the materials used are not high, but compared to return realized from unimproved pastures, it may seem so. Apparently, the benefits of increased forage production and increased efficiency of operation in treated pastures are not great enough, or are not obvious enough, to stimulate widescale use of herbicides for this purpose. It should be pointed out that in some of the south-western states, Oklahoma and Texas in particular, a programme of herbicide application to pastures is under way. In these states brushy plants are abundant in pastures and greatly reduce the production of forage through competition for moisture. The brushy plants also make management of animals in infested pastures very difficult.

CHANGES IN METHODS OF CONTROLLING PERENNIAL WEEDS

Another aspect of herbicide application is the change in methods used to control three widely distributed and serious weeds in the United States. Field bindweed (Convolvulus arvensis) is most troublesome in the sub-humid and semi-arid wheat-growing areas of the Middle West and Pacific Northwest but is found throughout the United States. Creeping thistle (Cirsium arvense) is of importance throughout the entire area. Couchgrass (Agrophron repens) is most troublesome in the northeastern states and in the northern states of the North Central Region.

Prior to the widespread use of herbicides, the control measure recommended for field bindweed was repeated tillage, usually over a two-year period. As many as 15 to 20 operations were required. The practice was expensive, it was tedious, and it often promoted soil erosion. While the tillage operation was in effect, the area could not be used for cropping purposes. Soil sterilants came into use for the control of weeds in small patches that could not be conveniently cultivated.

Several practices involving the use of herbicides have replaced tillage for control of field bindweed. In areas where corn, sorghum or small grain is grown, temporary control results from application of 2,4-D. If the weed has not become deep-rooted, complete control may be obtained. Infestations with deep roots are also treated by making applications of 2,4-D, 2,3,6-TBA, fenac and similar materials to the soil with the intent of securing sterilization of the soil for a period of one or two years. Such treatments are no more expensive than continued tillage, they are more convenient to conduct, and are less likely to allow soil erosion.

Creeping thistle was also controlled by repeated tillage in the years before the use of growth-regulating herbicides. Today very little tillage is used to control this weed. A common treatment is to apply 2,4-D or MCPA to the infested areas when sown to small grain. Eradication is not often secured by a single treatment but control is usually possible, even at reduced rates. 2,4-D is also used for the control of thistle in corn. In this instance, some means should be made to control the annual weeds in the crop initially by preemergence treatment or by use of a rotary hoe. In this manner, a good stand of thistles is allowed to develop. An overall treatment with 2,4-D will then give substantially better control than will applications made when only a portion of the stand remains after normal tillage has broken off a good share of the shoots.

Use of amino triazole has proved effective for the control of creeping thistle. Since this material is non-selective, it is commonly applied when the area to be treated is not producing a crop. This chemical is frequently applied to the thistle regrowth that occurs in grain stubble after the crop has been harvested. Regrowth of the thistles is promoted by mowing the infested areas immediately after the harvest of the grain. In certain instances, soil applications of 2,4-D and 2,3,6-TBA at rates of from 10 to 20 lb per acre have been used to eradicate the thistles from small areas.

Use of tillage for the control of couchgrass has not yet been replaced by herbicide applications but several possibilities are being considered. The traditional method has been to cultivate infested areas as frequently as once a week during the warm weather of late summer and early fall. A heavy-duty spring-toothed cultivator is most effective. The object is to bring the couchgrass rhizomes to the surface of the soil where they may be dried out and killed. Repeated cultivation is necessary to expose most or all of the rhizomes on the surface of the soil. We frequently plan on making as many as six or seven cultivations over a period of two months. The control is often good if the weather during the period of tillage is dry. If rain is frequent during this period, little control is obtained.

Attempts have been made to use dalapon for the control of couchgrass. Fall treatments are probably the most satisfactory. These require applications of about 10 lb of the chemical per acre. One or two tillage operations during the fall will improve the kill obtained. Some interest has been shown in the use of 5 lb of dalapon per acre applied in the early spring. This treamment is more economical than the fall application but presents a greater residue problem. The planting of most crops must be delayed until the residue in the soil has been reduced to an innocuous level.

Amino triazole has also been considered for use in controlling couchgrass. Applications made to the foliage of couchgrass in the spring have been moderately successful in controlling the weed. Control is best when the treated areas are ploughed about 10 days after treatment and then planted to some crop that can be cultivated for at least a portion of the season.

A third material that has shown promise for the control of couchgrass is atrazine. Fall applications of four pounds per acre have been effective and allowed the production of corn on treated areas the following year. Cost of the treatment is relatively high and it remains to be seen whether extensive areas will be treated.

Atrazine has also shown promise for the control of couchgrass when applied as a spring treatment. On many soil types application of two pounds per acre appears to be sufficient. The chemical seems most effective when applied early in the spring as a pre-plough treatment. Control is probably more complete on couchgrass grown on soils of moderate to high fertility or following the application of fertilizer containing nitrogen. Corn can be planted on treated areas as soon as the soil is prepared but no other crop will tolerate the atrazine residue present in the soil the year of treatment.

The foregoing discussion has shown that the methods used for controlling field bindweed and creeping thistle have changed materially in the past 15 years. Previously the main emphasis was on tillage with occasional use of soil sterilants for spot treatment. At present, tillage is infrequently used and greatest emphasis is placed on use of selective herbicides applied in the growing crop. In some instances non-selective herbicides or soil sterilants are applied after a crop has been harvested. With couchgrass, however, the main reliance is still on tillage although considerable efforts are being made to develop practices using herbicides that can be applied on the field scale. In areas where corn is grown, the work with atrazine indicates that excellent control will be obtained without disruption of cropping practices.

LEGISLATION AFFECTING HERBICIDE USE

The topic title does not suggest that I would consider the effect of pesticide legislation on herbicide use. However, legislation has had such a marked effect on the development and distribution of herbicides in the United States that its main points need to be kept in mind in order to more fully understand the trend in herbicide use. Since 1957, pesticides have been marketed under the provisions of Public Law 518, commonly known as the Miller Bill. There is no doubt but that the provisions of this law has slowed down the development and release of herbicides for commercial use. On the other hand, there has been greater assurance since the advent of this law that applications of a particular herbicide were reliable and that they would not result in undesirable residues if used according to recommendations.

Briefly, the provisions of the law require that directions for use on the label of a product be approved by officials of the U.S. Department of Agriculture as having substantial value. If no residue is found on the food or feed crop harvested, the product can be offered for sale on a no-residue basis. If the application does not involve the treatment of a food or feed crop, the residue status of the application may be ignored.

If a residue of the chemical is known to exist on the harvested crop, the product is brought to the attention of officials of the Food and Drug Administration. The level of the residue on the crop must be determined precisely by specific chemical analyses. Data on acute toxicity studies must be presented. Chronic feeding trials must be conducted over a period of two years using small animals, usually rats, but sometimes dogs. The level of toxicity must be established and compared with that known to occur following field applications. If the treated crop is fed as forage to dairy animals, it must be demonstrated that no detectable amount of residue exists in the milk from animals fed treated forage. Further, it must be demonstrated that no carcinogenic properties are evident even when the product in question is fed to experimental animals at rates as high as will be accepted even though this may be thousands of times greater than the rate at which the material would be consumed as a residue on food or feed. The costs for these studies are borne by the commercial concern introducing the herbicide.

The requirements of the law have substantially increased the costs of developing a herbicide or any other pesticide. It has extended the time required for development by at least two years. Ordinarily, feeding trials will not be initiated until a material has shown considerable promise in the field. The data from feeding trials must then be at hand before a commercial concern will see fit to develop the equipment needed for commercial production of a product.

The requirements have not only reduced the introduction of new materials but they have limited the possibility of securing additional label recommendations for use of materials now on the market for application to crops grown on limited acreage. The costs involved require that only the larger, most lucrative applications, be considered.

A number of promising applications cannot be recommended at present because of residue on the harvested crop or because of lack of knowledge about the residue that may be present. Some examples of the applications that cannot be made are: Use of dalapon to control weedy grasses in seedings of forage legumes; use of 2,4-DB and MCPB to control broadleaved weeds in stands of forage legumes; use of amino triazole for the control of creeping thistles in pastures or in areas to be planted to any crop but corn during the current growing season. We cannot use amino triazole for the control of poison ivy beneath apple trees. We cannot recommend the use of dalapon on canning peas. We cannot graze meat or dairy animals in fields treated with atrazine. The list could be extended at some length, but this will suffice to give an indication of the applications that cannot be recommended at present even though the treatment itself would result in satisfactory control of a weed or weeds and the growth of an associated crop would not be noticeably impaired.

Regulations of the type described might seem to be a decided handicap in developing a pesticide programme. To a degree this is true, but some advantages are present. A considerable advantage is the assurance that no hazard is present when an approved recommendation is made. We have a small, but an exceedingly vocal, group of persons in the United States who decry the use of any pesticide as being unnatural and liable to induce all sorts of ill effects. The need to be reasonably certain about the main effects and the side effects of the pesticides in use has given research workers an effective means of discounting the claims submitted by those striving to eliminate the use of pesticides.

SUMMARY

In view of the foregoing discussion, the evidence is clear that production practices in agriculture are changing rapidly in the United States. Numbers of farm workers and farms in operation are declining. On the other hand, total production, crop yields and the index of crop production per man-hour are increasing. Use of herbicides has increased steadily year by year during the past 15 years. There is evidence that the use of herbicides has contributed in some substantial measure to the increased efficiency of crop production. In some instances, it may have reduced costs of production. In others, it may have increased the convenience of farm operation. Increases in yield following treatment are common but not universal.

The initial use of herbicides was to supplement the control of weeds obtained by traditional procedures. However, in a number of instances cropping practices are now being modified to take full advantage of herbicide application. This is true in cotton and to a lesser degree in corn. As soon as desirable herbicides are developed, it is likely to occur in soybean production.

Imagination is needed to develop methods of application and cropping practices that will utilize to the fullest the unique responses possible when herbicides are applied. Certainly not all possible sources of herbicide selectivity have been explored. We have seen the development of several new and valuable methods of application in the past 15 years. No doubt other methods of application will follow. Cropping practices will change as we find that the newer methods are superior to the traditional ones. As research workers interested in the control of weeds we have the opportunity, and indeed the obligation, to develop the methods of weed control that will be used in future years. When we have done so, we can say with some satisfaction that we have contributed to man's oldest profession, agriculture. We will have aided in man's age-old struggle to feed the multitude.

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SESSION 2

Chairman: Mr. F. Rayns

WEED CONTROL IN ARABLE CROPS

FIELD TRIALS WITH ENDOTHAL/PROPHAM FOR THE CONTROL OF SEEDLING WEEDS IN SUGAR BEET

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Summary. Applications of a mixture of endothal and propham at three different rates were made at time of drilling sugar beet on a wide range of soil types. Twenty-one trials were carried out to cover as wide a range of conditions as possible. Application of a narrow band of spray generally proved to be as effective as overall spraying by hand. The three rates of use were shown to be necessary to allow for variation in soil type. Absence of rain during the last half of April 1960 clearly demonstrated that reliable results can only be expected where a reasonable amount of rainfall occurs during the period between drilling and emergence of the beet.

INTRODUCTION

Whilst endothal is already in commercial use on sugar beet in U.S.A., it has been shown by Parker (1954) that when used alone in Gt. Britain it has insufficient selectivity against a full range of weeds. The weed control value of a mixture of endothal and propham was therefore tested by Murant (1958) who showed that a wider range of weeds could be controlled by the mixture, propham controlling many of the weeds which were only partially checked by endothal. In planning these present trials one of the more difficult problems was that of choice of ratio for the endothal and propham mixture. After consultation with Dr. Murant it was decided that a ratio of 4 parts endothal : 3 parts propham, both materials expressed as acid equivalent, was likely to prove most useful. This ratio was chosen taking into account both the efficiency against a full range of likely weeds and the safety level of both herbicides to the beet crop. Previous work by Parker (1954) indicated that endothal was less effective on heavier soils. In addition to this fact, allowance must be made for the increased effect of the herbicides on the sugar beet where the soil type has a high sand content. Three rates of use of the mixture of endothal/propham were therefore selected and the most appropriate two of these rates were used at each experimental site. A general division between the sites was made at 17 per cent clay content. Soils above this figure received the medium and heavy rates whereas soil below 17 per cent clay received the light and medium rates.

The field trials were devised to show both the efficiency of the herbicide mixture and to demonstrate the possibility of fully mechanising the spring sugar beet programme, thus satisfying the demand for less labour in those areas where hand thinning is becoming a very expensive proposition.

METHODS AND MATERIALS

All the trials were of similar design, consisting of five large plots, each up to 1 acre in size. Two of the plots being drilled with Triplex M seed and three of the plots drilled with the seed variety normally used by the grower in question. Two rates of weed killer were used on each seed variety. In addition to the large plots there were at each site two small plots between 50 and 120 sq yd in size situated in a large plot of sugar beet which received no weed killer application. The two plots were sprayed by hand using a knapsack sprayer to apply the same rates of herbicide per unit area as in the big plots but giving complete cover instead of a band of spray.

The lay out was therefore as follows:

Plot 1 - Klein E or Hillshog Rubbed and Graded Seed - No weedkiller.
Plot 2 - Klein E or Hillshog Rubbed and Graded Seed - Weedkiller rate 1.
Plot 3 - Triplex M seed - Weedkiller rate 1, except for 1 row untreated.
Plot 4 - Triplex M seed - Weedkiller rate 2, except for 1 row untreated.
Plot 5 - Klein E or Hillshog Rubbed and Graded Seed - Weedkiller rate 2.

All plots were drilled with a 5 row precision drill and the spray applications to large plots were as seven inch bands applied immediately behind the rear wheel of the drill-units. By use of the band spraying technique, described by Bagnall, Caldicott and Minter (1960), approximately seven gallons of spray were used per acre of sugar beet. The herbicides were formulated as a combined emulsion in the desired ratio. Supplies of Penco Endothal Weedkiller were obtained from the Pennsalt Chemical Corporation, Washington. Counts were made on sugar beet emergence and weed population just before thinning operations commenced. The counts were made at 16 points in each plot selected at random. The weed counts were for an area of 50 x 2 in. i.e. 100 sq in. each, the beet emergence counts were for 50 in. units of row, which gave a total of 800 in./plot. After these assessments had been carried out the plots were sub-divided to allow some hand and some machine thinning. Unfortunately the machine thinning sections were generally unsuccessful, largely due to the plants getting too big before the operations could be completed in so large a number of trials. The final plant populations were therefore obtained by resorting to hand thinning. This has meant that due to the variation in treatment within the plots it has not been possible to obtain the anticipated crop yields. Similarly plant population counts in July were of little value.

RESULTS

Experimental details of twenty-one trials are shown in Table I. and the results are given in Tables II and III. The specific weed results of trials 9 to 21 are not given in detail since they are consistently poor, more than 40 per cent weed control seldom being achieved. There was no significant reduction in sugar beet emergence in any of these later trials.

DISCUSSION

Previous workers have demonstrated the importance of adequate rainfall to obtain the best results with herbicides such as endothal and propham. The present series of trials have borne out this finding. In sites 1 to 8 adequate rainfall occurred in the 3 weeks following drilling and satisfactory results were obtained. Sites 9 to 21 generally gave poor results; this appeared due to the fact that insufficient rain followed drilling. The possible exceptions amongst these later sites being those of 9 and 16 where some rain fell on an already moist seed bed. By reason of the more rapid drying conditions which usually prevail in April it can be expected that more rain is needed following application in April than would be the case during March. Comparison of the rainfall figures for the two periods adequately support the idea (see Table II).

A high soil moisture content without ensuing rain is insufficient to guarantee good results; although it obviously reduces the quantity of subsequent rain required. Similarly less rainfall seems to be required by the very light soils (e.g. sites 5 and 6).

Some effect on the emergence of sugar beet was observed at sites 1 to 8. This took the form of a slight delay in time of emergence and some reduction in braird density particularly at the higher doses of weedkiller. Counts made shortly after thinning showed that there was no effect on final plant population except 2 and 4 in the case of the high doses.

The choice of doses at each site was made at a time before information was available on the organic matter content of the soils in question. The choice of doses based on clay content has been shown by analysis of the beet emergence figures to have been correct except in the case of Site 2.

Site 1 was an exception to the normal decision on dose largely because of the very high sand content. In the case of site 4 due to an expected high organic matter the higher dose of weedkiller was used, subsequent analysis of the soil showed this decision to be wrong.

Whereas site 7 and 8 have a high clay content and are heavy soils, sites 1 and 2 have high clay content but are not heavy soils by reason of their coarse sand content. Conversely 5 and 6 have low clay and high coarse sand content and are typically light soils, whereas sites 3 and 4 have low clay content but owing to their very low percentage coarse sand are not really light soils.

Previous workers have been encouraged to utilise the Relative Absorption values (clay content + 5 x O.M.) in considering weedkiller requirement. With the range of soil types in this series of trials the value of this factor has not been borne out. The proportions of coarse sand to clay content would appear to be the governing factor.

The response of various weed species was in line with previous findings and the results are shown in Table III. The results include all weed species which occurred at any one site at an intensity of 10 or more per 1600 sq in.. Whilst the level of control of most species was reasonably high Chenopodium album, and Stellaria media were only partially controlled where the low rate of weedkiller was used.

The weedkiller applications maintained a weed free row until the time of singling, a period of some 6 to 8 weeks. The herbicide band was naturally destroyed by the thinning operations which prevented further observations on the length of freedom from weeds.

The results of the machine-applied band of herbicide was in general equally satisfactory to the hand sprayed plots where the same rate of weedkiller was applied as an overall cover.

CONCLUSION

The results with a mixture of endothal and propham proved satisfactory and confirmed those obtained by Murant in 1958. The selected ratio of endothal to propham appeared satisfactory both for weed control and safety to sugar beet. Unless a method can be developed whereby the weedkiller can be mechanically incorporated into the soil it is evident that adequate rainfall following spraying is necessary for satisfactory weed control.

The use of a 7 in. band of spray proved fully satisfactory in the trials. The price of the combined herbicide makes the use of a band of spray a necessity to keep the cost at an economic level.

Further investigations into the possibility of incorporating the herbicide into the surface of the soil are necessary. In addition it would seem valuable to make further comparisons of doses in relation to different soil types to confirm the 1960 findings.

Information to date suggests that the use of this weedkiller mixture on light and medium soils in the earlier part of the spring season is definitely worthwhile.

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TABLE I. DETAILS OF SPRAYING TRIALS

Trial	Site	Soil Texture Class	Mechanical Soil Ana.				O.M.	Relative Absorption
			Clay	Int. Silt	Fine Sand	Coarse Sand		
1	Orford, Suffolk	Loamy coarse sand	18.2	8.0	25.0	48.8	2.61	31.2
2	Mendlesham, Suffolk	Coarse sandy loam	21.6	11.4	35.2	31.8	2.51	34.1
3	Kirton, Lincs	Very fine sandy loam	11.0	23.2	65.6	0.2	2.08	21.4
4	Three Holes, Norfolk	Loamy very fine sand	7.0	14.4	77.2	1.4	3.40	24.0
5	Dersingham, Norfolk	Loamy coarse sand	8.4	7.4	38.8	45.4	3.24	24.6
6	Heacham, Norfolk	Loamy sand	9.6	5.4	44.6	40.4	1.80	18.6
7	Thorpe, Northants	Loam	22.4	25.0	31.2	21.4	3.80	41.4
8	Witham, Essex	Silt loam	24.8	18.2	47.4	9.6	3.26	41.1
9	Kirton Holme, Lincs	Very fine sandy loam	18.0	21.0	60.6	0.4	2.76	31.8
10	Baston, Lincs	Sandy loam	13.4	19.0	37.0	30.6	1.98	23.3
11	Croxton Kerrial, Leics	Sandy loam	17.8	20.8	29.6	31.8	3.23	33.45
12	Much Haddam, Herts	Silty clay loam	35.0	26.2	35.0	3.8	2.34	46.7
13	Eltisley, Cambs	Clay loam	33.0	23.2	35.8	8.0	3.64	51.2
14	Woodbastwick, Norfolk	Sandy loam	10.2	20.6	48.6	20.6	2.84	14.4
15	Thriplow, Cambs	Fine sandy loam	20.6	5.8	57.8	15.8	3.17	36.45
16	Tuttington, Norfolk	Fine sandy loam	14.2	17.6	51.4	16.8	4.08	34.6
17	Fen Ditton, Cambs	Clay loam	36.0	21.6	30.2	12.2	3.02	51.0
18	Netherthorpe, Yorks	Very fine sandy loam	15.8	28.8	51.4	4.0	3.84	35.0
19	Horringer, Suffolk	Sandy loam	14.4	14.2	47.4	24.0	2.89	28.85
20	Waldingfield, Suffolk	Clay loam	37.0	22.4	34.2	6.4	2.78	50.9
21	Sprowston, Norfolk	Sandy loam	12.0	16.0	72.0		2.10	22.5

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TABLE II. EFFECTS ON SUGAR BEET AND WEEDS OF PRE-EMERGENCE APPLICATIONS OF A MIXTURE OF ENDOTHAL AND PROPHAM

(treatments in lb/ac)

Trial	Date of drilling and spraying	Rain in 21 days after spraying. in.	Damage to beet as per centage of untreated			Weedkilling performance surviving weeds as per centage of untreated			No. of weeds on untreated/1600 sq in.			
			Endothal + Propham			Endothal + Propham			Total	Suscept	Mod Suscept	Poor Suscept
			2+1½	4+3	6+4½	2+1½	4+3	6+4½				
1	10/3	3.42	99	78.2		48.2	21.2		359	302	3	54
2	16/3	1.34		74.3	50.6		18.6	11.6	150	124	10	16
3	16/3	0.73	90.3	92.1		22.5	16.5		278	269	0	9
4	17/3	1.05		94.5	88.5		6.5	3.25	231	222	0	9
5	17/3	0.56	99.1	73.9		5.08	0.34		867	783	4	74
6	18/3	0.56	100	79.6		2.7	0.3		332	257	9	66
7	22/3	1.6		100	100		22.4	8.06	285	230	0	55
8	24/3	1.04		93.6	83.9		6.5	2.7	572	517	53	3
9	5/4	0.38		99.5	86.1		60.4	42.8	616	506	0	110
10	5/4	Nil	100	100		75.3	57.4		202	157	3	43
11	6/4	0.22		100	100		86.5	48.0	230	223	1	6
12	6/4	0.23		100	100		31.2	85.2	48	17	10	21
13	7/4	0.2		98.8	100		47.9	90.4	73	55	1	27
14	11/4	0.34	100	100		84.5	62.5		174	109	61	4
15	11/4	0.1	100	100		79.1	79.4		202	146	6	50
16	12/4	0.29	97.3	91.3		42.2	17.8		320	272	3	45
17	12/4	0.12		100			60.8		87	75	0	12
18	13/4	0.13	100	100		100	66.3		132	113	10	19
19	13/4	0.08	100	100		58.7	58.7		34	26	0	8
20	15/4	0.14					61.5	83.7	117	92	24	1
21	20/4	0.15		98.3			60.0		40	36	0	4