PROCEEDINGS OF THE

FIFTH BRITISH WEED CONTROL CONFERENCE 1960

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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

President, Weed Society of America

Department of Agronomy, University of Wisconsin, Madison

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 $5\frac{1}{2}$-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 $4\frac{1}{4}$ 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)

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

B. H. Bagnall, J. J. B. Caldicott and D. J. Minter.

The Murphy Chemical Co. Ltd., Wheathampstead, St. Albans.

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.

ACKNOWLEDGEMENTS

The authors wish to thank Dr. A. F. Murant and Mr. C. Parker for advice in the original planning of these trials. The assistance of staff of the British Sugar Corporation was invaluable in introductions to possible sites. These trials were only possible to carry out by the valued co-operation of many farmers and also the Directors and staff of Messrs. Bush Johnsons Ltd., The Dorman Sprayer Co. Ltd., Stanhay (Ashford) Ltd., and Salopian Kenneth Hudson and Son (S.K.H.)

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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

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	Sus-cept	Mod Sus-cept	Poor Sus-cept
			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

TABLE III. SUSCEPTIBILITY OF WEED SPECIES TO PRE-EMERGENCE APPLICATIONS OF MIXTURE OF ENDOTHAL AND PROPHAM.

Survivors as percentage of untreated. (treatments in lb/ac)

Site	Weed Sp.	Date of Assessment	No./1600 sq in.	Endothal + Propham		
				2 + 1½	4 + 3	6 + 4½
1	Stellaria media (Chickweed)	24/4	261	50	19	
2		11/5	29		3	6
3		3/5	110	45	22	
4		4/5	95		10	3
6		5/5	17	30	0	
7		4/5	72		2	1
8		8/5	111		4	1
1	Polygonum convolvulus (Black bindweed)	24/4	89	9	2	
2		11/5	21		0	0
3		3/5	13	0	8	
6		5/5	13	0	0	
7		4/5	85		10	8
1	Veronica persica (Speed well)	24/4	71	1	4	
2		11/5	18		0	0
5		5/5	39	0	0	
6		5/5	25	0	0	
8		8/5	225		0	0
1	Polygonum aviculare (Knotgrass)	24/4	67	6	0	
2		11/5	20		10	5
5		5/5	474		0	
6		5/5	49	0	0	
7		4/5	33		6	0
8		8/5	175		0	0
1	Sinapis arvensis (Charlock)	24/4	38	16	20	
1	Chenapodium album (Fat Hen)	24/4	16	94	88	
2		11/5	14		100	66
5		5/5	71	43	4	
6		5/5	66	4	1	
7		4/5	55		85	18

TABLE III continued

Site	Weed Sp.	Date of Assessment	No./ 1600 sq in.	Endothal + Propham		
				2 + 1½	4 + 3	6 + 4½
2	Galium aparine (Cleavers)	11/5	22		14	5
3 4	Urtica urens (Annual nettle)	3/5 4/5	81 113	0	0 0	 0
3 5 6 7	Poa annua (Annual Meadow grass)	3/5 5/5 5/5 4/5	27 14 131 10	22 0 0	44 0 0 0	 0
3 7	Senecio vulgaris (Groundsel)	3/5 4/5	19 10	25	20 20	 40
5	Melandrium album (White Campion)	5/5	128	0	0	
5	Capsella bursapastoris (Shepherds Purse)	5/5	65	0	0	
5	Trifolium sp. (Clover)	5/5	24	0	0	
5	Fumaria officinalis (Fumitory)	5/5	18	0	0	
5 7	Matricaria maritima (Mayweed)	5/5 4/5	16 31	0	0 9	 0
6	Anagallis arvensis (Scarlet Pimpernel)	5/5	13	0	0	
8	Avena fatua (Wild oat)	8/5	53		50	20

PRE-EMERGENCE WEED CONTROL IN SUGAR BEET: EXPERIMENTS IN 1959 AND 1960

A. F. Murant* and G. W. Cussans

Norfolk Agricultural Station, Sprowston, Norwich

Summary. In seven replicated trials in 1959 confirmation of earlier encouraging results was obtained with pre-emergence applications of endothal and mixtures of endothal and propham in sugar beet. Mixtures of cyclo-octyl dimethylurea (OMU) and butinol chlorophenyl carbamate (BIPC) appeared less reliable. The effectiveness of all treatments appeared to depend on the clay and organic matter contents of the soils, but the OMU/BIPC mixture seemed also to be affected by rainfall.

Tests on 28 sites in 1960 gave some confirmation of an influence of soil type on the action of endothal/propham but there was also a clear effect of rainfall after spraying. OMU/BIPC gave better results than in 1959 but some crop damage occurred.

Further work is required to study the effects of soil type and rainfall on the action of endothal/propham and OMU/BIPC and also on the effect of pre-sowing applications of endothal/propham.

INTRODUCTION

Experiments in 1958 on weed control in sugar beet with endothal and endothal/propham mixtures were described at the Fourth British Weed Control Conference (Murant, 1958). This paper presents the results of further experiments with these treatments and also with mixtures of cyclo-octyl dimethylurea (OMU) and butinol chlorophenyl carbamate (BIPC) which were tested successfully in Germany in 1958 (Hanf, 1959) under the code name HS/55.

METHODS AND MATERIALS

Experimental technique was the same as described previously (Murant, 1958). The chemicals used were as follows:-

Propham: 50 per cent w/w wettable powder (Bugges Insecticides Ltd.)

Endothal: 19.2 per cent w/v a.e. aqueous solution (Pennsalt Chemical Co., Washington, U.S.A.)

Endothal/propham mixture: in 1959 the above formulations were mixed and applied together; in 1960 a special formulation supplied by the Murphy Chemical Co. Ltd., Wheathampstead, was mostly used. This was a miscible oil containing 8.6 per cent w/v propham and 11.4 per cent w/v endothal a.e.

OMU/BIPC: miscible oil containing 8 per cent OMU and 5.5 per cent w/w BIPC (Boots Pure Drug Co. Ltd.)

* Now at the Scottish Horticultural Research Institute, Mylnefield, Invergowrie, By Dundee.

RESULTS

Experiments in 1959

In 1959 the chemicals were compared in seven replicated trials on a range of typical sugar beet soils, black fen being excluded because the chemicals were known to be inactivated on this soil type. Site details are given in Table I and results in Tables II and III. The herbicides were applied soon after sowing the crop in all trials except no. 3 at Ingham where the only weed of importance was wild oat; here OMU/BIPC was not used and the other chemicals were sprayed onto prepared land two days before sowing and harrowed into the soil. (The manufacturers of OMU/BIPC recommended it should always be applied after sowing, preferably within 3 days.)

Effect on Sugar Beet

Several treatments caused statistically significant reductions in braird at sites 1 - 4. These reductions assume practical significance when they are reflected in the final plant population. In Table II figures for percentage emergence are not given but it can be seen that 9 lb/ac endothal and the middle and upper doses of endothal/propham reduced the plant population in trials 1 and 3. Yield figures were obtained for trial 3 and show that this reduction in plant population led to a loss of yield of 7.8 cwt of sugar/ac, or 12 per cent of the crop. This was the only site where yield reductions were recorded; at Hemsby (trial 2) hoeing and singling of the plots was delayed and the sugar beet suffered considerable weed competition on the unsprayed plots, leading to significant increases in yield on all the treated plots.

Table II also confirms what has been noted previously, that, with sugar beet, considerable reductions in seedling size (vigour) may be produced by herbicides without affecting the yield.

Effect on weeds

Endothal was effective at all doses against Polygonum aviculare, P. convolvulus, Stellaria media (trial 1 only), Matricaria maritima ssp. inodora, Senecio vulgaris, Anagallis arvensis, Capsella bursa-pastoris, Viola tricolor, Papaver rhoeas, Poa annua, Rumex crispus and Veronica persica.

The endothal/propham mixture controlled all the above species well and gave improved control of Stellaria media, Avena fatua and possibly also of Atriplex patula (trial 1) and Fumaria officinalis. It is note-worthy that in trial 5 endothal/propham gave fair control of Avena fatua when not mixed into the soil.

Endothal and endothal/propham had little effect against Atriplex patula and Chenopodium album at any dose; the OMU/BIPC mixture gave better, although often still partial control of these species. Reduction in the number of other weeds with the OMU/BIPC mixture was of the same order as with endothal/propham for 8 species (including Stellaria media, Senecio vulgaris and Poa annua), but less for 8 other species (including Polygonum aviculare and Avena fatua).

Variation between sites

It was concluded as a result of the 1958 trials that there was no evidence that soil type influenced the action of these chemicals apart from their inactivation on black fen soil. However, it is clear from an inspection of Tables II and III that in 1959 the toxicity of all the herbicides, both to the crop and to the weeds, varied between sites and that they were most effective in trial 1 and least effective in trial 7. The trials have in fact been tabulated in order of decreasing crop and weed damage. Reference to Table I shows that there is a relationship between phytotoxicity and the amounts of organic matter and clay.

Information was also obtained on pH, free $CaCO_3$, and the N P_2O_5, and K_2O status of the soils but there is no obvious association of any of these factors with herbicidal activity.

If it is assumed that absorption onto soil colloids is important and that the absorptive properties of organic matter are 5 times that of clay (which may not necessarily be true for these herbicides) it is possible to calculate a figure for 'Relative Absorption' (= 5 x organic matter per cent + clay per cent) and the effect of this combined factor on the reduction in sugar beet vigour by the upper dose of endothal/propham is shown in Fig.1. Although adsorption onto soil colloids was almost certainly not the only cause of variation between sites, it appeared from this series of trials to be a major one, at least for endothal and endothal/propham. These latter treatments seemed to be relatively little affected by rainfall after spraying; for example the results at Sprowston in 1959 were not markedly different from those in 1958 described at the previous Conference (Murant, 1958), although the rainfall in the 28 days after spraying was 0.93 in. in 1959 compared with 2.77 in. in 1958. From some of the 1960 experiments and from tests carried out by the British Sugar Corporation the OMU/BIPC mixture appeared to be more dependent on rainfall than did the other treatments.

It was concluded as a result of the 1959 tests that although all the treatments were very dependent upon environmental conditions, endothal/propham was the most promising for future work, because it seemed likely to be affected mainly by soil type, a factor which could possibly be allowed for, as a result of further experiments, in selecting the dose to be applied. The dose of OMU/BIPC could probably not be chosen in the same way because of the rainfall effect. Endothal/propham was preferred to endothal alone because of the slightly broader range of weeds controlled.

Experiments in 1960

In 1960, endothal/propham was tested at four doses and OMU/BIPC at two, on 28 sites covering a wide range of soil types. Each dose was replicated twice at most sites. In all cases the chemicals were applied onto the soil surface soon after drilling.

Table IV gives relevant information for each site and Table V shows the effect of two doses of endothal/propham and one of OMU/BIPC on sugar beet and weeds. These doses were as follows:-

Endothal/propham A :- 6.75 lb endothal + 5.06 lb propham/ac

Endothal/propham C :- 3.00 lb endothal + 2.25 lb propham/ac

OMU/BIPC :- 0.50 lb OMU + 0.34 lb BIPC/ac

Effect on sugar beet

In Fig. 2 the figures for sugar beet vigour for endothal/propham dose A are plotted against those for "Relative Absorption" for comparison with Fig. 1, and in Fig. 3 against those for rainfall in the 21 days after spraying.

From these diagrams crop vigour appears to be positively correlated with "Relative Absorption" and negatively with rainfall.

The correlation coefficients are:-

Between crop vigour and "Relative Absorption" + 0.30 (barely significant at $P = 0.05$).

Between crop vigour and rainfall - 0.80 (significant at $P \leq 0.001$)

However, further inspection of Figs. 2 and 3, in which March applications have been distinguished from April ones, shows that:-

1) March applications were mostly on soils with low "Relative Absorption" figures. This is to be expected because light land is generally sown first.

2) More rain fell in the 21 days after spraying on sites sprayed in March than on those sprayed in April.

Thus there is a chance relationship between soil type, date of spraying, and rainfall following spraying and Figs. 2 and 3 are to some extent reflections of each other. Date of spraying could be important in so far as soil temperatures may affect the action of the chemicals but rainfall after spraying and soil type appear likely to have been of greatest importance.

The effect of these two factors has been examined independently by calculating the partial correlation coefficients. Thus the partial correlation coefficient between crop vigour and "Relative Absorption", eliminating the effect of rainfall from the analysis, becomes 0.15 (non-significant) whereas that between crop vigour and rainfall eliminating the effect of "Relative Absorption" becomes - 0.78 (significant at $P \leq 0.001$). Therefore in 1960 rainfall was apparently more important than soil type in determining the phytotoxic effect of endothal/propham.

Endothal/propham dose C and OMU/BIPC used at the dose recommended by the manufacturers both had similar effects on the crop; crop damage was generally low so that the effects of rainfall and soil type were less obvious than with the higher dose of endothal/propham, although they were similar.

Effect on weeds

No attempt was made in 1960 to score for control of individual weed species, so that some instances of poor weed control may be due to the predominance of resistant species. However, in general, weed control was good with dose A of endothal/propham and reasonably good with dose C except on sites with a high "Relative Absorption" figure and/or low rainfall after spraying.

The OMU/BIPC mixture was in most cases slightly inferior to dose C of endothal/propham.

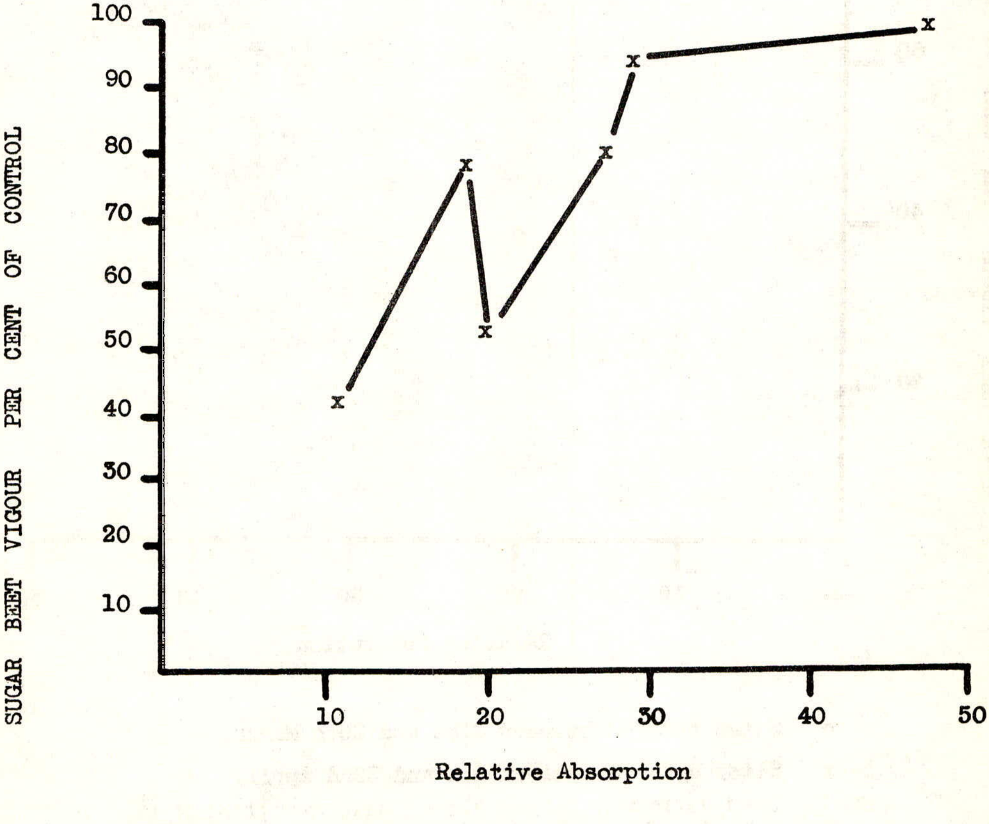
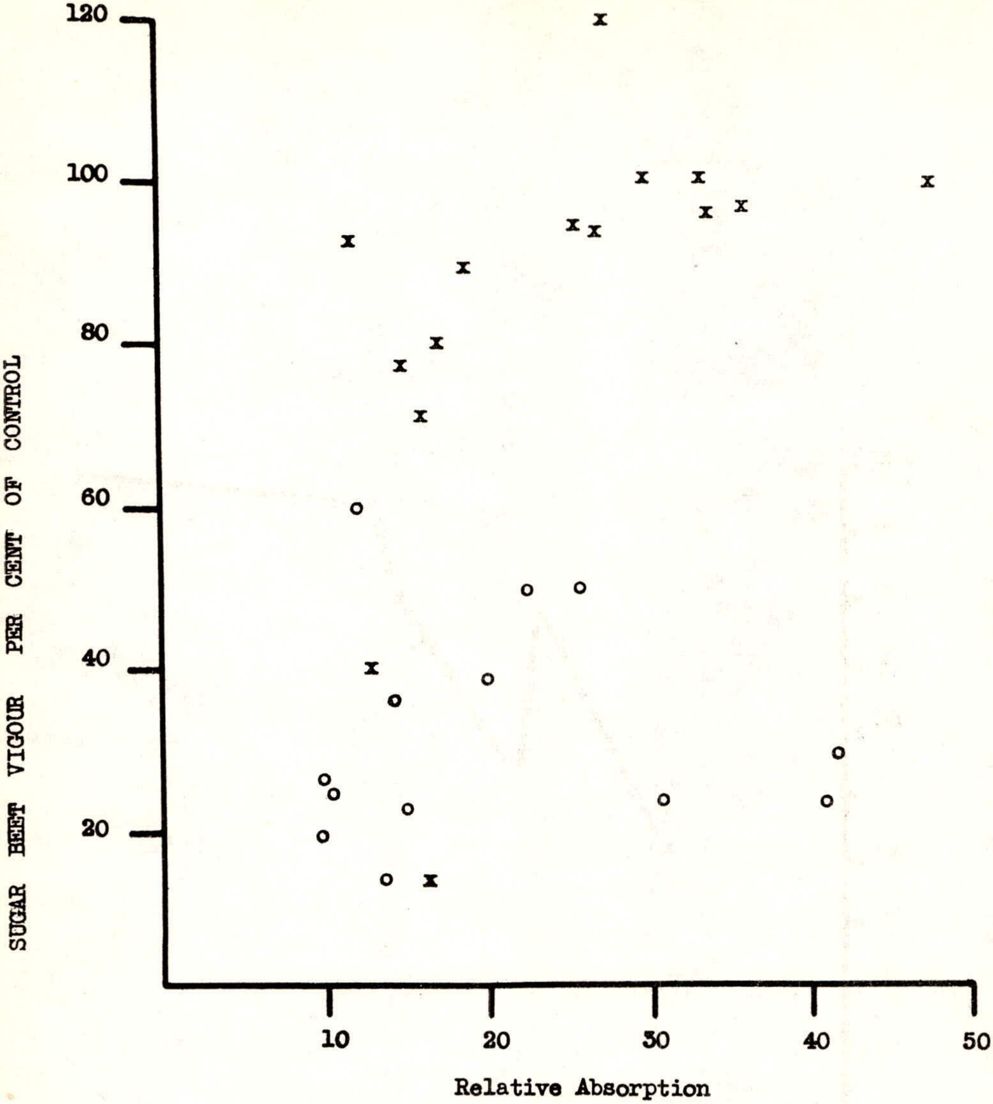


Fig. 1. The relationship between the Relative Absorption of the soil at each site and the effect on sugar beet vigour of 6 lb/ac endothal + 4.5 lb/ac propham (1959 experiments).



o Sites sprayed between 21st and 28th March.

x Sites sprayed between 4th and 22nd April.

Fig. 2. The relationship between the Relative Absorption of the soil at each site and the effect on sugar beet vigour of 6.75 lb/ac endothal + 5.06 lb/ac propham (1960 experiments).

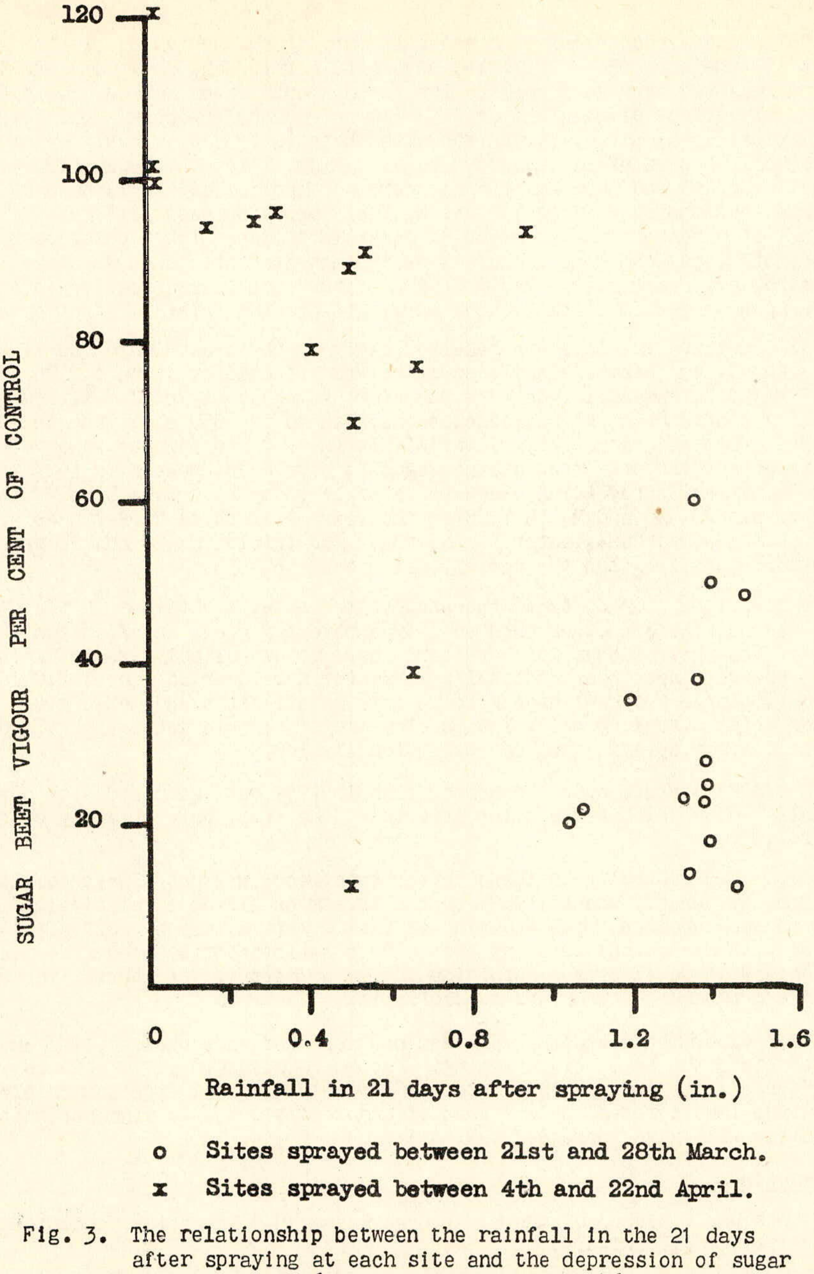


Fig. 3. The relationship between the rainfall in the 21 days after spraying at each site and the depression of sugar beet vigour by 6.75 lb/ac endothal + 5.06 lb/ac propham (1960 experiments).

Discussion

In 1959 seedbed conditions were generally dry at the beginning of the season but all the experiments reported here were carried out on middle and late sowings and received average precipitation in the month after sowing. No conclusions about the effect of rainfall on endothal or endothal/propham could be drawn from the 1959 trials except by comparison with those in 1958 previously reported (Murant, 1958), when rainfall amounts were very high. From this comparison it seemed that endothal and endothal/propham were not appreciably influenced by rainfall and that the main factor affecting their behaviour was soil type. Furthermore, it appeared that it might be possible to determine a relationship between phytotoxicity and some measurable soil characteristic such as clay content and/or organic matter. The OMU/BIPC mixture was less effective than endothal/propham and seemed likely to be more affected by rainfall after spraying.

In 1960 adequate rainfall was received early in the season when the lighter land was sown but the heavier land sown later was affected by drought. The effects of rainfall and soil type were therefore somewhat confused. Although there is some confirmation of the conclusions reached in 1959 about the influence of soil type, rainfall had a far greater effect in 1960 and appears to have been the more important factor. Crop damage seems to have been greater in 1960 than in 1959 on heavy soils receiving adequate rainfall (compare trials 6 and 7 in 1959 with trials 22, 26 and 27 in 1960). The reason for these differences are not clear but one important factor may be that 1960 trials 22, 26 and 27 were sprayed a month earlier than the corresponding ones in 1959.

It is clear that, in spite of the encouraging results obtained in the two previous seasons, factors other than soil type have too great an effect on the behaviour of endothal/propham for a suitable dose to be reliably predicted for any site. However, dose C of endothal/propham (or the lower dose D of 2.0 lb/ac endothal + 1.5 lb/ac propham) appear to be safe on all sites and would give fairly good weed control on soils low in clay and/or organic matter, provided that rainfall after spraying was not exceptionally low.

The OMU/BIPC mixture appeared better than in 1959 but, compared with dose C of endothal/propham which had similar effects on the crop, have slightly poorer weed control.

Although weed control with these latter treatments was not always complete there is some evidence (Murant, 1959) that a treatment giving a relatively small reduction in weed numbers, with stunting of the survivors, may be sufficient in combination with mechanical thinning, to leave a satisfactorily weed-free plant; the main object of developing a herbicide for sugar beet is, of course, for use as part of a programme of complete mechanisation.

In other experiments endothal/propham has appeared safe when applied and incorporated into the soil before sowing. Future work should be devoted to examining the effects and possible inter-relationships of soil type and rainfall on pre-sowing, incorporated applications of endothal/propham to find out whether this technique will give increased reliability.

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TABLE I. SITE DETAILS FOR 1959 SPRAYING TRIALS

Trial		Silt per cent	Clay per cent	O.M. per cent	Relative Absorption ⁂	Date drilled	Date sprayed +	Rainfall in 28 days after spraying (in.)	No. of days before rain
1	Docking, Norfolk	5	5	1.2	11.0	3/4	5/4	1.35	4
2	Hemsby, Norfolk	11	10	1.7	18.5	9/4	10/4; 19/4	2.26	4
3	Ingham, Norfolk	23	12	1.6	20.0	12/4	10/4	-	-
4	Sprowston, Norfolk	16	12	2.1	22.5	20/4	20/4; 21/4	0.93	3
5	Tannington, Suffolk	13	15	2.5	27.5	4/4	4/4; 9/4	1.51	1
6	Tacolneston, Norfolk	10	13	3.2	29.0	15/4	21/4	1.39	4
7	Swinefleet, Yorks.	26	27	4.1	47.5	23/4	23/4	1.30	3

⁂ See text

\+ Where two dates are given the first refers to the OMU/BIPC mixture only.

TABLE II. EFFECT OF HERBICIDES ON SUGAR BEET - 1959

(Treatments in lb/ac)

Assessment	Trial	Control	Endothal			Endothal + Propham			OMU + BIPC		S.E. per plot (per cent of mean)
			4	6	9	3 + 3	4.5 + 4.5	6 + 4.5	0.50 + 0.34	0.62 + 0.43	
Seedling Vigour, percent (Scores by two observers)	1	100	88**	84**	70**	88**	64**	65**	84**	66**	19.6
	2	100	99	95*	82**	80**	69**	49**	60**	64**	13.0
	3	100	-	69**	57**	53**	32**	36**	-	-	12.3
	4	100	98	93**	80**	92**	83**	82**	92**	82**	8.4
	5	100	102	90*	85**	82**	69**	75**	86**	72**	13.1
	6	100	98	96	98	95	84*	85*	88*	82*	19.5
	7	100	100	100	100	100	100	100	100	100	8.1
Final Plant Population (x 1,000/ac)	1	25.3	28.5	26.1	21.1*	24.7	17.6**	20.1*	25.1	22.1	13.9
	2	23.1	26.2	26.9	26.2	29.6	26.0	25.7	25.6	26.3	10.5
	3	27.5	-	26.6	24.8**	26.3	24.9**	24.0**	-	-	5.1
	4	28.9	29.0	28.8	28.0	29.4	28.4	28.6	28.6	29.3	4.2
	5	24.8	23.6	25.3	25.0	24.8	25.7	24.9	24.5	24.4	6.1
	6	17.6	18.4	16.8	18.7	18.8	17.6	21.5	17.9	17.8	12.4
	7	28.1	25.1	26.3	24.0	24.5	25.2	24.7	24.0	30.7	11.7
Sugar Yield (cwt/ac)	2	22.8	34.4**	34.0**	33.6**	33.2**	32.1**	32.0**	31.7**	33.0**	13.4
	3	63.7	-	65.2	59.3	61.1	57.9*	55.9*	-	-	6.9
	4	35.4	33.7	41.6	32.9	35.2	34.0	31.2	30.3	29.1	25.8
	5	58.3	56.0	59.9	59.6	57.7	55.4	55.4	56.9	55.2	5.6
	6	39.6	44.5	42.0	43.0	44.3	43.0	47.6	42.1	43.0	13.7

Asterisks indicate treatments showing significant differences from control at

* P = 0.05

** P = 0.01

TABLE IV. SITE DETAILS FOR 1960 SPRAYING TRIALS

Trial			Silt per cent	Clay per cent	O.M. per cent	Relative Absorption*	Date drilled	Date sprayed	Rainfall in 21 days after spraying (in.)	No. of days before rain
1	Roughton	Norfolk	8.2	2.0	1.6	10.0	24th March	24th March	1.36	1
2	Aylsham	"	6.2	2.0	1.6	10.0	24th March	24th March	1.36	1
3	Trimingham	"	6.2	2.0	1.7	10.5	25th March	25th March	1.36	1
4	Plumstead	"	4.1	2.1	2.0	12.1	21st April	22nd April	0.50	3
5	Gimingham	"	6.2	4.1	1.7	12.6	25th March	25th March	1.32	0
6	Bircham	"	8.0	8.1	1.0	13.1	1st April	4th April	0.63	1
7	Garboldisham	"	6.0	8.1	1.2	14.1	22nd March	22nd March	1.44	5
8	Martham	"	4.1	4.1	2.1	14.6	25th March	28th March	1.15	0
9	Docking	"	4.0	6.1	1.8	15.1	1st April	4th April	0.63	1
10	Hockham	"	8.1	6.1	1.8	15.1	19th March	22nd March	1.03	9
11	Sth. Creake (i)	"	8.1	12.1	0.9	16.6	5th April	5th April	0.48	2
12	Brancaster	"	2.1	10.1	1.4	17.1	5th April	5th April	0.48	2
13	Trimley	Suffolk	22.3	10.2	1.5	17.7	6th April	8th April	0.37	1
14	Sth. Creake (ii)	Norfolk	8.1	12.2	1.4	19.2	4th April	5th April	0.48	2
15	Brumstead	"	18.2	12.1	1.7	20.6	24th March	25th March	1.32	1
16	Kenninghall	"	10.2	12.3	2.1	22.8	22nd March	22nd March	1.44	5
17	Brantham	Essex	12.3	14.3	2.4	26.3	7th April	8th April	0.13	5
18	Easton	Suffolk	8.2	16.4	2.0	26.4	21st March	21st March	1.38	6
19	Bunwell	Norfolk	12.2	18.4	1.8	27.4	6th April	7th April	0.91	0
20	Baston (i)	Northants	14.4	10.3	3.5	27.8	4th April	6th April	Nil	36
21	Baston (ii)	"	18.5	14.4	3.2	30.4	4th April	6th April	Nil	36
22	Boxford	Suffolk	26.8	16.4	3.0	31.4	18th March	21st March	1.32	8
23	Werrington	Peterboro'	14.3	20.6	2.6	33.6	1st April	6th April	Nil	36
24	Eye	Suffolk	24.9	12.4	4.4	34.4	6th April	8th April	0.25	2
25	Rushbrooke	"	14.5	26.8	1.9	36.3	6th April	7th April	0.29	0
26	Halesworth	"	10.4	26.8	2.9	41.3	18th March	21st March	1.05	9
27	Attleborough	Norfolk	18.4	20.3	4.3	41.8	18th March	22nd March	1.39	6
28	St. Ives	Hunts	23.3	18.9	5.9	48.4	11th April	12th April	-	-

* See text

N.B. Rainfall figures were recorded as close to the trial site as possible but in a few cases the nearest rain gauge was up to 3 miles away.

TABLE V. EFFECT OF HERBICIDES ON SUGAR BEET AND WEEDS - 1960

Trial	Sugar Beet						Weeds		
	Emergence, per cent of control (counts on twelve 18in. x 4in. quadrats/plot)			Vigour, per cent of control (scores by two observers)			Cover, per cent of control (scores by two observers)		
	Endothal + Propham		OMU + BIPC	Endothal + Propham		OMU + BIPC	Endothal + Propham		OMU + BIPC
	Dose A	Dose C		Dose A	Dose C		Dose A	Dose C	
1	57	94	105	18	52	63	0	27	15
2	27	74	92	25	71	88	2	22	40
3	49	99	99	24	64	59	0	14	20
4	98	104	98	92	92	98	40	51	74
5	66	84	96	60	81	78	-	-	-
6	46	84	110	40	70	75	8	16	30
7	78	82	98	12	22	75	5	15	32
8	69	96	99	35	68	71	0	6	27
9	97	83	-	78	87	-	18	37	-
10	35	66	-	21	51	-	5	20	-
11	76	94	112	71	86	91	15	33	85
12	12	28	26	12	22	40	18	25	28
13	96	89	92	80	96	87	22	40	15
14	81	73	117	89	89	100	14	24	32
15	103	102	95	38	81	73	0	13	21
16	66	86	112	49	74	77	15	26	44
17	100	86	88	95	93	91	54	61	65
18	97	120	110	50	86	76	4	17	48
19	69	69	58	94	97	86	27	34	37
20	104	101	107	120	100	133	33	78	44
21	102	106	107	100	100	100	30	70	90
22	34	79	93	23	65	78	0	24	24
23	98	98	94	100	100	100	100	100	100
24	98	106	113	96	101	97	50	63	75
25	93	96	96	96	96	91	36	57	70
26	38	60	84	22	67	86	12	39	34
27	47	78	88	28	77	74	-	-	-
28	107	85	108	100	100	100	-	-	-

POST-EMERGENCE NITRATE OF SODA SPRAYS FOR COMBINED NITROGENOUS FERTILIZATION AND WEED CONTROL IN SUGAR BEET

A. Coombe and J. Dundas

Chilean Nitrate Agricultural Service

Summary. Effective weed control is obtainable in sugar beet fields by post-emergence spraying with 2½-3 cwt. nitrate of soda in 65-100 gal. water plus spreader/ac. The spray is most effective if applied when the beets have not more than two true leaves and the weeds are not beyond the cotyledon or small-rosette stage, and if preceded by good growing weather and followed by at least 24 hours' dry warm weather. Sixty per cent or more control is obtainable and the destruction and checking of weed growth make possible a saving of labour in hoeing and the postponement of hoeing and singling. There is no financial risk in the use of the spray because it acts as a nitrogenous fertilizer, giving a yield equal to that obtained with a solid top-dressing. The amount of nitrogen the spray contains should be taken into consideration in determining the nitrogen fertilization of the crop.

INTRODUCTION

A number of papers have been published recently in Britain, Eire and on the Continent on the use of nitrate of soda as a post-emergence herbicidal spray for sugar beet fields and it is the object of this paper to review the results of the trials described in these papers.

The apparent paradox of the use of a nitrogenous fertilizer as a herbicide is explained by the fact that the sodium in the nitrate of soda is beneficial to sugar beet, but is injurious to most annual weeds when applied as a solution to their leaves and can kill them or at least severely check their growth.

Lüdecke and Winner (1958) found that the susceptibility of plants to nitrate of soda spray is related to their threshold of plasmolysis. The higher the concentration of salt required to induce plasmolysis the greater is the resistance of the plant to the spray. For example, more than 50 per cent of the epidermal cells of leaves of Polygonum persicaria (redshank), a susceptible weed, were plasmolysed by the application of 0.3 mol $NaNO_3$ solution whereas sugar beet was unaffected by solutions of up to 0.5 mol.

Herbicidal sprays for sugar beet fields are of importance partly because of the extension of precision sowing with reduced quantities of monogerm seed, a practice which makes the crop more susceptible to weed growth (Detroux, L. *et al* 1959a, Parker, C. 1956) and partly because they save labour in hoeing (Joyce, J. 1958, Murant, A.F. 1959, Schaeffler, H. *et al* 1957).

METHODS AND MATERIALS

The materials used are nitrate of soda, water and a spreader. The addition of a spreader to the solution does not increase the susceptibility of resistant species but it does increase the injurious effect of the spray on susceptible species (Schaeffler, H. et al 1957). Spreaders which have been used successfully are Agral 90 at 2½ pt per 100 gal solution, Shellestol at ½ gal/100 gal and BASF Rapid-Netzer Special at 0.5 per cent.

Nitrate of soda is highly soluble in water and no difficulty is experienced in making up the spray provided that the material is added slowly to the water and the water is thoroughly agitated meanwhile (Parker C. 1955).

For the application of the spray a high-volume sprayer is required. The Belgian Institute for the Improvement of the Beet, Tirlemont, use a 2½-metre sprayline fitted with five nozzles (Detroux, L. et al 1959a). In Eire a special 4-nozzle boom has been designed for use with a high-volume sprayer (Joyce, J. 1958). The spray is generally applied to the whole field but band spraying is practised in Eire (4 in. bands) and has been successfully tested at Tirlemont (4 in. bands) and at the Göttingen Sugar Beet Research Institute (6 in. bands)(Detroux, L. et al 1959b, Joyce, J. 1958, Lüdecke, H. et al 1958).

The rates at which nitrate of soda overall sprays have been applied range from 1½ cwt in 50 gal (Malmus, N. 1959) to 3 cwt in 100 gal (British Weed Control Council 1958, Murant, A.F. 1959, Parker C. 1956). Those which have given the best results are 2½-3 cwt in 65-100 gal/ac (320-380 kg in 800 - 1,135 l/ha). Rates for band spraying vary greatly, e.g. 70 lb in 18 gal/ac (80 kg in 200 l/ha) for 4 in. bands in Belgium (Detroux, L. et al 1959b), 2 cwt in 80 gal/ac for 4 in. bands in Eire (Joyce, J. 1958) and 1¾ cwt in 50 gal/ac (230 kg in 600 l/ha) for 6 in. bands in Germany (Lüdecke, H. et al 1958).

Most investigators spray within 2 weeks of the emergence of the beet crop or when the beets have two true leaves. The best results are obtained when the spray is applied just after weed emergence or when the weeds are not beyond the cotyledon or small-rosette stage (Joyce, J. 1958, Lüdecke, H et al 1958, Murant, A.F. 1959); and after the dew has evaporated in the morning and before it begins to form again in mid-afternoon.

It has been found at Sprowston that spraying is most effective if preceded by rapid growing conditions so that the leaf tissues are soft and susceptible (Murant, A.F. 1959), and followed by at least 24 hours of warm, dry sunny weather (Parker, C. 1956). In Germany susceptible weeds have been observed, to show symptoms of injury 2 hours after spraying in warm, sunny weather (Schaeffler, H. et al 1957).

RESULTS

Effect on weeds

In Belgium 64 per cent and 45 per cent weed control was obtained with 2½ cwt nitrate of soda in 65 gal water plus spreader in 1958 and 1959 respectively (Detroux, L. et al 1959 a and b). In Bavaria 40 per cent control was obtained with 2 cwt in 50 gal plus spreader at Innerhienthal and 59-62 per cent with 3 1/8 cwt in 88 gal with or without spreader at Puch (Malmus, N. 1959, Schaeffler, H. et al 1957). At Göttingen the percentage weed control was 89-90 with 1¾ cwt in 65 gal and with 2½ cwt in 70 gal, plus spreader in both cases (Lüdecke, H. et al 1958). At Sprowston 53 per cent, 70 per cent and 80 per cent control was obtained with 2, 2½ and 4 cwt respectively in 100 gal water plus spreader (Norfolk.Agric.Station 1955). Thus, apart from one case in Belgium where the figure was only 45 per cent, 60-90 per cent weed control was obtained with 2½-3 cwt in 65-100 gal/ac (320-380 kg in 800-1,135 l/ha) in all trials for which adequate data are available.

According to Lüdecke and Winner (1958) it is not necessary that a selective herbicide should destroy virtually 100 per cent of the weeds; the success of the operation is ensured if only 60-80 per cent are killed or severely injured provided that these include the species which render hoeing difficult. They point out that it is precisely the species which have broad leaves and which cover the beets rapidly, which are largely destroyed by nitrate of soda spray.

Weed species have been classified according to their susceptibility to nitrate of soda spraying by Parker (1955), Schaeffler and Schmid (1957), British Weed Control Council (1958), Lüdecke and Winner (1958) and table 1 presents their conclusions.

Weeds in the susceptible class are either completely or almost completely killed or severely injured; those in the moderately susceptible and moderately resistant classes are more or less severely injured and impeded in development and those in the resistant class are either slightly injured or undamaged. Of the 49 species of weeds listed in the table, 32 are susceptible or moderately susceptible, only 11 are moderately resistant or resistant and 6 are variable.

All authors are agreed that weeds are mostly much less susceptible after the 2- or 3-leaf stage or when over 3 in. high. According to the British Weed Control Handbook (1958) weeds which are susceptible at the "seedling" (i.e. cotyledon to 2- or 3-leaf stage) are only moderately susceptible or moderately resistant at the "young-plant" (3- or 4-leaf to early flower-bud) stage and those which are moderately susceptible or moderately resistant at the seedling stage are resistant at the young-plant stage. There are some exceptions, however; Stellaria media and Veronica spp., for example, can be successfully controlled after the juvenile stage (Schaeffler, H. et al 1957).

The susceptibility of some species to nitrate of soda sprays has been found to depend on environmental conditions. Polygonum spp., Thlaspi arvensis and Veronica spp. are reported to be very susceptible under fairly moist conditions in Bavaria but only moderately susceptible under drier conditions, owing to denser hair growth interfering with the wetting of the leaves with the spray (Schaeffler, H. et al 1957).

An important aspect of the effect of nitrate of soda sprays which has been widely observed is the distinct retardation of the growth of the weeds (British Weed Control Council 1958, Lüdecke, H. et al 1958). Detroux and Wauthy (1959a) lay particular stress on this effect which they regard as the most important result of the treatment. They found that weeds which were not killed grew slowly and that those whose aerial parts were destroyed did not shoot again for six weeks. Norfolk Agricultural Station say that severe scorching and defoliation can be almost as useful as killing as it makes the beet more easily visible for hoeing and singling (Parker C.1955). It is not necessary for the nitrate of soda spray to kill all weeds; if susceptible species are destroyed and species of intermediate reaction are temporarily suppressed this enables the beet crop to become established and to outgrow the weeds.

TABLE I. WEED SUSCEPTIBILITY TO NITRATE OF SODA SPRAYS APPLIED AT THE SEEDLING STAGE

	Susceptible	Moderately susceptible	Moderately resistant	Resistant
Alchemilla arvensis	x			
Anagallis arvensis	x			
Anthemis arvensis		x		
Anthemis cotula		x		
Atriplex hastatum				x
Atriplex patula				x
Capsella bursa-pastoris	x	x		
Chenopodium album			x	x
Cirsium arvense			x	
Convolvulus arvensis	x			
Equisetum arvense				x
Euphorbia helioscopia				x
Fumaria officinalis	x	x	x	x
Galeopsis ladanum	x			
Galeopsis tetrahit	x	x		
Galinsoga parviflora	x			
Galium aparine			x	x
Lamium amplexicaule	x	x		
Lamium purpureum		x		
Lycopsis arvensis		x	x	
Matricaria discoidea		x	x	
Matricaria maritima inodora	x	x		
Myosotis arvensis	x			
Papaver rhoeas	x	x	x	x
Plantago major			x	
Poa annua			x	
Polygonum aviculare	x	x		
Polygonum convolvulus	x	x		
Polygonum lapathifolium	x	x		
Polygonum persicaria	x	x		
Raphanus raphanistrum	x	x	x	
Senecio vulgaris	x	x		
Sinapis alba		x	x	
Sinapis arvensis	x	x		
Sonchus arvensis		x		
Sonchus asper		x		
Sonchus oleraceus		x		
Spergula arvensis	x	x		
Stachys palustris			x	
Stellaria media	x	x		
Taraxacum officinale			x	
Thlaspi arvense		x		
Tussilago farfara	x			
Urtica urens	x			
Veronica hederifolia	x	x		
Veronica persica	x	x		
Vicia cracca	x			
Viola arvensis	x			
Viola tricolor	x			

(78178)

Effects on labour

The percentage of labour saved by nitrate of soda spraying has been calculated in Germany. In Bavaria (Schaeffler, H. et al 1957) the saving amounted to 5-6 per cent. At Göttingen (Lüdecke, H. et al 1958) there was a saving of 11-15 per cent at 1½ cwt in 60 gal/ac and of 25 per cent at 2½ cwt in 70 gal.

The destruction and the retarded growth of weeds as a result of the use of herbicides make it possible to delay hoeing and singling and to carry out these operations with a smaller labour force. Hoeing and singling should however be carried out within a few days of spraying. (Detroux, L. et al 1959a, Murant A.F. 1959).

Effects on yields

Nitrate of soda sprays are a form of nitrogenous top-dressing and give yield increase equivalent to those obtained with solid top-dressings.

At Göttingen yields with nitrate of soda sprays were as good as or better than those obtained with equivalent solid top-dressings with nitrate of soda provided that the crop was thoroughly hoed. (Lüdecke, H. et al 1958). Root and sugar yield increases ranging up to 10 per cent and 5 per cent respectively as compared with the non-top-dressed control are reported (Detroux, L. et al 1959a, Malmus, N. 1959).

Other considerations

At Göttingen sugar yields were slightly reduced when the nitrogen contained in the nitrate of soda sprays (32 lb N/ac) was not taken into consideration in fixing the total nitrogen dressing for the crop (Lüdecke H. et al 1958). Parker (1956) says that when the basal dressing is reduced by the amount of nitrogen to be applied as top-dressing, in the form of spray, yields are unaffected by the spray. Trials at Sprowston (Murant, A.F.1959) have established that nitrate of soda applied as a spray before singling is as effective as the equivalent quantity of nitrogen applied to the seedbed.

There is no greater financial risk in the use of nitrate of soda spray than in the application of the nitrogenous top-dressing in solid form. Should the weed control given by the spray be inadequate owing to unfavourable weather, faulty technique or some other factor, the spray still acts as top-dressing.

Nitrate of soda sprays are to be regarded as having two combined roles - nitrogenous top-dressing and post-emergence herbicide. Most workers emphasize that they should be used in conjunction with and not as a substitute for proper cultural operations.

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Presentation by Mr. C. Parker of preceding three papers on sugar beet

Mr. Dadd has already mentioned the necessity for a reliable herbicide treatment in sugar beet to supplement the various mechanical aids for quicker and easier singling of the crop with reduced hand labour. Quite intensive work has been in progress in this country for the last eight years but few truly selective herbicides have emerged. Against grass species (Avena fatua in particular) sodium trichloroacetate and propham have shown promise as selective herbicides.

Against broad-leaved weeds post-emergence nitrate of soda and sodium chloride have proved usefully selective and the paper by Coombe and Dundas provides a very useful review of the work done with nitrate of soda, indicating the way it should be used and the results to be expected. The drawbacks of nitrate of soda treatment are (i) the problem of handling large quantities of the chemical (2½-3 cwt/ac)(ii) the high volume of water required (100 gal/ac) when many farmers no longer retain a high volume sprayer. (iii) dissolving the material is time consuming (iv) for good results the treatment requires favourable weather conditions - preferably 24 hr dry post-application and finally (v) the important weeds Chenopodium album and Atriplex patula generally show some resistance to the treatment. In favour of nitrate of soda is its value as a nitrogenous fertiliser and references are quoted to work showing that it is of as much benefit to the crop applied as a herbicidal spray as it would be as a dry top-dressing or applied to the seed-bed, in terms of manurial value. It is certainly of great value in an emergency and could probably be used on a wider scale than at present. This paper is of value in reminding us of this well-established and somewhat neglected treatment. One aspect of nitrate of soda spraying not mentioned above is that the larger weeds may eventually recover from the scorch effect and necessitate hand-hoeing. Therefore the treatment is assisting rather than replacing hand-labour and there is great scope for a more thorough and reliable treatment.

Many pre-emergence treatments have been tested over the years and if a good one could be found it could have the advantage of removing weed competition from the start and in that respect be more ideal than a post-emergence treatment. Out of the many compounds tested, endothal and propham are the two which have proved truly selective, each against its own limited range of weeds. Murant first tried a combination of the two in 1958 and having obtained a useful widening of the weed spectrum, without any undue increase in toxicity to the crop, extended the work to seven experiments in 1959; these being reported in the first half of the paper by Murant and Cussans. Useful results were obtained with doses of 3 lb/ac of each, controlling most of the troublesome weeds other than Chenopodium or Atriplex. There was adequate rainfall at most of the sites reported upon and under these conditions there appeared to be some correlation of results with soil type. This led to considerations of how soils could be classified in relation to herbicidal activity and a factor known as "relative absorption" was suggested. Plotting herbicidal activity against this factor indicated some relationship-the greater the absorbing power the lower the activity.

In 1960 Cussans extended the work in an attempt to confirm the relationship of activity with soil type and laid down an extensive programme with 28 sites. In the meantime the Murphy Chemical Co. Ltd. had prepared a formulation incorporating both herbicides in a ratio of 4 parts endothal to

3 parts propham. This mixture was tested at 21 centres during 1960 as reported by Bagnall, Caldicott and Minter. The results from this series of trials indicated, in general, a tolerable relationship of herbicidal activity with relative absorption except at one centre where crop damage was greater than expected. Mr. Cussan's results were less satisfactory and there were three sites where appreciable crop damage occurred, following the application of a standard dose, in spite of a high relative absorption of the soils. The general conclusions therefore is that relative absorption is not a reliable criterion to use in fixing the dose of endothal/propham mixtures for weed control in sugar beet. There appears to be a risk of crop damage on certain heavier soils or under certain circumstances. Bagnall and his colleagues believe it may be due to high coarse-sand contents resulting in undue percolation of the prophem to the crop, while Cussans wonders if the anomalous results were associated with the long period of cold weather which followed these particular applications in mid-March.

Weed control varied considerably from site to site. In any one experiment there was always one selective dose but this dose was quite unpredictable. On some of the heavier soils the effective dose was unexpectedly low whilst in the absence of a reasonable rainfall, during seven to ten days after application, it was invariably high. This factor of rainfall was especially important this season and seriously affected the results reported in both papers. Hence it is still difficult to make reliable recommendations but, with the proviso that under dry conditions weed control may be disappointing, the following doses should be safe:

on light sands	2 lb endothal and 1½ lb propham/ac
on light/medium soils	3 lb endothal and 2½ lb propham/ac
on medium soils	4 lb endothal and 3 lb propham/ac (although there may be some element of risk of crop damage at this dose)

The treatment is definitely of value and should be useful but with endothal having high mammalian toxicity the search goes on for safer materials.

Results with a mixture of CMU and BIPC are reported by Cussans. The tests were not so intensive as with the endothal/propham mixtures and firm conclusions cannot be drawn. It is certainly of interest, having somewhat similar performance to endothal/propham under favourable conditions with, perhaps, superior control of Chenopodium album. This mixture is volatile and appears particularly subject to failure under warm dry conditions as may occur later in the season.

Either or both of these mixtures might be improved, so far as reliability of weed control is concerned, if they were incorporated shallowly into the soil. Bagnall and his colleagues have tested a simple V-shaped coverer-bar trailed immediately behind the spray. They believe that the results show some promise. With the aid of such a technique, or something similar, it is hoped that residual pre-emergence herbicide application in sugar beet might be made more reliable.

THE USE OF HERBICIDAL SPRAYS ON THE POTATO CROP

I. M. Robertson

N.I.A.E. Scottish Station, Howden, Mid Calder, Midlothian

Summary. The passage of tractor wheels over potato land can increase the number of clods and render more difficult the separation of tubers on a potato harvester. A technique has been evolved which reduces to a minimum the number of tractor operations. A fine tilth is produced before planting and inter-row cultivation eliminated by replacing mechanical with chemical methods of weed control. In three seasons of widely differing climatic conditions a mixture of dinoseb and TCA has given a uniformly high standard of weed control. With an early variety more rapid tuber formation and a slightly increased yeild have been obtained; with a late variety yields have remained unaffected. In all cases the clod content has been reduced. Tasting trials have failed to establish taint from the herbicide.

INTRODUCTION

A considerable amount of working is normally necessary on potato land in the early part of the season. This is associated with the production of a satisfactory tilth and with the control of weeds. Thus, during the growing season it is not uncommon to give upwards of ten passes of a variety of tractor drawn implements such as harrows, cultivators and drill ploughs. Whilst the use of these implements may reduce the clod size in the upper surface, observations have shown (N.I.A.E. 1958-59) that the passage of tractor wheels can produce consolidation of the soil and increase the number of clods, particularly in the sub-surface layer. Many of these clods are not subsequently broken down and render more difficult the ultimate separation of tubers in potato harvesters. In Britain, farming tradition has favoured inter-row tillage of the potato crop on the score of increased yield but there is no clear-cut evidence to support this practice. Indeed Pereira (1941) and Russell (1949) confirmed earlier American work when they found inter-row cultivation to depress slightly the yield of potatoes.

A reduction in the number of cultural operations would seem highly desirable and can be achieved simply by (a) producing the desired tilth before planting the crop and (b) the substitution of chemical for mechanical methods of weed control (Robertson 1960).

METHODS AND MATERIALS

In 1958, trial areas were cultivated with (a) disc harrows and rollers to give a uniform tilth similar to that normally accepted for potato land and (b) a rotary cultivator to produce finer clod sub-division. Furrows were opened at 28 in. row width, sets were planted and artificial fertilizer applied by hand after which the drills were split with front-mounted ploughs fitted with covering bodies. The land was then ridged to the final contour. The herbicides were applied by spraying when the first few leaves of the potato plants appeared above ground among the weed seedlings already covering the drill. The weeds were mainly *Polygonum persicaria* (redshank), *Polygonum* aviculare (knotgrass), Galeopsis tetrahit (hemp nettle) and Lolium italicum (Italian ryegrass) with some Chenopodium album (fat hen), Stellaria media (chickweed) and Agropyron repens (couch grass). The herbicides used were (i) dinoseb-ammonium salt and TCA-sodium salt at rates of 6 lb/ac and 10 lb/ac of active ingredient respectively and (ii) MCPA and TCA-sodium salt at 2¼ lb/ac and 10 lb/ac of active ingredient respectively. Dilution was such that the sprays were applied at about 40 gal/ac. A third series of plots in the randomised lay-out were left unsprayed. No further treatment of any kind was given after this stage. For comparison, plots were laid down which were not sprayed and received the mechanical cultivations normally carried out in the potato crop.

In 1959 and 1960 the dinoseb/TCA mixture was used at the same concentration and rate as previously. The land was prepared in a coarse and a fine tilth but the plots were much larger and a commercial planter was used to open the furrows, plant the tubers, apply fertilizer and cover, all in one operation. Drilling to the final contour was carried out immediately. Also in 1960 a smaller trial was laid down using diquat and TCA-sodium salt at rates of 2 lb/ac and 10 lb/ac respectively.

RESULTS

With the dinoseb/TCA mixture, weed seedlings were entirely eliminated and at harvest only occasional plants of couch grass were observed. These all emerged some time after spraying and stemmed from rhizomes covered deeply in the ridge. The potato varieties used were Kerr's Pink and Epicure and plants developed normally with perhaps a slight tendency in the former for the pink colouration in stem and mid-rib to be rather less obvious than usual. Tasting tests carried out on the tubers failed to disclose any residual effect.

The MCPA/TCA mixture used in 1958 gave good control of some of the weeds but others survived, especially Italian ryegrass and soon covered the drill. This treatment was discontinued in the subsequent trials. Diquat/TCA has given excellent control of all weeds in the present season although final results will not be available until the crop is harvested.

The crop yields in Kerr's Pink in 1959 were uniformly high. On the soil of normal tilth which received six inter-row cultivations the average yield was 13.0 ton/ac while on the same soil with herbicide and no inter-row cultivation it was 13.2 ton/ac. Where additional preliminary treatment had been given to produce a fine tilth the yields were 15.0 ton/ac and 15.1 ton/ac respectively for conventional inter-row cultivation and spray treatment. There was therefore, no evidence of a depression in yield following the use of the herbicide.

With the early variety Epicure grown in the 1960 trials inter-row cultivation, which amounted to nine tractor operations, retarded the rate of development when compared with the spray treatment. Although in the latter case, the plants did not appear through the ridge so early, they subsequently developed more rapidly. Size distribution analyses made throughout the growing season showed a consistently greater number of larger sized tubers in the sprayed plots. The final yields were 10.5 ton/ac and 11.9 ton/ac for normal and spray treatment respectively.

An analysis was made of the material discharged over the web of an elevator potato digger. In this way it was possible to obtain a reasonably accurate measure of the clods and tubers which have to be separated in a complete potato harvester. Results set out in table I represent mean values from five runs of the digger. Two main treatments are given for comparison (a) normal working before planting followed by inter-row cultivation and (b) rotary cultivation before planting followed by spray treatment only.

TABLE 1. CLODS AND TUBERS HARVESTED PER 100 FT OF RIDGE

Size Group	Inter-row Cultivation				Spray Treatment			
	Clods		Tubers		Clods		Tubers	
	Number	Wt(lb)	Number	Wt(lb)	Number	Wt(lb)	Number	Wt(lb)
Over 2¼ in	46	31	141	53	9	5	213	75
2¼ in - 1¾ in	72	23	272	55	23	6	261	53
1¾ in - 1¼ in	319	44	211	18	110	13	173	14
Total over 1¼ in	437	98	624	126	142	24	647	142

It is obvious that the number of clods was much reduced by producing initially a fine soil tilth and replacing chemical for mechanical methods of weed control. The ratio of clods to potatoes was approximately 2 to 3 with the conventional cultural methods and 2 to 9 with rotary cultivation and spraying, an alteration which must have a material effect on the ease of separation. There was also a more rapid development of tuber size in the sprayed plots. This would enable an economic yield to be obtained slightly earlier, a feature of some importance with an early variety such as Epicure.

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TRIALS OF CHEMICAL WEEDKILLERS IN POTATOES

C. A. Wood, J. P. Sutherland* and R. J. Stephens

Scottish Horticultural Research Institute, Mylnefield, Invergowrie, Dundee

Summary. An account is given of herbicide trials in potatoes at Invergowrie in 1959 and 1960. Dinoseb-amine, applied at 6 lb/ac to the ridged drills shortly before the emergence of the crop, successfully replaced cultivations as a means of weed control and caused no reduction of crop yield in 1959. Yields for 1960 have still to be recorded. Simazine and other residual herbicides of low solubility gave poor results, probably because their application was followed by dry weather conditions: but some of the less insoluble triazines showed promise. The results largely confirmed North American experience. Preliminary tests on cooked tubers suggested that slight tainting might have been caused by certain of the treatments. Tubers from all treatments sprouted normally in the spring after harvest.

INTRODUCTION

Potatoes require intensive working for weed control until the haulm forms a continuous cover. In some soils cultivations may have beneficial effects in addition to the control of weeds (Hawkins, 1960; Aldrich & Campbell, 1952), although excessive cultivations can reduce yields (Aldrich et al., 1954) and probably retard maturity. Tractor operations on some soils, especially in wet conditions, produce clods which remain until lifting and increase hand work on mechanical harvesters (Robertson, 1960). Chemical weedkillers have successfully been used in North America, where several states issue recommendations (Aldrich et al., 1954; Trevett & Murphy, 1960). These are either for residual herbicides to be sprayed at planting time or for contact herbicides to be used just before the crop emerges. Diuron is recommended at 0.75 lb/ac but is ineffective unless rain falls within two weeks of spraying. Other substituted ureas and several triazines have been used, but all, like diuron, depend for success on rainfull soon after application (Bell & Tisdell, 1958). Dinoseb-amine at 3-6 lb/ac, applied just before the crop emerges, is used to destroy young seedlings of broad-leaved weeds which have grown since planting, and can be combined with either TCA or dalapon if annual grasses are present. Provided that the potato growth is normal, further weed growth is smothered by the crop. Much of the American work refers to "lay-by" weed control (Sawyer et al., 1960). This means control of weeds, mainly annual grasses, that germinate after the final cultivation - a problem that occurs in Britain only when volunteer plants of Italian Rye-grass germinate at this stage.

METHODS AND MATERIALS

Weed control work in potatoes at Mylnefield began in 1959 with a screening trial of a large range of materials and a replicated trial of three herbicide mixtures and simazine. The varieties grown were Home Guard, Majestic and Redskin, planted on 20 - 21 April. The herbicides were applied

* Now at The North of Scotland College of Agriculture, Drummondhill, Stratherrick Road, Inverness.

at the weights of active ingredient per acre shown below and each at a volume rate of 40 gal/ac. In the screening trial the treatments were:

1. fenuron 0.5 and 1.0 lb 2. monuron 1.0 lb 3. atrazine 1.0, 2.0 and 3.0 lb 4. EPTC 9.4 lb 5. tris - (2, 4 - dichlorophenoxyethyl) phosphite* 6. chlorpropham 2.4 lb	Applied 17 days after planting, without renewed cultivation
7. trietazine 1.0, 2.0 and 3.0 lb 8. propazine 1.0, 2.0 and 3.0 lb	Applied to a re-cultivated, weed-free surface 36 days after planting.
9. TCA 8 lb. + dinoseb-amine 6 lb 10. dalapon 2.5 lb + dinoseb-amine 2.7 lb 11. dinoseb-amine 2.7 lb 12. dinoseb-amine 6 lb 13. PCP 3.6. lb 14. MCPB 2 lb 15. mecoprop 1.88 lb	Applied 36 days after planting, without renewed cultivation.

The treatments in the replicated trial were:

1. 2,4-DES 3.6 lb + propham 4 lb 2. 2,4-DES 3.6 lb + fenuron 0.5 lb 3. simazine 1.5 lb	Applied 4 - 7 days after planting.
4. dalapon 5 lb + dinoseb-amine 6 lb	Applied 32 days after planting, without renewed cultivation.

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* as 379 ("Falone")

(78178)

At the time of the earlier sprays no weeds had germinated, but a heavy growth of Fumaria officinalis, Chenopodium album, Lamium amplexicaule, Veronica persica, Polygonum aviculare and P. convolvulus was present when the later sprays were applied. The control plots, cultivated according to normal local practice, were kept clean until nearly the end of June, about 8 weeks after planting. They received nine post-planting cultivations, as follows:

planted	20.4.59	grubbed	24.5.59
harrowed	12.5.59	grubbed	5.6.59
grubbed	13.5.59	grubbed	16.6.59
ridged	14.5.59	grubbed	21.6.59 approx.
harrowed	23.5.59	ridged	21.6.59 approx.

The 1959 season was unusually dry, and the residual herbicides were applied to dry soil. Although 0.74 in. of rain fell soon after the simazine was applied to the main trial, only 0.62 in. fell during the following five weeks. The experimental area appeared from July onwards to be divided into areas of good growth and of relatively poor growth, but the explanation of these differences was not established.

The potatoes in the replicated trial were lifted and weighed. Chats were weighed separately at harvest and the clamped tubers were later graded into ware, seed and thirds. Tubers from all treatments were kept for sprouting tests in 1960.

Tuber samples from the replicated trial were sent to the Ministry of Agriculture, Fisheries and Food's Research Establishment at Aberdeen and to the British Food Manufacturing Industries Research Association at Leatherhead, Surrey, to be tested for chemical tainting. The tests at Aberdeen were on cooked samples from fresh and dehydrated material, and those at Leatherhead on potato crisps. The technique used at Aberdeen relied on a panel of tasters who attempted to pick out the odd sample from three, two of which were from potatoes not sprayed with herbicide. The chance of doing this by a simple guess is 1 in 3. At Leatherhead the method was similar, except that the tasting panel of 12 was selected from a larger group of 33 for ability to detect taint induced in potato crisps by soaking in dilute solutions of "T.C.P." proprietory antiseptic. In the tests for herbicide taint, each combination of herbicide and variety was tested at least twice. In most of the tests the crisps from treated and control plots of the same variety were fried together, because colour differences had been noted in earlier tests where samples had been cooked separately. Note was made of any differences in appearance following identical cooking.

In a further replicated trial on the variety Majestic in 1960, herbicide sprays were applied just before the potatoes emerged. The treatments were:

dinoseb-amine 6 lb (a.e) + dalapon 2.5 lb

trietazine 2 lb

atrazine 2 lb

hand-hoed control

mechanically cultivated control

A screening trial of various rates of dinoseb-amine, diuron, simazine, CMU/BIPC (as "H.S.55") and simazine + chlorporpham was also conducted.

RESULTS

Weed Control

(i) 1959 replicated trial

In this trial the three residual mixtures applied a few days after planting gave negligible weed control, probably because of the low rainfall already noted. There was a reduction in Chenopodium album on the fenuron/ 2,4-DES plots, but the plots of all the residual treatments were smothered with weeds by the beginning of June and the potato haulm growth was obviously depressed. The contact spray of dinoseb and dalapon, however, which was applied to a heavy cover of weeds as mentioned above, gave an almost complete kill, and very few seedlings developed later. These were quickly smothered by the haulm growth. In the poor areas of growth that have been mentioned, the potatoes competed less successfully with the weeds. Few weeds grew on the control plots after cultivations ceased in early June.

(ii) 1959 screening trial

Of the treatments applied 17 days after planting, atrazine at 2 lb and 3 lb gave good weed control despite the dry conditions, and caused no apparent damage to the potatoes. The other treatments gave negligible weed control.

Of the later treatments, propazine and trietazine applied at 2 lb and 3 lb after re-cultivation gave good weed control with little or no effect on the potato growth. Dinoseb-amine at 6 lb was also effective, but dinoseb at 2.7 lb and PCP at 3.6 lb were much poorer. The addition of TCA to the lower rate of dinoseb appeared to decrease the subsequent weed growth. Neither mecoprop nor MCPB gave adequate weed control, and both had a direct stunting effect on the potatoes. Following the use of either TCA or dalapon, tubers of the variety Redskin were less highly coloured than tubers from the control plots.

(iii) 1960 trials

The results in 1960 were similar to those of 1959. Dinoseb-amine at 6 lb with or without TCA or dalapon, again gave a good control of annual weeds which had germinated since the time of planting. None of the residual treatments gave adequate weed control, possibly because the soil was again dry at the time of spraying and rainfall was negligible for several weeks after spraying.

Yield of crop

Total yields from the 1959 replicated trial are given in Table I.

TABLE I. YIELDS OF POTATOES (ALL GRADES) IN 1959

Treatment	Majestic cwt/ac	Redskin cwt/ac	Home Guard cwt/ac
2,4-DES + propham	122.8	104.4	59.4
2,4-DES + fenuron	87.1	81.6	43.1
Simazine	90.4	74.7	53.3
dinoseb-amine + dalapon	183.3	150.4	85.5
Control	194.8	144.5	102.4
S.E. of the difference between any 2 chemical treatment means	17.9	12.9	9.4
S.E. of the difference between the control and any other means	17.3	15.9	15.4

Despite the large experimental errors, probably caused by the uneven growth in different parts of the field, analysis of the total yields showed clear results. The dinoseb/dalapon treatment caused no significant reduction in yield (compared with the control) in any variety, whereas each of the remaining treatments, in which weed control was very poor, significantly depressed yield.

Figures are not yet available for the 1960 replicated trial.

Taint tests and sprouting

Aberdeen tests. The proportion of tasters able to discriminate between controls and herbicide-treated potatoes was in most cases more than 1/3, but only in the case of simazine did a clear majority of the tasters detect the treated samples.

Leatherhead tests. The tasting panel at Leatherhead was asked to comment on the flavour of the crisps, in addition to trying to pick out the odd sample in each triangular test. They did successfully detect some samples from the sprayed plots, but not consistently either for variety or for treatment. The panel did not detect the simazine-sprayed sample of any variety more frequently than could have occurred by chance. On 14 occasions when the treated sample was correctly identified an adverse comment was passed on the flavour of the treated potatoes, but in 125 other correct identifications no preference was shown. In one case the flavour of a control sample was criticised. Colour differences occurred between the controls and the treated samples even after identical cooking, but there was no consistent connection between the presence of a colour difference and detection of taint by the panel.

Potatoes from all the treatments sprouted normally in spring 1960.

DISCUSSION

Dinoseb-amine gave as good a control of weeds in 1959 as normal cultivation, with no reduction in yield. The effects of cultivations on the potato crop, apart from the control of weeds, are little understood, but certainly vary from season to season. Too much, therefore, should not be read into this result. The spring of 1959 was unusually dry, which was perhaps the reason for the unreliability of all the residual herbicides except some of the triazines. Both the success of the dinoseb treatment and the variable results with residual herbicides were to be expected in view of published North American work.

No chemical method of weed control will be acceptable if unpleasant or dangerous residues reach the tubers. The tests conducted at Leatherhead and Aberdeen might suggest that weedkillers used at rates that give good weed control do not cause tainting which is easily recognizable. It is very important, however, that tests of this kind should regularly be included in herbicide work on crops for human consumption.

Acknowledgments

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THE USE OF SIMAZINE ON WINTER SOWN FIELD BEANS

P. Gregory

Chesterford Park Research Station, Fisons Pest Control Limited.

Summary. This paper describes the effects of applying simazine at rates of 2 lb, 1 lb, and 0.5 lb/ac to winter sown field beans (*Vicia faba*) during the 1959-1960 season. Fifteen experiments on different soil types were carried out. Ten were sprayed only pre-emergence in early winter; the remaining five compared winter pre-emergence treatments with spring post-emergence treatments. Soil moisture conditions over the whole of the spraying period were favourable for the action of simazine and control of annual graminaceous and broad-leaved species was excellent. Wild oats (*Avena fatua*) was more effectively controlled by winter than by spring treatments. The converse was true of most annual broad-leaved species. The best time for the effective control of blackgrass (*Alopecurus myosuroides*) was dependent on soil type. The probable reasons for these findings are discussed.

The experiments confirmed previous findings that damage to field beans may occur at rates of simanzine in excess of 1 lb/ac. In these experiments, more damage was observed from winter applications than from spring applications of 2 lb/ac of simazine. Damage was greater on light or chalky soils than on heavy soils. Where the infestation by blackgrass was heavy, significant yield increases accompanied its control by simazine. No yield increases were obtained on light gravelly sand where broad-leaved annuals were dense. On the contrary, on such soils significant yield decreases were recorded for the winter and spring treatments at the highest rate. In the absence of dense weed infestation, on heavy clay soils significant depressions only occured at the highest winter rate of application. No yield depressions occured on heavy soil sites heavily infested with wild oats, but increases obtained failed to reach significance.

INTRODUCTION

Following work reported by J.G. Elliot (1958a) which showed that field beans (*Vicia faba*) could be selectively sprayed and might prove resistant to simazine, a number of workers carried out trials during the following year on spring sown field beans.

The work carried out during 1959, the results of much of which were collected and tabulated by Elliot, led to the adoption of a tentative recommendation by the Recommendation Committee of the British Weed Control Council for the year 1960. The recommendation applied to spring applications of simazine to spring sown field beans. There was therefore a need to carry out some work on winter sown field beans to find out if it was possible to use simazine selectively under the very different climatic and soil moisture conditions prevailing during the winter.

Roberts (1958) has shown conclusively that in light soils simazine could reduce the stand and yield of *Vicia faba* at doses well below those considered safe on clay soils. Elliott (1958b) had found that field beans killed or damaged by simazine were often closer to the soil surface than those not damaged by the same rate of simazine. Gregory (1959) has since demonstrated that under moist soil conditions, bean damage increases inversely as the depth of sowing of bean seeds.

Finally, Hartley (1960) has suggested that in soils at or near full moisture capacity, such as would be encountered over the winter months, rainfall will be readily "accepted" by the soil aggregates and even leaching of the chemical will take place.

These considerations led to the conclusion that the winter application of simazine to field beans might be more hazardous than spring application. For this reason five replicated split plot experiments were laid down to compare winter and spring applications of equivalent rates of simazine.

Field beans are traditionally grown on the heavier soils and there are sound reasons for this practice. Because of the known differences of behaviour of simazine on different soil types, however, it was thought desirable to undertake work on as many soils as was practicable. Nine sites were chosen on typical heavy boulder clay soil, two on chalk marls, one on a Kimmeridge clay - skirt soil, one on loam, and one each on chalk and river gravel soils. No fen soil sites were used.

The preparation of winter seed beds on clay soils is normally extremely coarse Based upon experience obtained with coarse soil surfaces in the spring it is usually held that such conditions are unsatisfactory for the successful application of residual herbicides. In consequence fine seed beds are recommended. In the present studies, no attempt was made to alter in any way the soil surfaces as found on the fields chosen as experimental sites. Instead observations were made on the average size and frequency of the clay aggregate resting on the surface. These were also examined to determine their external and internal moisture condition.

The purposes of the experimental work carried out were as follows:-

1) to determine the effect on the crop of early winter applications of simazine, involving a relatively long period of exposure to subsequent rainfall,

2) to compare the winter applications of simazine with equivalent spring applications involving a shorter exposure to subsequent rainfall,

3) to record the effect of these winter and spring applications on the weed flora, with particular reference to blackgrass and to wild oats,

4) to ascertain the relative differences in response of crop and weeds to known quantities of simazine when applied to heavy, intermediate and light soils,

(5) to observe any differences of effect which could be ascribed to surface soil texture.

METHODS AND MATERIALS

Two types of trial were laid down. The same doses of 2, 1 and ½ lb/ac simazine were used in each trial, and all were sprayed on the soil surface at a volume of approximately 20 gal/ac. The first series comprised five trials, each of eight randomised blocks of four main plots for doses and control. Main plots were divided into sub-plots for time. Plot size in these experiments was 28 sq yd. It was found possible only to determine dry bean yield on one experiment, the remaining four experiments being cut and weighed green.

The other series of trials, ten in number, were composed only of two replicates of four treatments, and included only winter applications. Plot size was 60 sq yd. Three of these trials were harvested green for yield data.

Winter applications were made between 4.11.1959 and 1.1.1960 as soon as practicable after the beans were sown. Spring applications made between 4.3.1960 and 18.3.1960.

Observations were made at the time of spraying of the condition of the soil as regards moisture content, with special reference to the soil surface and its texture as well as the moisture content of clay aggregates resting on the surface.

Observations were made at intervals throughout the year of the effects of treatments both on crop and weed. Weed counts were made during May and June of 1960. Two methods were used according to weed density or method of bean sowing. Where weeds were dense or bean rows too narrow or uneven, random quadrats were used. Where weeds were sparse and row width regular and wide, the method used was a count of seven (or fifteen) yards of randomly chosen alley between two rows. In this case figures were adjusted to a mean area on the basis of actual row width and length.

In trials harvested green, weights of bean plants, on an average sample of ten stems, were recorded as well as mean height of stem and number of pods.

RESULTS

Weeds

At four sites there were too few weeds to give useful information and at one site the crop and wild oats were too thick to allow counting without crop damage. Instead of counts at the latter site, weight of wild oats was recorded at harvest.

Wild oats occured on ten sites. When sprayed in the early winter 2 lb/ac simazine gave an average of 94 per cent kill of wild oats and the control ranged from 79 per cent to 100 per cent. Soil type appeared to have played little part at this dose. At doses of 1 lb and 0.5 lb, simazine was most effective on chalky soils and least effective on heavy clays. Spring applications of simazine were comparatively ineffective at the doses used. The results are shown in the tables on the next page.

TABLE I. PERCENTAGE REDUCTION OF WILD OATS

Winter spraying only

(i) Heavy soils (counts of wild oats)

Site	2 lb	1 lb	0.5 lb
T.21	79	46	72
T.22	95	33	-11
T.26	100	74	27
T.23	94	50	38
T.30	92	87	58
Mean	92	58	25

(ii) Heavy soils (weights)

Site	2 lb	1 lb	0.5lb
T.27	99	99	63

(iii) Chalky soils (counts)

Site	2 lb	1 lb	0.5 lb
T.29	99	96	83
T.31	98	90	72
T.35	88	72	51
Mean	95	86	69

(iv) Light loam (counts)

Site	2 lb	1 lb	0.5 lb
T.20	94	69	55

TABLE I (Continued)

Winter versus Spring spraying

Site	Winter 2 lb	Winter 1 lb	Winter 0.5 lb	Spring 2 lb	Spring 1 lb	Spring 0.5 lb
T.20	94	69	55	53	7	41
T.21	79	46	12	28	-20	30
T.22	95	33	-11	-23	40	-103
Mean	89	49	19	19	9	-11

Blackgrass was well controlled on heavy and chalky soils at all doses of simazine. The question of time of application of simazine appears to be important at least on some soils. Blackgrass occurred at only two sites where comparisons between winter and spring applications were made. The soils on the two sites were quite different, one being light loam and the other heavy boulder clay. On heavy clays and chalk marl soils, over 90 per cent of blackgrass control was obtained with a winter application of 0.5 lb/ac simazine. On the light loam site only 54 per cent control occurred with this application. Simazine applied at 0.5 lb/ac in spring gave only 31 per cent control on a heavy clay site, but gave 85 per cent control on the light loam site. These results are shown in the Table II.

TABLE II. PERCENTAGE REDUCTION OF BLACKGRASS

Winter spraying only

(i) Heavy soils and Chalk marl

Site	2 lb	1 lb	0.5 lb
T.22	100	99	95
T.30	100	99	92
T.35	100	100	99
Mean	100	99	95

(ii) Light loam

Site	2 lb	1 lb	0.5 lb
T.20	100	95	54

TABLE II (Continued)

Winter versus spring spraying

	Winter			Spring		
Site	2 lb	1 lb	0.5 lb	2 lb	1 lb	.5 lb
T.20 Light loam	100	95	54	99	98	85
T.22 Heavy clay	100	99	95	90	79	31

Broad-leaved annual weeds were frequent and included some 25 to 30 species. With the exception of cleavers (Calium aparine) good control of annuals was obtained. The influence of soil type and of time of spraying is shown in Table III. Spring applications of 1 lb and 0.5 lb gave excellent control, but except on chalk marl soils, winter applications of 1 lb and 0.5 lb were not so effective.

Table III. PERCENTAGE REDUCTION OF ANNUAL BROAD-LEAVED WEEDS (except Cleavers)

Winter spraying only

(i) Heavy soils

Site	2 lb	1 lb	0.5 lb
T.21	79	61	46
T.22	97	97	66
T.23	99	83	29
T.26	98	72	70
T.30	100	99	88
Mean	95	82	60

(ii) Chalk marls

Site	2 lb	1 lb	0.5 lb
T.29	99	96	81
T.35	97	95	93
Mean	98	96	87

TABLE III (continued)

(iii) Light loam, light sand and chalk

Site	2 lb	1 lb	0.5 lb
T.20	100	62	46
T.25	100	91	40
T.31	89	68	0
Mean	96	74	29

Winter versus spring spraying

	Winter			Spring		
Site	2 lb	1 lb	0.5 lb	2 lb	1 lb	0.5 lb
T.20	100	62	46	99	100	98
T.21	79	61	46	97	90	73
T.22	97	97	66	100	97	82
T.25	100	91	40	99	90	80
Mean	94	78	49	99	94	83

Crop

Visible depression of bean plants was noted at several sites though none of these were on heavy clay. The greatest depression was on the light sandy soil (T.25). Here both the 1 lb and 2 lb/ac doses of simazine applied in the winter and 2 lb applied in the spring caused reduction in plant height. Similar effects were noted on the chalk and chalk marl sites (T.29, T.31, and T.35). At the light loam site (T.20) plants on sprayed plots were taller because of the suppression of blackgrass. The 1 lb per ac spring treatment increased height of beans by 27 per cent and even the 2 lb winter application gave an increase of 13 per cent. Any direct stunting effect of the simazine on beans was therefore obscured. It is possible that even at the heavy soil sites, weed competition in the controls masked any depressing trend of the chemical.

Chlorosis and necrosis of bean leaves were not found until rapid growth of bean plants began in the spring. It was associated with the highest winter treatment only and occurred on the light sand, loam and chalky soils. None was observed at any other site. At the light sand and chalk sites a small proportion of dead plants were later found but most recovered. On the light loam site initial thinning of the beans was followed by strong tillering of the remaining plants.

Counts of pods at harvest indicated that thinning combined with removal of weed competition resulted in increased numbers of pods per stem. This was well demonstrated at the light loam site as shown in Table IV.

TABLE IV. NUMBER OF BEAN PODS PER STEM EXPRESSED AS PERCENTAGE OF UNTREATED CONTROLS

(Mean of 40 stems)

Winter sprayed			Spring sprayed		
Simazine dose lb/ac			Simazine dose lb/ac		
2	1	0.5	2	1	0.5
246.3	214.5	216.2	196.1	179.3	175.4
Sig. diff. at P 0.05 = 43 P 0.01 = 59					

The 2 lb/ac winter treatment had significantly higher pod numbers than the 1 lb and 0.5 lb spring treatments. The untreated control plots had significantly fewer pods per stem than any treated plots. This phenomenon has been noted and commented on by Hodgson and Blackman (1955) in studies of winter bean plant densities, and is probably associated with competition for light.

Although harvest yields were taken from all five trials comparing winter and spring applications, time did not permit for more than four random replicates being harvested at any one site. In addition, yields were taken from three of the ten (twice replicated) trials where winter applications only were made.

At two of the heavy clay sites (T.22 and T.34) comparing winter and spring applications, a significant yield difference was obtained between treatments. At these sites where weed density was low the 2 lb/ac winter dose of simazine yielded significantly less than any other treatment. At a third site (T.21) the trend was the same but the reduction was not significant. These results are shown in Table V.

TABLE V. GREENWEIGHT AS PERCENTAGE OF CONTROL

(Mean of 4 replicates)

Heavy boulder clay. Low weed density.

Site	Winter sprayed			Spring sprayed			Sig. diff.	
	Simazine dose lb/ac			Simazine dose lb/ac				
	2	1	0.5	2	1	0.5	P 0.05	P 0.01
T.22	77.0	95.6	110.1	96.6	100.3	99.2	10.4	14.2
T.34	67.6	86.7	94.6	95.5	91.8	101.7	18.0	24.6
T.21	82.3	92.4	90.8	85.7	91.5	91.6	21.2	29.9

At the light loam site there was a very dense infestation of blackgrass, averaging 285 per sq yd. Germination occurred mainly if not entirely during November-December. Other weed species included wild oats, but were not of great importance at this site. As all chemical treatments gave some control of blackgrass it is not surprising that this is reflected in the yield figures shown in Table VI.

TABLE VI. GREENWEIGHT YIELD AS PERCENTAGE OF CONTROL (EXPT. T.20)

Light loam and high weed density

Winter sprayed			Spring sprayed		
Simazine dose lb/ac			Simazine dose lb/ac		
2	1	0.5	2	1	0.5
219.7	225.9	191.7	205.3	217.4	198.3
Sig. diff. at P 0.05 = 36.8 P 0.01 = 50.4					

In this experiment all treated plots produced yields significantly higher than the untreated controls. There was no significant difference between chemical treatments.

The light sand site where there was a fairly high density of broad-leaved annuals but virtually no grasses gave a very different result.

TABLE VII. YIELD OF DRY BEANS AS PERCENTAGE OF CONTROL
(Expt. T.25)

Very light gravelly sand - Moderately dense broad-leaved weeds.

Winter sprayed			Spring sprayed		
Simazine dose lb/ac			Simazine dose lb/ac		
2	1	0.5	2	1	0.5
59.9	95.5	90.9	79.2	103.4	96.2
Sig. diff. at P 0.05 = 12.8 P 0.05 = 17.3					

Both winter and spring applications at 2 lb/ac gave significant yield depressions, the effect of the winter spray being particularly severe.

Dense infestations of wild oats occurred at three heavy clay sites where twice replicated winter sprayings were made. The yield figures for these sites are given in Table VIII.

TABLE VIII. GREENWEIGHT YIELD OF BEAN PLANTS AS PERCENTAGE OF CONTROL

(Expts. T.24, T.27 and T.29)

Heavy clay and chalk marl soils - Heavy wild oat density.

Winter sprayed only.

Expt	Dose			Sig. diff. P 0.05
	2 lb	1 lb	0.5 lb	
T.27	136.1	145.5	136.1	63.5
T.29	194.3	203.6	202.0	75.0
T.24	137.7	120.6	105.9	3.7

The trend towards reduction in yield with winter applications of 2 lb/ac simazine observed in the trials on heavy clay with low weed density is completely absent in these trials. Instead a trend towards increasing green weight yield may be observed which follows the pattern of increasing wild oat control.

Soil Surface Texture

On the heavy soils, aggregates varied in size from 9 in. diameter to fairly fine tilth with few clods. No differences in weed control could be detected which could be attributed to the varying soil surface conditions. In all cases, aggregates were wet or moist throughout. Erosion of the clods during the winter did not give rise to patches of soil in which weeds could grow and develop normally. On the lighter soils, aggregates up to 12 in. in diameter were present on one site (T.20). The surface of this field was extremely rough and cloddy yet weed control was excellent. On the other light soil (T.25) there were no clods of any kind and the surface was rolled level.

DISCUSSION

With the exception of wild oats, volunteer barley and wheat (and black-grass on heavy soils), annual weed species were more effectively killed by the spring spraying than by the winter spraying. The annual broad-leaved weeds germinated mainly in the very early part of the year just prior to the spring applications or just after. The advantage of spring spraying in this respect was more evident at the lower dose levels than at the higher. It was also more marked on light soils than on heavy soils. On chalky soils, winter spraying was very effective even at the lowest level of simazine. However, in this case no comparison could be made with spring spraying.

A possible explanation of this is to be found in the additional rainfall received by the winter applied simazine. Rainfall between winter and spring spraying lay between 5.82 in. for the longest period and 3.81 in. for the shortest period. This was more than sufficient rain to mobilise the highest dose of simazine, which may have been partially leached to a lower level leaving insufficient herbicide in the zone of weed-seed germination and early root development. Additionally, in the case of clay soils, the influence of adsorption cannot be ruled out. The fact that the differences were greatest at the lowest doses adds support to these arguments.

In the case of the spring spraying, there would have been insufficient rainfall to leach simazine, even at the low dose, and diffusion would have been slow. In consequence even the lowest doses would provide sufficient simazine at the site of root development in the critical early stages.

Wild oats, volunteer wheat and barley were controlled better by the winter than by the spring applications. This could be ascribed to the greater depth from which these species germinate and in addition, to earlier germination.

Perennial species were present at all sites but at only one site (T.26) were they an important section of the weed flora. Included were field bindweed (Convolvulus arvensis), creeping thistle (Cirsium arvense) and horsetail (Equisetum arvensis). None of these species was controlled nor indeed visibly affected by any dose of simazine used in these experiments.

Cleavers (galium aparine) were only slightly stunted by the highest dose of simazine as a general rule, but some individuals were killed and others were unaffected. The different reaction of individual cleaver plants may depend on their depth of germination.

Damage and death of beans occurred only at the highest doses and were consistently greater in the winter sprayed plots than in those sprayed in the spring. Damage and death were also more frequent in the light soils. These results are consistent with the arguments put forward in the case of annual weed control. At its maximum, damage resulted in death of individual bean plants, these being often close to apparently healthy plants. It is unlikely that this was due to uneven leaching of simazine, for under the soil moisture conditions prevailing leaching is likely on theoretical grounds to be even (Hartley 1960). It is more likely that death and survival of individuals is associated with depth of planting. This phenomenon has been reported by Roberts 1958) and Elliott (1958b).

Damage not resulting in death of beans sometimes caused stunting of the plants. It appeared, however, that at least in some cases this resulted in increased tillering, the additional tillers being usually healthy. In one case the number of pods per tiller was increased significantly. It is clear that damage to individual beans and especially damage giving rise to tillering may not cause a reduction in yield of winter beans. This view is supported by the findings of Hodgson and Blackman in their work on bean plant density.

Where aggressive weeds were dense and numerous, any effect upon the weight of beans harvested green was counter-balanced by the increase in weight due to weed control. The species with the greatest depressing effect on bean yield in these experiments was blackgrass. This weed was most economically controlled by the application of 0.5 lb simazine applied in the early spring on light loam or in early winter on heavy clay. The reasons for the failure of 0.5 lb simazine to give good control of blackgrass on heavy clay when applied in the spring are not obvious. It does not appear to be due to differences in stage of development, for both at the light loam site and at the heavy clay site blackgrass plants were 2-3in. high with 3-4 leaves.

At the rates of chemical used in these experiments, no differences in the behaviour of susceptible weed species were observed comparing coarse and fine soil surfaces of the same type. The condition of both large clods and fine crumbs are similar in that both were wet or moist and in most cases the soils approached field capacity.

It seems likely that the simazine suspension on reaching the soil surface in the spray droplets was readily mobilised throughout the soil surface layer, for the effect on germinating seedlings of susceptible species was both rapid and even. As the season progressed some erosion of the clods occurred, but judged by subsequent reactions of seedlings germinating on and around large aggregates no fenestration occurred in the distribution of the simazine in the soil surface layers. This gives support to the arguments of Hartley that even leaching would occur under such circumstances. The practicability of applying sprays to field crops in early winter is not high because of the excessively wet conditions often prevailing, especially on heavy soils. However, it would not be impracticable to apply the spray immediately after or at the time of drilling the crop.

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NAAS/ARC TRIALS WITH SIMAZINE ON FIELD BEANS

E. R. Bullen, and R. G. Hughes,

National Agricultural Advisory Service

Summary. Results are presented of ten trials on weed control in beans using simazine applied pre-emergence at doses usually from ½ lb to 2 lb per acre. Applications of ½ lb simazine gave the highest crop yields at some centres. Higher doses gave improved weed control but this was not necessarily reflected in yields. A tendency to reduced yields was noted at the highest dose at most centres. No adverse effects were observed in the 1960 wheat crops following simazine treatment to the 1959 bean crops.

INTRODUCTION

The discovery of the triazine herbicides was announced at this conference four years ago (Gysin H. & Knusli E. 1956) and at the last conference the results of three trials on beans (Vicia faba) incorporating simazine were presented (Elliott 1958). This work was followed up by the N.A.A.S. and the present paper reviews 10 trials carried out on a range of soil types in 1959 and 1960 on both winter and spring beans. Experiments in 1959 using simazine on beans at Rothamsted and Woburn have been reported elsewhere by Moffatt & Hill (1959).

METHODS AND MATERIALS

Details of the sites used and treatments are summarised in Table I.

At all centres a wettable powder (50 per cent w/w) formulation of simazine was used, sprayed at a volume rate of 20 gal/ac. The normal dose range used was ½, 1, and 2 lb/ac simazine, applied pre-emergence. At centre 7 the doses were modified to ¾, 1½ and 3 lb/ac; at centre 9 to ½, ¾ and 1 lb/ac. In addition, centre 2 included the normal doses, applied by spraying on the plough furrow before drilling, and centres 4, 5, 6, 8, 10 and 11 tested the 1 lb dose applied in two instalments of ½ lb each. At centre 3, other pre-emergence herbicides were included; simazine was the most effective and the results from other materials are not presented here.

The spraying was carried out by Oxford Precision Sprayer (Centre 1, 3, 4, 10 and 11) or by Landrover mounted sprayer (all other centres).

Most of the bean crops used for these trials were not of any named variety. However, at centres 6, 7, and 10 the varieties were Gartons S.Q., Hedingham, and Minor respectively.

A randomised block layout was used with three (centres 1, 2, 3, 11) or four replicates (all other centres). Results were assessed by scoring for weed control during the season, by weed counts (Centres 1, 2, 3, 4, 5, 7, 10, 11) and by observations of the stubble after harvest. In addition bean counts were made at centres 1, 2, 3, 9, 10, and yields were taken from centres 1, 2, 5, 6, 7 and 9. Observations were made on the crops following the 1959 trials and grain yields were obtained from the wheat following at centre 2.

TABLE I.

Trial year	1959	1959	1959	1960	1960
Trial No.	1	2	3	4	5
Site	Bicester, Oxon	Cambridge, Cambs	Histon, Cambs	Rearsby, Leics	Cambridge, Cambs
Soil Type	Medium clay loam (Gt oolite)	Clay loam (Gault)	Clay loam (Gault)	Heavy loam (Boulder Clay)	Clay loam (Gault)
Type of bean	Spring	Winter	Winter	Spring	Winter
Sowing date	26.2.59	20.10.58	17.11.58	22.3.60	15.11.59
Spraying date	23.3.59	17.10.58 21.10.58	21.11.58	24.3.60 13.4.60	17.11.59 24.11.59

LOCATION OF SITES

1960 6 Covington, Hunts	1960 7 Wareside, Herts	1960 8 Otley, Suffolk	1960 9 Bicester, Oxon	1960 10 Blewbury, Berks	1960 11 Long-benton
Heavy loam (Boulder Clay)	Heavy loam (Boulder Clay)	Heavy loam (Boulder Clay)	Medium Clay loam (Gt oolite)	Lower chalk	Boulder clay over coal measure
Winter 10.11.59	Spring 10.3.60	Spring 6.4.60	Spring 23.3.60	Spring 23.3.60	Spring 21.4.60
12.11.59 24.11.59	11.3.60 23.3.60	6.4.60 14.4.60	23.3.60	1.4.60 11.4.60	26.4.60 10.5.60

RESULTS

Weed Control

Table II summarises the effect of simazine on the numbers of weeds at the centres where critical counts could be taken. Similarly Table III summarises the score results from the centres where this method of assessment was adopted.

The chief monocotyledonous weeds were Alopecurus myosuroides and Avena fatua. The former was substantially reduced by 1 lb simazine at all centres and further reduced by 2 lb. At centre 2, where volunteer ryegrass was also present, 2 lb was needed to give maximum grass weed control. Avena fatua was reduced at 2 centres especially by the 1 and 2 lb rates, but at best the control was only 75 per cent. With Polygonum aviculare results were rather variable. At centre 1, 1 lb gave an effective control, but at centre 10, 2 lb only reduced the population by 57 per cent. Polygonum convolvulus was not easily killed at centres 4, 7 or 8, but at centre 10 the divided application gave a useful reduction. With Sonchus oleraceus also, results were inconsistent; at centre 7 it was susceptible but not at centre 10. Sinapis arvensis and Stellaria media were generally much more susceptible, except at centre 8 where conditions after spraying were extremely dry and Sinapis arvensis was not effectively controlled. Stellaria was not well controlled at centre 11. Veronica spp also proved susceptible, but at least 1 lb/ac was needed to reduce the very dense stand (almost all V. hederifolia) at centre 5. Chenopodium album was fairly readily controlled by 1 lb except under dry conditions (centre 8) but Cleavers (Galium aparine) appeared fairly resistant and even 2 lb did not markedly reduce numbers at centres 2 & 5; however the vigour of the surviving plants was markedly reduced. At centre 8, where other annual weeds were not effectively controlled, the population of Anagallis arvensis was reduced at all doses.

Perennial weeds were noted at very few sites and in most cases were not sufficiently numerous to be counted. No centre gave any indication that simazine effectively controlled any of the perennials encountered.

TABLE II. EFFECT OF SIMAZINE ON ANNUAL WEEDS
(Population as plants/sq yd)

Weed	Centre	Date of Assessment	Simazine lb/ac							
			0	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{2}$	2	3	$\frac{1}{2}+\frac{1}{2}$
Alopecurus myosuroides	(1	5.5.59	74	20		2.4		0		
Alopecurus myosuroides	(2	18.3.59^{x}	26	(18		6.5		6.0		
Alopecurus myosuroides	(			(20+		13+		11+		
Alopecurus myosuroides	(3	26.2.59	14	2.6		0.9		0.1		
Alopecurus myosuroides	(5	4.4.60	301	64		5.3		2.0		6.0
Anagallis arvensis	8	1.6.60	240	107		96		36		46
Avena fatua ⁄	10	30.5.60	8.7	7.0		2.2		2.2		2.2
Chenopodium album	(1	5.5.60	4.8	3.6		0.6		0		
Chenopodium album	(7	27.5.60	9.6		1.6		3.8		0.3	1.0^{x}
Chenopodium album	(8	1.6.60	23	26		22		24		23
Chenopodium album	(11	26.5.60	42	41		16		19		27
Galium aparine	(2	18.3.59	0.2	(0.5		0.4		0.4		
Galium aparine	(			(0.4+		0.1+		0.1+		
Galium aparine	(5	22.5.60	22	17		12		14		11
Galium aparine	(7	27.5.60	3.2		1.6		1.0		0.3	0^{x}
Polygonum aviculare	(1	5.5.59	2.1	1.2		0		0		
Polygonum aviculare	(4	13.5.60	20	7.4		4.7		3.3		6.7
Polygonum aviculare	(7	27.5.60	9.3		1.0		1.0		0.3	0^{x}
Polygonum aviculare	(10	30.5.60	26	26		20		11		24
Polygonum convolvulus	(4	13.5.60	84	93		53		46		84
Polygonum convolvulus	(7	27.5.60	107		50		33		24	27
Polygonum convolvulus	(8	1.6.60	57	70		47		59		52
Polygonum convolvulus	(10	30.5.60	3.8	3.2		2.0		3.2		0.2
Polygonum lapathifolium	11	26.5.60	35	5.5		15		5.5		6.5
Polygonum persicaria	11	26.5.60	6	4.5		2.5		1.5		3.5
Sinapis arvensis	(7	27.5.60	23		0.6		0.3		0	0.3^{x}
Sinapis arvensis	(8	1.6.60	25	35		7.9		16		25
Senecio vulgaris	11	26.5.60	7.5	2.5		1.5		0.5		1.5
Sonchus oleraceus	(7	27.5.60	5.1		0		0		0	0.3^{x}
Sonchus oleraceus	(10	30.5.60	8.9	7.7		2.9		7.0		2.5
Stellaria media	(1	5.5.59	42	4.2		0		0		
Stellaria media	(4	13.5.60	6.0	4.0		2.7		0		2.7
Stellaria media	(10	30.5.60	36	12		5.2		2.5		3.3
Veronica spp.	(1	5.5.59	20	4.2		0.6		0		-
Veronica spp.	(2	18.2.60	4	(3.5		4		1.2		-
Veronica spp.	(			(4+		3+		3+		-
Veronica spp.	(5	5.4.60	404	253		21		1.4		34
Veronica spp.	(7	27.5.60	6.8		0.6		0		0	0^{x}

+Herbicide applied pre-drilling. ^{x}rate $\frac{3}{4}$ + $\frac{3}{4}$ at this centre.

*Counts include some self sown ryegrass.

⁄*Avena fatua* visibly reduced at centre 6 but counts not made.

Table III summarises data on scores. In most cases scoring was carried out on the basis of general weediness but at centres 1 and 5 monocotyledonous weeds were scored separately from dicotyledons.

TABLE III. EFFECT OF SIMAZINE ON ANNUAL WEEDS

Weed density in spring (10 maximum weed in trial)

Centre	1				2	5	
Date of assessment	5.5.59		3.6.59		9.2.59	16.2.60	
Simazine lb/ac	monocots	dicots	monocots	dicots		monocots	dicots*
0	10	10	10	10	9.5	10.0	10.0
½	3.0	2.0	2.0	1.0	(4.3 (8.3*	1.9	3.6
1	1.8	0.3	0.4	0.3	(6.3 x (4.3	0.3	2.2
2	0.7	0.1	0.2	0.0	(2.7 x (2.3	0.2	0.5
½ + ½	-	-	-	-	-	0.3	3.9

Weed cover in late summer (10 = complete ground cover)

Centre	1	4		11
Date of assessment	18.8.59	20.7.60	27.9.60	Sept. 60
Simazine lb/ac				
0	7.9	5.4	8.5	5.8
½	1.0	1.1	1.8	5.3
1	1.0	1.4	0.8	5.6
2	0.2	1.5	0.2	2.7
½ + ½	-	1.0	0.6	3.5

x = applied pre-drilling   * almost entirely *Veronica hederifolia*

(78178)

Effect on bean crop

Plan counts were made at centres 1, 2, 3, 9, 10.

At centre 1, simazine reduced vigour and also gave progressive and significant reductions in flowering stems when applied at doses exceeding ½ lb/ac. Elsewhere flowering stem numbers were not recorded and there was no consistent trend to the (non-significant) fluctuations in the stand of young plants. The counts are summarised in Table IV.

Apart from the differences noted at centre 1, there was little information on vigour; most centres observed no differences but where weed growth was severe on the control plots (e.g. centre 5) the treated plots became progressively superior in vigour as the season advanced.

TABLE IV. EFFECT OF SIMAZINE ON PLANT POPULATION (1000/ac)

Centre	1	2		3	9	10
Date of Assessment	(5.59)	(12.58)		(3.59)	(5.60)	(5.60)
		pre drilling	pre emergence			
Simazine lbs/ac						
0	160	139		116	195	162
½	168	141	137	102	207	149
¾					181	
1	193	139	125	120	184	168
2	160	156	153	122		162
½ + ½						170

The visual damage to the beans at centre 1 was classified into 'mild' (partial leaf margin scorch) and 'severe' (severe scorch on older leaves, some yellowing of new growth and a reduction of internodes). The results of this assessment are given in Table V.

TABLE V. CENTRE I. POPULATION OF SPRING BEAN PLANTS PER ACRE; NUMBER OF DAMAGED BEANS AND NUMBER OF FLOWERING STEMS

Date of Assessment	5.5.59				1.6.59
Simazine lb/ac	Bean plants per acre	Unaffected plants/acre	Plants showing mild damage/acre	Plants showing more severe damage/acre	Flowering stems/ acre
0	160	160	0	0	277
½	168	163	5	0	277
1	194	150	34	10	203
2	160	48	70	42	155

Grain yield

The grain yields which were obtained from six centres are summarised in Table VI. In comparing treatments, it should be noted that the control plots did not receive identical treatment in all trials. The controls were not cleaned at centres 1, 2, 7, 9, 10 but were hoed at centre 5. At centre 6, where weeds were relatively few, all plots were hoed in April as it was thought desirable to obtain some measure of the effect of simazine on a clean crop. In fact the treated plots were visually cleaner than the control plots at harvest, and the herbicide appeared to have had more effect than was anticipated when the land was hoed.

. ½ lb simazine appears to have increased grain yields consistently except at centre 6 where all the plots were hoed. On average, this increase amounted to nearly 2 cwt/ac grain. Except at centre 6, where the response was not significant, increasing the quantity of herbicide to 1 lb gave no further increase in yield, despite a generally better weed control, and at centre 9 significantly reduced yields were obtained. Here, 1 lb gave almost 2 cwt/ac less beans than ½ lb.

2 lb simazine gave the maximum yield at centre 2, and the response was significant, but 2 lb gave a lower yield than 1 lb at centre 1, and 3 lb gave a lower yield than 1½ at centre 7. There was little difference between 1 lb and 2 lb at centres 5 and 6.

TABLE VI. GRAIN YIELDS CWT/AC (85 per cent D.M.)

Centre	1	2		5	6	7	9
Simazine lb/ac		Pre-sowing	Pre-emergence				
0	24.5	21.2		20.5	41.5	29.5	21.1
½	27.7	22.8	22.8	24.1	41.1		22.5
¾						32.9	21.4
1	27.2	22.5	21.8	23.9	42.5		19.5
(½ + ½)				25.2	41.1		
1½						34.8	
(¾ + ¾)						34.8	
2	23.3	26.1	24.6	23.3	42.4		
3						31.3	
S.E. treatment mean	± 2.04	±0.90		± 0.84	± 0.74	± 0.93	± 0.48
S.E. control mean	± 1.45	±0.64		± 0.84	± 0.74	± 0.93	± 0.48

At centre 10 samples of 80 stems per plot were taken at random and the number and the weight of pods determined. The results, summarised in Table VII, showed appreciable yield increases.

TABLE VII. BEAN POD COUNTS AND DRY MATTER YIELD. CENTRE 10

Simazine lb/ac	Mean no. of pods/stem	Dry matter: pods + grain 80 stems
0	4.9	23.1
½	5.7	29.3
1	6.2	33.2
½ + ½	6.7	35.4
		± 4.76

Effect on subsequent crops

Visual observations were made on the wheat crops in 1960 which followed the 1959 centres. No symptoms of damage were noted. At centre 2 the wheat was harvested in plots corresponding to the simazine treatments; there was no indication of yield reduction after any application of simazine and on average the plots receiving no simazine gave slightly lower yields than the wheat grown on plots sprayed with simazine for the previous crop.

DISCUSSION

At current prices, the cost per lb of simazine is approximately 75/-. It is difficult to give precise figures for the benefits from spraying a bean crop. Apart from the tangible response which may be obtained in yield, a cleaner crop will be easier to combine, particularly in poor harvesting conditions. From the trial results presented in this paper it would seem that an extra 2 cwt of grain is a likely response, and if valued at 30/- per cwt one can justify applying say ¾ lb of simazine. This rate will give a fair control of the more susceptible weeds, e.g. *Alopecurus* and *Stellaria*.

Yield responses to heavier dressings than this were only obtained under very weedy conditions (centre 2). It would seem likely that there may be some danger of crop damage where doses exceeding ½ lb were applied. It is not possible to specify the conditions where damage is likely from this trial series. However, there were indications that on soil with a high silt or clay fraction damage was less than on lighter soils.

Some weeds, such as wild oat and cleavers, are not reliably controlled by simazine and under very dry conditions e.g. centre 8 the control of relatively susceptible weeds may prove uncertain. For this reason it would seem possible that a combination of low doses of simazine, say ½ lb per acre, with cultivation techniques (e.g. hoeing) might well be more effective than reliance on simazine alone although this would preclude the use of narrow row spacings. The interaction between the use of simazine and subsequent cultivations was not studied in these trials, but since it has been shown on a small scale that severe crop damage followed harrowing-in simazine two days after spraying (R. G. Hughes unpublished data) there would appear to be need for more work on these lines.

In the 1959 trials wheat was taken in 1960 and there was no visual evidence of any damage to the wheat from simazine residues. In fact at the centre where yields were obtained, the grain yield after simazine treatments tended to be higher than the grain yield after the control, presumably due to fewer grass weeds being present in the wheat crop. If it could be shown that succeeding crops derived any consistent benefit from the use of simazine on the beans the economic advantages in the use of this material would be more attractive.

Acknowledgements

Acknowledgement is made to the farmers concerned for the facilities so readily provided for these trials; and to colleagues in the East Midland, South Eastern and Eastern regions who collaborated in the field work.

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FURTHER EXPERIMENTAL EVIDENCE ON THE FATE OF SIMAZINE IN THE SOIL

O. R. Dewey

Chesterford Park Research Station, Fison's Pest Control Ltd.

Summary. The paper presents experimental evidence adding some information to the following aspects of the fate of simazine in soil: absorption by plants, adsorption onto soil particles, leaching, evaporation, photochemical degradation, and breakdown by soil micro-organisms.

INTRODUCTION

The major uptake of simazine by plants is by absorption through the roots. As for all other root-absorbed herbicides, the fate of simazine applied to the soil is important in its influence on the weed control obtained, future cropping on agricultural land, and for persistence of weed control on industrial sites. The low solubility of simazine in water (5 p p m) and in lipids which restricts the major entry into the plant to that via the soil, also has a profound influence on its behaviour in the soil.

A number of papers have appeared, especially in the U.S.A., regarding persistence or disappearance of simazine agricultural land. The diversity of results obtained show how greatly the fate of the chemical can depend on a number of inter-related factors which are difficult to separate, and this makes forecasting of exact amounts of remaining simazine unreliable, except in extreme cases.

The simazine applied to soil may have any of the following fates:-

1) absorbed by plants
2) adsorbed into soil particles
3) leached into sub-soil or drainage water
4) evaporation
5) photochemical degradation
6) broken down by soil micro-organisms

Factors which have an overriding influence on any of the above six fates include (a) the crops sown or weeds present, (b) soil type, (c) the precipitation/evaporation ratio, and (d) temperature. Under normal soil water conditions hydrolysis of simazine is unlikely to be a factor leading to significant losses. Each of the above six possible fates of simazine will now be discussed, and recent experimental studies on them described. All rates of simazine quoted are for total active ingredient per acre.

RESULTS

Simazine absorbed by plants

The roots of plants absorb simazine but the degree of injury obtained depends on the ability of the plant to decompose or tolerate it. Simazine can be metabolised by Saccharum officinarum (sugar cane), Cynodon dactylon, Sorghum halipense as well as by Zea mays (maize), Gast and Grob (1960). The speed of decomposition of simazine is slower in the more sensitive plants that have been examined.

When using bioassay techniques of growing sensitive plants to test for simazine residues, the percentage kill due to any one dose can be varied considerably by changes in illumination and relative humidity. Increased transpiration resulting from a low relative humidity would be expected to cause an increased intake of soil water containing simazine and lead to increased kill; however, Burnside (1959) reports decreased toxicity to maize under these conditions.

Interesting results were obtained from an experiment where two logarithmic plots were sprayed on a clean heavy clay soil using peak doses of 20 lb simazine in May 1958. Excellent weed control was obtained on both plots in 1958, down to 1½ lb. In 1959 one plot (A), remained weed free down to 7 lb while the other became severely infested with Cirsium arvense especially at the high rates. The two plots were within 50 yards of each other; no differences in soil composition could be found. When sampled sixteen months later, the two plots gave totally different residue data as shown in Table I.

The summer of 1958 was wet, with sixteen inches of rain between May and September; 1959 was dry with five inches of rain in the same period. In September 1959, four cores of soil twelve inches deep were removed, sliced into six sections and bioassayed for residue within two inch layers. The figures given are arrived at from extrapolation of bioassay standards.

TABLE I. TABLE OF SIMAZINE RESIDUES IN OUNCES, SIXTEEN MONTHS AFTER TREATMENT

Treatments	20 lb		10 lb	
Depth of soil in inches	Plot A	Plot B	Plot A	Plot B
0-2	4	1	1	½
2-4	4	½	1	0
4-6	4	0	1	0
6-8	2	0	1	0
8-10	1	0	½	0
10-12	1	0	0	0
Total oz/ac	16	1½	4½	½

At 5 lb no residue was found on either plot at any depth.

The question of whether the Cirsium invasion in Plot (B) was a cause of this difference in simazine residue or a result of it, could not be settled;

but it appeared from the logarithmic plot, that once the simazine level had fallen below a 3 oz/ac equivalent, the rapid growth of Cirsium quickly disposed of the remainder except for that held in the surface layer of the soil.

Simazine adsorbed onto soil particles

In practical tests Gast (reported in Gysin and Knusli, 1959) showed that soil type has a marked effect on the toxicity of simazine to plants. When a soil of high humus content was used two to five times as much chemical may be necessary to produce the same toxicity found in a sandy soil. Heavy clay soils also need more chemical for an equivalent plant response.

Aelbers and Homburg (1959) have confirmed this in their plant response curves. They needed 5.5 times as much simazine in a soil containing 30 per cent each of humus and clay as compared with a sandy soil. The 60 per cent clay soil needed 1.3 times as much as sandy soil.

Similar results found by the author are given in Table II.

TABLE II. MINIMUM DOSE OF SIMAZINE NEEDED TO KILL OATS IN 21 DAYS

Soil type	per cent clay	per cent humus	oz/ac simazine
acid sand	0	10	3
clay soil	50	5	5
fen soil	5	60	16

The effect that pH variation may have on the adsorption of simazine by soil, or absorption by plants has not been resolved. Burnside (1959) reports that raising the pH from 5.4 to 7.2 caused increased toxicity to maize.

Leaching from soil

It has been calculated that one inch of rainfall over an acre could dissolve 1 lb of simazine spread uniformly over the surface. Under normal spray conditions chemicals are not spread molecularly uniformly even on a plane surface. The leaching of very soluble chemicals from soil is inefficient and rain does not penetrate uniformly. This illustrates that only under conditions of high rainfall where there is little chemical adsorption onto soil particles, is any leaching of simazine likely to occur. In general the bulk of simazine recovered by various experimenters has shown how the chemical remains at or near the soil surface.

Roadhouse and Birk (1959), reported this effect in a Canadian loam soil using chemical analysis. After fourteen weeks the total amount present on plots that had received 6-20 lb was 34.9 per cent of that applied, and of this 78 per cent was in the top inch. A year later 10 per cent remained and 70 per cent of it was in the first inch. This illustrates well how simazine stays in the top layer of soil and is not leached under temperate conditions.

Under dry loam soil conditions in Canada in 1958, Switzer and Rauser (1960) found some activity persisting from 2 lb/ac until the following spring. The following year irrigation was used and another plot lost all activity from 2 lb/ac in eight weeks. This difference in soil moisture could have a marked effect on activity of soil micro-organisms and it is quite possible that they are more likely to have caused the difference than leaching.

On an English heavy clay soil, treated with 10 lb in the wet summer of 1958, small amounts of simazine did penetrate the soil to a depth of twelve inches, but the majority of the chemical recovered was in the top two inches. The location of simazine as a percentage of the total recovered four months later is given in Table III.

TABLE III. LOCATION OF SIMAZINE AS PERCENTAGE OF TOTAL RECOVERED

Lb/ac Simazine applied	10	2.5
Total lb/ac recovered	5.1	0.28
Depth of soil sample (in.)	per cent	per cent
0-2	70	25
2-4	18	25
4-6	5	18
6-8	4	14
8-10	2	14
10-12	1	4

The following year a crop of potatoes showed no toxic symptoms from simazine.

From an experiment in 1959 where 1 and 2 lb of simazine had been sprayed in April on barley, soil samples were bioassayed four months later. The soil was a chalky fen skirt. No residue was found from the 1 lb plots. Of the 7 per cent recovered from the 2 lb plot, 68 per cent was in the top two inches, 23 per cent in the two to four inch layer, and 9 per cent between four and six inches.

Where simazine has been used as a selective weedkiller at 2 lb in six bean experiments in 1959 on various soils, no trace of residue was seen in cereal crops in 1960.

The reason for the importance of precipitation/evaporation ratio is that any rate of leaching may be greatly influenced by water evaporation from the soil between periods of rain. As Hartley (1960) has pointed out, the evaporation of water from surface soil will cause the surface soil layers to be less well extracted of chemical than deeper ones. This effect is much more pronounced on herbicides of low solubility such as simazine than readily soluble ones, and as the chemical will crystallise out in the surface crumbs, the delay of chemical movement during the next period of rain may be considerable. Hartley has also further considered the aspects of the water status of the surface soil at time of herbicide application. Simazine is normally sprayed onto a dry soil which results in much of the chemical being absorbed by capillary action into the dry lumps, thus much of the herbicide is in a region where it is least accessible to leaching by rain.

Evaporation and Photochemical degradation

The possibility of disappearance of simazine from soil due to ultra-violet light was mentioned by Aelbers and Homburg (1959). No published experimental work on the subject of evaporation from soil or photochemical degradation has been found.

In an experiment which did not attempt to separate the two factors, soil sprayed with simazine in 20 gal/ ac water was exposed dry under a 700 watt Phillip's mercury vapour lamp at twenty inches distance for fourteen days. The air temperature was about 140°F in spite of a fan below circulating air round the pans containing the soil. After exposure, the soil was mixed in the pan, and serially diluted with fresh soil for biological assay, using oats and peas. Similar sprayed pans of soil were kept in the same room, but were covered and did not receive the same light or heat.

Where 32 lb of simazine had been applied, the toxicity after fourteen days was equivalent to that produced by 4 lb on soil not exposed to these conditions; similarly, 8 lb was reduced to approximately 2 lb, but not more than half disappeared at the 2 lb rate.

Break-down by soil micro-organisms

Guillemat (1960) has proved the existence of species of fungi capable of breaking down simazine in the soil and using its nitrogen for their metabolism. The fungal species involved include *Fusarium oxysporum*, *F.avenaceum*, *Penicillium cyclopium*, *P.lanosocoeruleum*, *Cylindrocarpon radicicola* and a *Stachybotrys* species. The fungi did not use the carbon of simazine but degradation was favoured by high carbon availability in the soil. Simazine does not affect the balance of fungi or bacteria in the soil (Guillemat 1960, Pochon 1960). *Bacterium globifrome* and its allies are also capable of degrading simazine (Reid 1960).

The study of the disappearance of simazine in the soil is made more difficult by soil particle adsorption of the chemical. Rates below 1 oz/ac have little effect on the most sensitive test plants in organic soils, but such soils are useful for breakdown work because of their rich micro-organism content. For one experiment, large samples of fen soil were mixed with a range of simazine concentrations and stored in their polythene bags under conditions listed below. One sample was steam sterilised before mixing to kill the micro-organisms. The amount of simazine remaining after two months was determined by bioassay. Assuming that no breakdown occurred at 4°C, and using this as a standard, the percent loss of activity found is given in Table IV.

TABLE IV. PER CENT LOSS OF SIMAZINE IN FEN SOILS

Storage temperature	Pre-treatment	Bag condition	Water Status	oz/ac simazine applied		
				16	4	1
4°C	nil	closed	moist	0	0	0
20°C	steam sterilised	closed	moist	0	0	50
20°C	steam sterilised	open	fluctuating	25	75	100
20°C	nil	closed	moist	61	87	100
20°C	nil	open	fluctuating	44	87	100
20°C	nil	open	dry	38	75	100

Where the bags containing steam sterilised soil were kept closed, no loss of simazine was found except at 1 oz. The open sterilised bags had the moisture level kept up by the periodic addition of distilled water, fresh micro-organism invasion occurred with the resulting loss of simazine. The greatest loss was found in bags kept closed as if under these conditions the micro-organisms made most use of the simazine available to them.

DISCUSSION

This brief summary of information on the behaviour of simazine in the soil, together with the further experiments reported, illustrates that the possible influence of numerous factors must be known before any disappearance of simazine can be ascribed to any one cause.

The absorption and breakdown by resistant plants plays a large part where they are found, and if simazine alone is repeatedly used it can lead to healthy monocultures of a particular weed. If further treatment is not given the appearance of a resistant pioneering species appears to lead to a faster rate of colonisation by susceptible species, than these latter species would do on their own, presumably due to simazine removed by the pioneer species.

The effects of soil particle adsorption, leaching, evaporation, photochemical and micro-organism degradation cannot be sorted out in the field. Laboratory experiments tend to be unreliable as they may introduce artefacts such as abnormal packing density of soil in columns, rain applied as a single head of water and either a limitation or excessive supply of air.

Work so far indicates that with rates of 6-20 lb (non-selective uses), only a small percentage (10 per cent or less) of the applied chemical can be found below the top two inches unless cultivations have taken place. At the normal selective rates of up to 2 lb no residues affecting the next years crop were found under experimental conditions encountered.

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The main weeds present were broad-leaved but the results on individual species were not wholly consistent between centres. In some trials doses as high as 2 or even 3 lb did not adequately control weeds which were effectively reduced at other centres by lower doses. One is forced to a tentative conclusion that the results must be dependant upon soil moisture (affected both by cultivation, precipitation and soil type) in relation to the time of germination of the weeds and the time of application of the chemical. This is a complex and rather difficult matter to sort out from the records which are available.

Both autumn and spring sown crops were damaged by simazine at a few centres. Lighter land, or shallower drilling, increased this risk.

With both winter and spring beans consistent yield increases were obtained by the lower doses of simazine. From these trials ½ lb would generally appear to be about the optimum. 1 lb gave similar yields, except at one centre, despite the weed control being rather better. While higher rates occasionally gave better yields, quite marked yield reductions were noted at some centres - particularly those not on the heaviest land - and from these results one cannot with any confidence recommend other than a modest dose.

Perhaps the factor of paramount importance is that of economics. Simazine is a good deal more expensive in relation to the profits from beans than are most other herbicides now in use. One wonders what expenditure may be justified for the sake of having a clean bean crop if the crop itself does not respond to more than low doses of simazine. If subsequent crops in the rotation derived some benefit from cleaning the beans with simazine the economics would, of course, be completely altered.

REACTION OF PEA VARIETIES TO COMMONLY-USED HERBICIDES

J. D. REYNOLDS

Pea Growing Research Organisation, Yaxley, Peterborough

Summary. Results are presented of two experiments undertaken in 1958 and 1960, to compare the effects of 8 herbicide treatments at higher rates than normal on 14 popular vining and threshing pea varieties. TCA, applied pre-sowing, induced greatest loss of "bloom" in Big Ben, Lincoln, Pauli and Zelka, and most retarded the growth of Big Ben, Lincoln and Perfected Freezer. MCPB, applied post-emergence, caused most stem distortion in Gregory's Surprise and Thomas Laxton, and to a lesser extent in Dark Skin Perfection, Perfected Freezer and Witham Wonder (tall strain). Gregory's Surprise, Perfected Freezer, Thomas Laxton and Witham Wonder were stunted. Gregory's Surprise and Thomas Laxton sustained most scorch damage from dinoseb- amine and -ammonium, applied post-emergence, and their straw length was also reduced. When dinoseb- ammonium was applied after TCA, the extent of leaf loss due to scorching was increased, on average, by 10 per cent on all varieties. Propham applied pre-sowing, and chlorpropham/fenuron and chlorpropham/diuron mixtures as pre-emergence treatments, had no apparent deleterious effects on any variety. In terms of yield, measured only in the 1960 experiment, adverse effects were caused by TCA to Perfected Freezer and Thomas Laxton, by MCPB to Kelvedon Wonder, Meteor and Perfected Freezer, and by dinoseb- amine and -ammonium to Gregory's Surprise and Thomas Laxton; dinoseb- amine also had a similar effect on Kelvedon Wonder. None of the herbicide treatments affected rate of maturation (measured by a tenderometer) of any variety.

INTRODUCTION

That differences exist in the degree of susceptibility of pea varieties to some of the herbicides used in the crop has been recognised for some time, but there has been a dearth of critical data, particularly as regards effect on yield (the most important factor to be considered) in respect of the many varieties now grown for vining and threshing. Results of early studies in this country with dinoseb led Roberts and Woodford (1951) to classify picking varieties as most susceptible to this herbicide, vining and threshing varieties as intermediate, and field peas as least susceptible. More recently Roberts (1959) presented data which showed differences in reaction to the ammonium salt of dinoseb, in terms of yield, of a number of picking varieties; he also confirmed the greater selectivity of the amine salt to which all varieties tested were tolerant when it was used at the recommended rate. Some results on the differential effect of MCPB on different varieties has also been reported by Hirst et al (1957), Reynolds et al (1957) and Carpenter et al (1957); the latter have also alluded to effect on ripening. Procter and Armsby (1960) presented evidence which suggested that Zelka - a marrowfat variety grown for harvesting dry - is particularly susceptible to damage by TCA, while Butler (1960) has shown that certain other varieties can sustain damage by this herbicide. So far as is known no critical data has been published on the reaction of pea varieties to pre-emergence applications of carbamate/urea mixtures, fairly widely used in the crop during the past three seasons.

In the present contribution, the comparative effect of each of these commonly-used herbicides on widely-grown varieties is described, in an attempt to give guidance to growers and spraying contractors regarding adjustments in rates of application and varieties unsafe to treat with certain herbicides. Factors influencing the effect of these herbicides on the crop in general are not discussed.

METHODS AND MATERIALS

Experiments were laid down in 1957, 1958 and 1960 but for various reasons useful information was obtained only from single sites in 1958 and 1960. Each experiment consisted of long narrow plots of a number of varieties, chosen on the basis of their popularity for vining (canning and quick freezing) and threshing, sown in randomised blocks with three-fold replication. The herbicide treatments were applied randomly, at right angles across the variety plots to give 297 (1958) and 210 (1960) sub-plots per experiment, each sub-plot occupying 54 and 40 sq ft respectively.

Each herbicide was used at the standard time of application, and at a dose equal to $1\frac{1}{3}$ - $1\frac{1}{2}$ times the recommended dose, according to prevailing conditions, in an attempt to accentuate possible differences in reaction between varieties. Applications were made with an Oxford Precision Sprayer, using Allman "O" jets ("OOO" jets for MCPB).

Since all varieties were sown on the same day at each site, they were inevitably at different stages of development when the post-emergence applications were made. However, it was considered that this shortcoming was better than making a series of applications, probably under varying weather conditions.

Control plots were included in both experiments. In 1958 they were left untreated, but in 1960 they were kept free of weeds, from early May onwards, by careful hand-hoeing supplemented by handweeding within the pea rows.

Treatments compared and site details were as follows:-

Herbicides tested

Treatment no.	Chemical	Formulation per cent	Formulation Type	Time of application	Dose in lb.* and volume per acre 1958	1960
1	TCA	94	Na salt	Pre-sowing	9.4lb/40 gal	9.4lb/40 gal
2	TCA followed by dinoseb-ammonium	94 17	Na salt soln.	" " Post-emerge.	9.4lb/40 gal 2.4lb/50 gal	- -
3	Propham	50	wet. powder	Pre-sowing	4.5lb/40 gal	-
4	Chlorpropham/ fenuron	20) +5)	misc conc.	Pre-emerge.	3.0 lb)45 +0.75lb)gal	-
5	Chlorpropham/ diuron	20) +4)	misc conc.	" "	-	1.3lb) 40 +0.27lb) gal
6	dinoseb-ammonium	17	soln.	Post-emerge.	2.4lb/50 gal	1.7lb/100 gal
7	dinoseb-amine	18.5	soln.	" "	-	3.4lb/100 gal
8	MCPB	40	Na salt soln.	" "	3.0lb/20 gal	2.7lb/20 gal
9	Control		-	-	Untreated	Clean-weeded
10	"		-	-	"	" "
11	"		-	-	"	-

Varieties tested

Used for vining green

Dark Skin Perfection
Gregory's Surprise
Kelvedon Wonder
Lincoln
Meteor†
Onward (1958 only)
Perfected Freezer (1960 only)
Thomas Laxton
Victory Freezer (1958 only)
Witham Wonder (tall strain)

Used for harvesting dry

Big Ben (1960 only)
Pauli† (" ")
Rondo† (1958 only)
Zelka (" ")

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* Active ingredient/acid equivalent
† Round seeded. All other varieties wrinkle-seeded.

(78178)

Site details

Year	1958	1960
Site	Nordelph, Norfolk	Yaxley, Hunts.
Soil type	Silty clay	Sandy clay loam
Dates. Pre-sowing applics	4 March	21 March
Sowing	6 " *	5-6 April
Pre-emerge applics	31 "	8 "
Pea emergence	10 April (approx.)	20 " (approx.)
Post-emerge applics	20 May	17 May†
Clean weeding	-	4-12 and 12-26 May
Weather conditions at times of applic. Pre-emerge	Not recorded	Warm and sunny
Post-emerge	Air temp. 55-60°F.	17 May - Air temp. 65°F. 23 " - " " 67°F. 24 " - Very windy
Ave. size of peas at times of applic Pre-emerge	Radicles up to 1¼ in. plumules "moving"	Seeds swelling
Post-emerge	5" high	3-9 in. high, with 4-5 expanded leaves ‡

* Gregory's Surprise, Lincoln and Witham Wonder re-sown on 28 April due to thin plant establishment on first sowing. Since data obtained is not strictly comparable with the other varieties, reference to these three varieties is omitted from this report.

† Except dinoseb-ammonium, applied on 23 May. An application on 17 May had no effect so the plots were re-sprayed six days later.

‡

Variety	Height (in.)	No. of expanded leaves
Big Ben	5	5
Dark Skin Perfection	6	5
Gregory's Surprise	7	5
Kelvedon Wonder	6	5
Lincoln	4	5
Meteor	5	4
Pauli	3	4
Perfected Freezer	6	5
Thomas Laxton	9	5
Witham Wonder (tall)	5	5

RESULTS

In 1958 observations were confined to visual scorings, presented in Table I. In 1960 assessments comprised visual scorings (Table II) and straw lengths (Table III), tenderometer readings (Table IV) and yields on the date of harvesting of each variety (Tables IV and VI).

All plots of each vining variety were harvested as closely as possible to the date they reached, on average, the "practical canning stage", corresponding to a tenderometer reading of 120; in practice the mean reading per variety ranged from 104 to 113, with one exception.ϕ The other varieties were harvested dry.

Although differences recorded in the scorings had largely disappeared by the time of harvest, in many cases effects were reflected in the straw length and yield data.

TABLE I. SCORING FOR EFFECTS ON VARIETIES 1958
(assessed 23 May)

Treatment	Basis of assessment	Varieties							
		Dark Skin Perfection	Kelvedon Wonder	Meteor	Onward	Rondo	Thomas Laxton	Victory Freezer	Zelka
TCA	Loss of bloom, stunting and scorching (10 = no effect; 0 = complete kill)	7.3	8.3	7.7	7.7	7.3	6.3	8.0	2.7
TCA followed by dinoseb-ammonium	Per cent loss of leaf by scorching	48	52	40	50	38	55	48	55
Propham	-	No effect on any variety							
Dinoseb-ammonium	Per cent loss of leaf by scorching	42	42	33	40	30	47	37	35
Chlorpropham/fenuron		No effect on any variety							
MCPB	Stem contortion (10 = no effect: 0 = complete kill)	6.3	5.7	8.7	8.3	9.3	7.0	7.3	9.3

ϕ Meteor, a variety which ripens very quickly, harvested at an average tenderometer reading of 178.

TABLE II. MEAN SCORINGS : 1960 EXPERIMENT

Treatment	Date of assessment	Basis of Assessment	Varieties									
			Big Ben	Dark Skin Perfection	Gregory's Surprise	Kelvedon Wonder	Lincoln	Meteor	Paull	Perfected Freezer	Thomas Laxton	Witham Wonder (tall)
TCA	17 May	Loss of bloom (10 = no effect; 0 = considerable effect)	0.4	2.6	6.7	5.6	0.4	3.3	0.0	3.3	3.0	3.0
	27 May	Loss of bloom (10 = no effect; 0 = considerable effect)	3.3	6.7 *	6.0	4.7 **	2.7 ** +	6.7 **	2.7	5.3 **	6.0 **	5.3 **
Chlorpropham/diuron	-	-	No effect on any variety									
MCPB	23 May	Stem contortion (10 = no effect; 0 = severe effect)	8.0 ≠	3.3 ≠	0.7 ≠≠	4.7 ≠	5.3 ≠≠	4.0 ≠≠	6.0 ≠	3.3 ≠≠	2.0 ≠≠≠	3.3 ≠≠
Dinoseb-ammonium	27 May	Leaf loss by scorching (10 = no effect; 0 = severe effect - over 40 per cent of leaf surface)	7.5	6.3	2.9	6.3	7.1	7.1	7.5	5.8	2.5	6.7
Dinoseb-amine	23 May	Leaf loss by scorching (10 = no effect; 0 = severe effect - over 40 per cent loss of leaf surface)	5.4	2.9 δ	0.8 δδ	3.3 δ	3.8	3.3 δ	4.6 δ	3.8	0.8 δ	2.9 δδ

* Also slight scorch of lower leaves
** " moderate " " " "
*** " severe " " " "
\+ " slight bunching (rosette effect)
\++ " severe " "
≠ " slight marginal scorch
≠≠ " moderate " "
≠≠≠ " severe " "

δ " occasional plants dying off
δδ " a number of plants dying off

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TABLE III. MEAN STRAW LENGTH DIFFERENCES (IN INCHES) ON DATES OF HARVESTING, IN RELATION TO CLEAN-WEEDING : 1960 EXPERIMENT

Based on 10 plants, chosen at Random, per treatment per variety

Variety	Date of harvesting	Clean-weeded (means of 20 plants)	TCA	Chlorpropham/ diuron	MCPB	Dinoseb-ammonium	Dinoseb-amine
Big Ben	2 August	24.5	-4.7	-0.4	-0.9	-3.7	-2.8
Dark Skin Perfection	7 July	28.0	-2.8	-1.1	-1.0	-2.9	-2.2
Gregory's Surprise	29 June	44.9	+5.1	-2.8	-3.7	-3.6	-4.3
Kelvedon Wonder	30 "	15.7	-1.4	-1.5	-1.8	-2.0	-1.0
Lincoln	11 July	19.3	-4.2	0.0	-0.4	-2.7	0.1
Meteor	29 June	17.9	-2.6	+1.0	-0.7	-1.0	-2.1
Pauli	2 August	18.6	-2.6	-1.1	-2.6	-2.3	-1.1
Perfected Freezer	8 July	29.6	-6.9	-0.9	-3.9	-2.0	-2.1
Thomas Laxton	1 "	42.5	+0.8	+0.8	-6.2	-5.9	-7.8
Witham Wonder (tall)	7 "	25.8	-0.6	+1.3	-3.4	-1.8	-3.7
Mean	-	26.7	-2.0	-0.5	-2.5	-2.8	-2.7

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TABLE IV. MEAN TENDEROMETER READINGS : 1960 EXPERIMENT

Each value normally represents the mean of 2 or 3 tests (4 or 6 tests in the case of the clean-weeded treatment)

Variety	TCA	Chlorpropham/ diuron	MCPB	Dinoseb-ammonium	Dinoseb-amine	Clean-weeded	Mean
							(± 3.2)
Dark Skin Perfection	110	106	106	104	105	104	106
Gregory's Surprise	115	112	113	111	118	110	113
Kelvedon Wonder	123	117	123	119	122	122	121
Lincoln	109	105	104	98	102	107	105
Meteor	172	188	173	179	172	180	178
Perfected Freezer	113	101	101	104	101	103	104
Thomas Laxton	108	111	111	113	113	112	111
Witham Wonder (tall)	119	114	111	109	107	114	112
Mean (±1.6)	121	119	118	117	117	(±1.1) 119	119

Herbicide S.E. per plot ± 2.7 (12 d.f.)
Variety S.E. per plot ± 5.5 (14 d.f.)
Herbicide x Variety S.E. per plot ± 5.0 (84 d.f.)

	Body of table	Clean-weeded
S.E. for use in horizontal comparisons (12 d.f.)	±3.1	±3.0
" " " " interaction " (84 d.f.)	±2.9	±2.2

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TABLE V. MEAN YIELDS OF PEAS IN CWT/AC 1960 EXPERIMENT

Variety	TCA	Chlorpropham/ diuron	MCPB	Dinoseb-ammonium	Dinoseb-amine	Clean-weeded	Mean
							(± 1.9)
Big Ben	35.1	37.6	36.2	42.5	35.9	36.4	37.2
Dark Skin Perfection	39.1	50.7	35.5	42.0	37.1	40.2	40.7
Gregory's Surprise	15.7	21.5	15.3	13.8	11.3	16.7	15.9
Kelvedon Wonder	27.1	36.7	25.8	36.2	19.9	31.9	29.9
Lincoln	46.9	60.3	49.3	53.9	45.7	57.0	52.9
Meteor	33.4	46.2	31.1	37.0	33.1	39.8	37.2
Pauli	37.5	39.8	37.8	39.5	35.8	40.1	38.6
Perfected Freezer	21.8	34.4	25.2	33.8	30.2	33.0	30.2
Thomas Laxton	26.3	29.4	31.7	29.9	25.2	34.0	30.1
Witham Wonder (tall)	35.0	45.0	34.8	35.8	28.3	34.4	35.4
						(± 0.8)	
Mean (± 1.2)	31.8	40.2	32.3	36.4	30.3	36.3	34.8

Herbicide S.E. per plot ± 2.1 or 5.9 per cent of general mean (12 d.f.)
Variety S.E. per plot ± 3.3 or 9.5 " " " " " (18 d.f.)
Herbicide x Variety S.E. per plot ± 2.1 or 6.1 per cent of general mean (108d.f.)

	Body of table	Clean-weeded
S.E. for use in horizontal comparisons (12 d.f.)	± 1.7	± 1.5
" " " " interaction " (108 d.f.)	± 1.2	± 0.9

TABLE V (continued)

Significant differences in cwt/ac	P = 0.05	P = 0.01
Between herbicide treatments for one variety	5.1	7.2
Between clean-weeded and herbicide treatments for one variety	4.8	6.8
Between means of herbicide treatments	3.7	5.1
Between clean-weeded mean and means of herbicide treatments	3.2	4.5

TABLE VI. MEAN YIELDS AS PERCENTAGES OF CLEAN-WEEDED MEAN FOR EACH VARIETY 1960 EXPERIMENT

Variety	TCA	Chlorpropham/ diuron	MCPB	Dinoseb- ammonium	Dinoseb- amine
Big Ben	96	103	99	117	99
Dark Skin Perfection	97	126	88	104	92
Gregory's Surprise	94	129	92	83	68
Kelvedon Wonder	85	115	81	113	62
Lincoln	82	106	86	95	80
Meteor	84	116	78	93	83
Pauli	94	99	94	98	89
Perfected Freezer	66	104	76	102	92
Thomas Laxton	77	86	93	88	74
Witham Wonder (tall)	102	131	101	104	82
Mean	88	112	89	100	82

DISCUSSION

Propham, chlorpropham/fenuron and chlorpropham/diuron. - Neither propham applied pre-sowing nor the two carbamate/urea mixtures had any adverse effect on the varieties tested in these experiments and it would appear that varietal differences are slight or non-existent. None of the treatments delayed pea emergence.

TCA - When TCA was used as a pre-sowing treatment, the marrowfat varieties, Big Ben and Zelka, sustained the greatest visual damage; this accords with the results of other work (Proctor and Armsby, 1960; Proctor, 1960). Pauli, a blue variety grown for harvesting dry, was also markedly affected, but it is of note that yields of this variety and Big Ben (Zelka yields were not measured) were not significantly depressed. Of the vining varieties, Perfected Freezer was most affected visually, and its yield was significantly reduced. Kelvedon Wonder, Lincoln and Thomas Laxton appeared rather less tolerant than the remaining varieties.

MCPB - The marrowfat and blue varieties were least susceptible to this post-emergence herbicide. Dark Skin Perfection, Kelvedon Wonder, Meteor and Perfected Freezer were rather sensitive in that yields of these varieties were reduced. The greatest degree of stem contortion was caused to Gregory's Surprise and Thomas Laxton but yield reductions were not significant. Witham Wonder also sustained injury in the form of stunting, but yield was not affected.

Contrary to popular belief, differences in maturity rating between MCPB-treated and clean-weeded plots, as measured by tenderometer on the dates of harvesting, were not significant for any variety. This supports the findings of Carpenter et al (1957).

Dinoseb - Most scorch damage resulted to Gregory's Surprise and Thomas Laxton. Dark Skin Perfection and Witham Wonder were also affected to a greater extent than the remaining varieties. The marrowfat and blue varieties - Big Ben, Pauli, Rondo and Zelka - were least susceptible to scorching, and Meteor and Lincoln were also quite tolerant. Both salts retarded growth, reflected in a straw length reduction, on average, of nearly 3 in. The effect of scorching resulted in decreased yields in the case of Gregory's Surprise and Thomas Laxton; the yield of Kelvedon Wonder was also reduced.

In general, it would seem that varieties may be placed in two broad groups: the shorter, stronger-strawed and firmer (less lax) leaf types which are generally tolerant, and those of weak appearance which tend to be rather susceptible (Proctor, 1958).

Normally, less scorch damage should be caused by the amine compared with the ammonium salt since the former is more selective (Roberts, 1959). In the 1960 experiments, however, where both were compared, applications were made on separate dates and the different weather conditions obtaining probably accounted for the more drastic effect of the amine salt.

TCA followed by dinoseb - There appeared to be no interaction effect between TCA and dinoseb. The effect of dinoseb on TCA-treated plots compared with