# PROBLEMS OF ADVICE AND EDUCATION : A MANUFACTURER'S POINT OF VIEW

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The manufacturer's problem, like that of the Ministry and the merchant, is, basically, to ensure that the farmer is aware of the technical and economic possibilities of the use of weedkillers - on different weeds, in different crops, under the particular conditions of his holding. The difference is that he then tries to persuade the farmer to use his particular products. To this end the manufacturer must have a highly skilled technical staff at his home base, and a competent field force working for his sales department in regular contact with selected merchants and farmer customers.

The technical staff at the home base may, in the case of a small company, consist of a few graduates each skilled in his own particular discipline - chemistry, physics or engineering, agronomy or botany. But with large companies the organisation may be much more elaborate and consist of a research and development department in addition to a separate technical service department. The former will be carrying out basic plant physiological and chemical work on herbicide problems, exploratory work on potential new herbicides, small and large scale screening, field evaluation and so on. For these purposes this department will be contacting farmers primarily from the point of view of their unsolved or only partially-solved herbicide problems and to provide areas where particular weed problems may be investigated.

The technical service department on the other hand will be concerned primarily with taking new products from the Research & Development department, seeing them through their inevitable teething troubles when they get into the hands of farmers, referring intractable problems back to R. & D, and generally helping their commercial colleagues in the office and in the field to exceed their sales forecasts. In the early days of a new product members of technical service department will do a great deal of work going out with the field representatives to visit and expound the new story to merchants and farmers. As progress is made the field representatives take over more of this work, coming back to the Technical Sales department only when they get stuck, and leaving that department to get on with even newer products. Because of their spearhead activity these technical service men are expected to know all the answers to questions which arise from the customer's own particular problems. This calls for great experience and diplomacy, for the customer expects decisiveness, often on questions to which there is no immediate answer.

Because there are some 409,000 holdings of over 5 acres in the United Kingdom it is obviously difficult for the staff of any company, however large, to visit a significant proportion of them. The manufacturer must, if he aims at nation-wide distribution, use the services of a great number of merchants; with the aid of their representatives he multiplies up his total field force and, therefore, the number of farm calls.

Before referring to the detail of providing advice and education to merchants and farmers, I would mention one more general and controversial matter.

WORD OF MOUTH

Under the heading of "making known" by word of mouth I comprehend a wide range of talks and lectures to the manufacturers' own technical and field representatives, agents and their representatives, contractors and their staffs, agricultural societies, N.F.U. and Y.F.C. groups, individual farmers and farmer groups and occasionally broadcasts.

In my own particular company we hold regular conferences with our own technical and field staffs; special conferences when we have a new weedkiller, technique or machine to describe.

Similarly we arrange frequent meetings with our agents and their representatives with the object of helping them to put the correct story over to their customers and, of course, helping us to reach a far wider farmer audience. Here I would make a special point. Very seldom does weedkiller business, or even crop protection business collectively, represent more than a small percentage of the agent's total turnover. As a result I am frequently and pleasantly surprised at the amount of time they are prepared to devote to our products. I think the answer must be that we are much more likely to provide new products than, say, the manufacturer of fertilizers, feeding stuffs and binder twine. We thus provide talking points and excuses for the agents' representatives to visit their customers.

Contractors and their staffs are met regularly and here, as is self-evident, discussion ranges over machinery and techniques at least as much as over products.

Mainly during the winter the technical staffs of all companies are regularly committed to series of lectures to and discussions with agricultural societies of all kinds, N.F.U. and Y.F.C. parties and of course local farmer groups. Incidentally, I can say from my own experience that in any one season it is curious how quickly a pattern of questions emerges and continues throughout that season.

Few industrial technical men have frequent opportunities to address growers on radio or television but, as one who has done a certain amount of it, I would state the obvious. Talks must be studiously objective, at least on the home programmes, and even indirect references which might be construed as advertising will be cut out by the producer. When, as inevitably happens occasionally, anything of this kind slips through it is promptly pounced on by competitors.

VISUAL AIDS

A rather miscellaneous list appears under what I call visual aids: films and film strips, weed charts, show exhibits, and field demonstrations and farm walks.

My own company has made a great number of films of various kinds over the past twenty years. From experience I prefer 16 mm in colour. For the average farmer audience, and provided a competent representative is in charge of the proceedings, it is better not to provide sound; the lecturer can then give a commentary slanted to suit the particular type of audience and the locality. A set commentary can occasionally offend an audience by not using, for example, the local names of weeds; in the absence of a sound track a skilled commentator can make a virtue of some incident that may seem wrong in a particular locality. When, of course, you want to use films in different countries, it is cheap, in the absence of a sound track, to introduce suitable captions.

The difficulty with films, is that, to do a really good job, they must be limited to a single theme. This is suitable for a product or a new spraying technique, but it is liable to become too difficult if the new theme is complicated by the introduction of comparative methods for use under different conditions or in particular parts of the country.

To illustrate a series of specific points widely separated in a lecture and, of course, for providing data it is much better, and cheaper, to use 35 mm film transparencies. May I say, however, that even when you have an enormous library of transparencies, it is extraordinarily difficult to find exactly the shots you need.

The use of charts is obvious. Not only can they be helpful in the course of lectures but they usefully adorn agents offices and agricultural college lecture rooms. But they must be well done, with several weed stages shown. I've never been satisfied with our own.

Show exhibits are usually a mixture of several things I have already mentioned - plus photographs, trade samples and, sometimes, machines. The primary object of course is to keep your name in front of your customers, but you also hope to induce interest and provoke questions. After that it is up to the company's representative. It is most important to have the exhibit adequately manned.

Field demonstrations, again well done, can be an enormous aid to weedkilling education. But they must be coupled with farm walks during which the amounts and conditions of application, of what product through which machine, can be described and discussed.

The last few remarks bring me to a final statement, used frequently in the past but nevertheless still true. I have a brother who farms on a reasonable scale. He doesn't believe a word I tell him about our new weedkillers; he doesn't believe our advertisements or our leaflets. He looks over the fence and, when his neighbour uses such a product and it seems to do good, he tries it the following year on a small scale. If it still does good under his conditions he uses it on a farm scale. After that you might think he was selling me something!

I conclude that despite all the labels and leaflets, and all the lectures and films, the best way to tender advice and provide education on weedkillers is to encourage progressive farmers to use new products at strategic points well distributed over the country. Then leave the generality of farmers to look over the fence.

Discussion on preceding three papers, opened by Mr. R. B. Ferro, National Agricultural Advisory Service

Mr. Ferro. This Session is entitled "Problems of Advice and Education" and having listened to the three speakers there is no doubt that there are problems in bringing the knowledge of weed control and all that it entails to the user and non-user of herbicides. I will not attempt to differentiate in this context between advice and education and, for the sake of simplicity, let us call it merely informing the user. But who is the user that we wish to inform? Not, I suggest, so much the farmer or grower who diligently searches for the latest information and is capable of reaching his own decisions, but rather the man who is making less than the optimum use of the latest methods and who is so often reluctant to seek information. We must also include the farm workers, who carry out the precise field work without which successful results will not be obtained. These are the men we must have in our mind in our discussion which is of extreme importance to us all; and, I hope, we shall hear from some of our overseas delegates who are faced, at home, with similar problems.

Dr. Holmes discussed the various means available to manufacturers to inform users about their products and emphasised that the underlaying purpose was to sell the product. Perhaps it is this thought that prompted Mr. Mason to lament that many users sought guidance from commercial advisers rather than from the independant advisers in the N.A.A.S. Mr. Bradford told us how, as a merchant, he was attempting to overcome these difficulties and meet the needs of his customers.

The N.A.A.S. is independent and at times we are asked to advise on the suggestions put to farmers by others. That type of enquiry will, undoubtedly, remain, as will the direct enquiries to us about treatment about particular weeds. Of greater significance I am sure, is developing work of the N.A.A.S. in advising on the Farm Organisation as a business, the type of work that is often referred to as Farm Management. Weed Control is one of the management factors to consider, affecting as it does the cropping, crop production methods, mechanisation and labour organisation on the farm. I was impressed by the frequency yesterday of references to the economics of weed control and, undoubtedly, this will gain greater prominance as the seasons go by. It is during this work that we can do a great deal to bring weed control into focus and give the farmer a clear understanding of its significance.

However independent N.A.A.S. may be, it can never deal with all the day-to-day enquiries on herbicide usage, nor is there any need for it to do so when we consider the other facilities that there are. To me, therefore, it is clearly a case of all concerned playing their full part, N.A.A.S., the manufacturers, the merchants, the farm institutes, colleges, university departments and, of course, the Weed Research Organisation, and it seems to me that the discussion could well fall under four headings:-

1. How best can we integrate our efforts. Much has already been done through local contacts, local conferences and discussions. It is essentially local integration that is required.

2. How best can the "informers" be kept fully in touch with developments and have the information as quickly as possible.

3. How can the jargon of weed control and the meaning of herbicides be simplified so that it is comprehensible to those who have yet barely a nodding acquaintance with the use of herbicides.

4. What is the simplest form of approach to the user. To be effective it must be simple and easily understood.

Mr. J. A. R. Lockhart. I was disappointed that no one who is concerned with lecturing to students on herbicides was asked to read a paper in this session, but I am pleased to find that most of the problems which the lecturer encounters were aired by the speakers - particularly Mr. Mason of N.F.U. Headquarters. The subject of herbicides now required about 20 lectures compared with 1 or 2 ten years ago and this is often difficult to fit into a full course. The Weed Control Handbook has been very helpful. I am satisfied that the new approved products scheme is a considerable improvement on the old scheme and I hope that most products which come on the market will be approved about the same time. I am not very happy about the fact that the scheme is officially financed by the firms whose products are approved and it is just possible that the scheme could be improved if additional finance was provided by other interested sources and/or by the Ministry. Reports along the lines of those given in "Which" or "Shoppers Guide" are perhaps too much to ask for, although they would be very welcome. I apologise for again bringing up the problem of "Trade Names" - they are a real menace and most of the trouble is due to many firms who only buy the chemicals from the manufacturers and give them fancy names. I feel that firms who do the valuable research work should be allowed some freedom in labelling their products but the others should not be allowed to complicate matters by coining names which mean nothing. In fact, some scheme could possibly be developed whereby Royalties were paid to the research worker's firm and this need not mean an increase in cost to the farmer - in fact it would probably allow for a reduction in cost. I find it very difficult to compare costs of herbicides produced by various firms: students and farmers would very much like to be able to do this. Mr. Bradford's Booklet is not the last word by any means, but it is definitely a big step in the right direction.

Dr. R. E. Slade. Might I suggest that the Weed Control Handbook should publish only those advertisements which show the composition of the products the advertisers wish to sell?

Mr. H. W. Salmon. I would like to be allowed to congratulate the first speaker of this paper. I feel he has most adequately dealt with the farmers' point of view. After all the farmer is the ultimate customer and I hope the suggestions in the paper will receive most careful consideration by the Council and manufacturers present. I am rather disappointed that there is no paper on "Weeds in Cereals and Undersown Crops". I find great difficulty in controlling chickweed in the latter, and would also suggest that the control of mayweed coupled with the control of other prevalent weeds by the same chemical still leaves room for improvement.

Dr. E. Holmes. I think Dr. Woodford should be answering this: there is too much to try to fit in a Conference of three days and the Organising Committee has to be selective. It takes items of current interest and leaves out those things which have been adequately dealt with in the past or where there is nothing much new to say.

Mr. H. Geary. In answer to some of Mr. Limb's criticisms I must say that I am always amazed at the efficiency with which spray chemicals are used by the farmer - this achievement is due to the efforts made by the leading manufacturers and such organisations as Mr. Bradford's. I feel that this section of agriculture has developed very quickly in the short space of 15 years, due to the dissemination of knowledge to the farmer, particularly when one considers the comparatively slow development by the farmer in the use of fertilizers and animal feeding stuffs which have been available in some form since the beginning of man. This young industry has developed to the present high level due to the effort by all concerned who serve the farmer, for which in return he pays so little and achieves so much.

Mr. J. S. W. Simonds. I am horrified still to find elements of suspicion between the various bodies who advise the farmer on herbicide useage. Surely we all have only one object in view, profit for the farmer. From that profit it is hoped that the farmer will be able to pay his merchant and from such monies received the manufacturer hopes he will be paid by the merchant. Further unless the farmer makes a profit he will be unable to pay his taxes which keep alive and pay for the various Ministerial Agricultural Bodies.

SESSION 6

Chairman: Dr. W. G. Templeman

THE CONTROL OF GRASS WEEDS

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## AGROPYRON REPENS - AN INTRODUCTION

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*Agropyron repens* is a pernicious weed of arable land and although many regard it as a symbol of bad farming, increasing mechanisation and the reduction in the farm labour force have tended to make the conventional methods of control uneconomic. It is natural, therefore, that attempts have been made to find alternative means to control the weed. The introduction of the powerful rotary cultivators and the production of herbicides which will kill grasses, stand out as major lines of recent advance.

The undoubted success of the rotary cultivator in controlling rhizomatous grasses does not involve the removal of the couch as did some of the older methods but depends on the stimulation of dormant buds and the destruction of the resulting shoots. The best growth stage at which to 'strike again' at the regenerating weed is determined as I shall later show, by a knowledge of the biology of the species.

Control methods which depend on the use of chemicals rely for their success on many factors, both environmental and innate. It is the innate factors which will concern me most since they are the least easily measured and assessed.

It was perhaps too much to hope that TCA, dalapon or amino triazole would be as immediately successful in controlling *Agropyron repens* as were the substituted phenoxyacetic acids in ridding our corn of many dicotyledonous weeds. Let it be sufficient at present to say that the degree of control of *Agropyron repens* in the field by any of these chemicals is unpredictable, varying from occasional complete success to complete failure. It is my task to suggest some of the causes of this variability.

### THE IMPORTANCE OF SEED AS A MEANS OF SPREADING AND INTRODUCING *AGROPYRON REPENS*

Palmer (1958) states '*A. repens* spreads and reproduces principally by means of its rhizomes; since fertile seed is rarely formed.' Although *A. repens* is self sterile and since owing to extensive vegetative spread one genetical

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individual might be expected to occupy a large area, thus bringing about a degree of spatial isolation, I have recorded a high level of seed production for *A. repens* where the weed was allowed to complete its flowering cycle. From one such stand (Headington, Oxford), 58 per cent of the flowers produced seed which germinated in soil. It is clear from my own observations in the field that this seed will germinate immediately it is shed, that is, in the autumn of the year of its production. A combine harvester which returns the waste to the field at the time of the harvest could be almost as efficient as a seed drill in sowing *A. repens* if that species was a weed of the harvested crop. Cooke (personal communication) claims that the spread of *A. repens* in the Holland district of Lincolnshire can be correlated with the changeover to combine harvesting.

Standard laboratory germination tests of crop seed may fail to detect viable *A. repens* since the seed will germinate successfully only with a fluctuating temperature and not at a constant 5, 10, 15, 20, 25 or 30°C.

Mr. J. R. Thomson, Department of Agriculture for Scotland, (personal communication) has reported that 'In the year 1956-7 the following proportions of seed samples received for test contained enough couch for some to be found in the standard purity test'.

| | From Denmark | From England |
|---|---|---|
| Cocksfoot | 25 per cent | 3 per cent |
| Perennial Ryegrass | 85 per cent | 5 per cent |

The Committee for Transactions in Seeds have recommended that a much more strict control should be kept over the spread of *A. repens* with crop seed. (Anon, 1957). Ovservations suggest, however that the landowner himself must guard against dissemination of seed of *A. repens* by his own machinery. Regeneration of *A. repens* populations from seedlings may mask the efficiency of a spray treatment.

## THE BIOLOGY OF *AGROPYRON REPENS* WITH REFERENCE TO THE CONTROL OF THE WEED

Palmer (1958) has described how the rhizomes which grow horizontally below the soil surface during the late spring and summer, erect in the autumn to produce an aerial shoot which survives throughout the winter. This shoot develops tillers and produces new rhizomes in the following spring. By investigating a stand of *A. repens* which was not disturbed by cultivations, Palmer was able to relate the beginning of rhizome production and tillering to the calendar. He was also able to demonstrate that each overwintering shoot normally gave rise in late March or early April to three tillers and 3-4 rhizomes and that in July, some rhizome buds grew out to produce lateral rhizomes. Further, he showed that this pattern of development was modified if the individual was grown free from interference from other plants, when tillers themselves produced subtillers and rhizomes. Thus the plant was capable of exploiting a virgin habitat by producing numerous rhizomes and Palmer quotes '... such a plant may produce as many as 50 rhizomes in a single growing season.' Anyone who has tried to control *A repens* will need no reminder of this potential.

It has been possible during the last 12 months to relate Palmer's work to the pattern of behaviour of *A. repens* under conditions of agricultural practice.

When a rhizome system is broken up by ploughing or other cultivation, one or more of the rhizome buds, hitherto dormant, grow out to produce aerial shoots which altimately tiller and produce rhizomes in the manner described by Palmer. The only difference is that the pattern of development is no longer related to the calendar. This would confirm Palmer's (1958) findings that the onset of rhizome production is under the control of environmental factors and that the cessation of horizontal rhizome growth may be correlated with senescence of the parent shoot. Applied to farming practice this finding means that it should be possible, by cultivation, to bring A. repens to any stage in its growth cycle if it should prove that the weed is more successfully controlled by chemicals at, e.g. the time when the rhizome production commences, rather than later when the parent shoot begins to age.

Palmer (1958) has reported that the parent shoot dies back in the autumn when the new rhizome tips have erected as aerial shoots, but that in the following season one or more buds occasionally grow out from the old stock and produce tillers and rhizomes. Because the morphology of the rhizome system can be related to the growth pattern of the weed an examination of entire rhizome systems allows a determination of the longevity of the rhizomes. In an undisturbed stand of A. repens at Headington, Oxford, it was found that rhizomes disappeared during the third year after their production. Thus in May 1960, rhizomes produced in 1960, 1959, 1958 and 1957 were found, although the latter were frequently moribund.

Nevertheless, all the living rhizomes of such a system bear dormant buds which become available for regeneration if the intact system is damaged. A primary rotary cultivation produces such a regeneration, bringing about a depletion in the number of dormant buds as well as returning the Agropyron repens to the beginning of its growth cycle, i.e. a single shoot which will produce tillers and new rhizomes. Subsequent cultivations serve to break off the new sprouts, to encourage more dormant buds to grow out, to expose the segments to desiccation and perhaps to deplete to some extent the food reserves in the rhizome segments. The relative importance of bud removal and food depletion is not known. It has been suggested (Fryer, personal communication) that disc harrows may also be effective in breaking up the rhizomes but it is generally agreed that rotary cultivators will be most efficient.

## BIOLOGICAL FACTORS WHICH MAY AFFECT THE EFFICIENCY OF HERBICIDE TREATMENTS

There is little doubt that save under exceptional circumstances, a herbicide applied to the foliage of a plant must move down to the below ground organs in the phloem. Although the factors which cause movement in the phloem are in dispute, it is clear that substances do not move aimlessly about the plant, but travel to regions where they are used or stored. On the mass-flow hypothesis, downward movement in the phloem will be greatest when the demand for metabolites below ground is also greatest. On the other hand if different substances move independently in the phloem, they must do so in response to a gradient between the 'source' and the 'sink'. It would seem of paramount importance that, at the time of the herbicide application, the below ground organs should be in a state of rapid growth.

As a segment of rhizome of A. repens regenerates, there will be, for a time at least, a movement of materials from storage tissues to the new shoot and roots. Following this, there will be a period when the new shoot produces sufficient assimilate to be dependent no longer on rhizome reserves. Movement of materials at this stage will be from photosynthetic regions to sites of active cell division and cell extension. Later still, metabolites will be moved from leaves to new tillers and new rhizomes. It seems celar that the maximum below ground activity of the weed occurs during the period of rhizòme growth.

The conclusion from this briefly developed argument is that a translocated herbicide applied to the foliage of A. repens will move downwards most efficiently during the period of new rhizome growth. Nevertheless, environmental factors may affect this movement, for temperature and light intensity must be such that active photosynthesis occurs. Field applications of translocated herbicides in late autumn or early winter are likely to yield uncertain results since the growth of new rhizomes will be slow and will in any case vary from day to day depending directly on temperature, and indirectly via the photosynthetic rate on light intensity and day length.

It is clear, from a consideration of the growth form of A. repens that in an undisturbed stand of the weed in the spring of, e.g. 1961, there will still be present rhizomes produced in 1961, 1960, 1959 and probably 1958. These rhizomes will be connected via the base of the parent plants of 1961, 1960 and 1959 but apart from the 1961 rhizomes, they are unlikely to be metabolically active and therefore unlikely to import any substances from the above ground part of the plant. Nevertheless, the ageing rhizomes still bear buds which are capable of regeneration. It is, in fact, difficult to suggest any mechanism which would lead directly to the accumulation of a herbicide by the rhizome buds, no matter what the age of those buds, and even more difficult to conceive of a mechanism which would lead to the movement of the herbicide into older rhizomes of the system. And yet such movement is essential if control is to be complete.

It could be argued that death of the apices which receive a direct supply of the chemical could lead to the sprouting of dormant buds and consequent retranslocation of the herbicide to the new regions of metabolic activity. However, a chemical like dalapon, which in low doses promotes dormancy, is liable to reach the sprouting bud initially in very low doses, arresting the activity and consequently preventing the accumulation of a lethal dose.

There are two possible solutions to these problems.

1. Cultivation prior to spraying will break up the rhizome system, inducing many dormant buds to sprout and appear as above ground shoots. This cultivation will also serve to reduce the maximum distance that a herbicide must be moved as well as increasing the general metabolic activity of the weed. Thus the herbicide would not need to move so far and might be expected to move faster.

2. Johnson (1958) has shown that applications of ammonium nitrate break the dormancy of rhizome buds even when it is enforced by low doses of dalapon. Applications of ammonium nitrate prior to or soon after spraying might be expected to increase the metabolic activity of the rhizome buds and lead in consequence to the accumulation of lethal doses. In addition, Dexter (1936) showed that applications of nitrogen to stands of Agropyron repens resulted in an increased shoot: rhizome ratio, leading to a greater relative area of foliage for spray retention.

The sole purpose of this introductory paper is to throw light on some of the peculiarities in the life cycle of A. repens which might affect the success of chemical and cultural control measures.

Although this hypothesis has been argued with particular reference to A. repens, most of it would seem to be applicable to any rhizomatous perennial treated with a translocated herbicide applied to the foliage. Finally, I wish to acknowledge that part of this hypothesis is not original, but I hope that its completeness will to some extent compensate for this.

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ROTARY CULTIVATION FOR THE CONTROL OF RHIZOMATOUS GRASS WEEDS

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Summary. Rotary cultivation of a couch infested light silt soil in 1959 gave a reasonable control of *Agrostis gigantea* and *Agropyron repens* but the rotary cultivator could not give effective control where tractor power was inadequate. When a chemical (amino triazole, dalapon or TCA*) was combined with rotary cultivation a rather better control was obtained than from either alone but this was not sufficient to make the combined treatment worthwhile. Rotary cultivation alone appeared more effective than herbicides alone. Of the chemicals used, activated amino triazole appeared the most promising.

## INTRODUCTION

It has been shown (Fail 1956) that rhizomatous grasses may be eliminated by 2 to 6 rotary cultivations, kill being attributed to the exhaustion of the small rhizome pieces produced by the initial rotary cultivation.

In order to obtain field experience of this technique in conjunction with chemical sprays, two experiments were laid down in 1959 by the N.A.A.S., Eastern Region, Crop Husbandry Department. Both sites were on a light silt soil with a heavy infestation of couch, mainly *Agrostis gigantea* with some *Agropyron repens*. Fail considered 119 in. of rhizome/sq ft to be a heavy infestation, but these trials had an infestation of about 800 in./sq ft or a "rhizome yield" of about 2½ ton of dry matter /ac.

## METHODS AND MATERIALS

### First Trial

The chemical treatments were unsatisfactory and only the rotary cultivation treatment will be considered in this paper.

The machine used, a 60 in. Howard Rotovator (made by Rotary Hoes Ltd.), had no easy means of altering gear ratios. It was towed by a Ferguson tractor (diesel TEF 20 in only fair condition) with a minimum forward speed of 2.5 mph. Theoretically, maximum rotor speed was about 170 rpm giving an "increment of cut" or "bite" of 5 in. The land was in deep plough furrows well greened over when treatments commenced in April. Subsequent rotary cultivations were done when the land became well greened over, at approximately fortnightly intervals. The progress of the trial is summarised in Table I.

It was clear that insufficient progress was being made and the trial was abandoned. The failure of the rotary cultivation appeared to be due to the low power of the tractor which was unable to maintain adequate p t o speed at a

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* Used respectively as the commercial formulations "Weedazol TL", "Dowpon" and "Tecane".

reasonable depth of penetration. In fact the final depth of 4 in. (in comparsion with untreated land) was quite unsatisfactory in view of the depth to which some of the rhizomes had been buried by deep ploughing (11 in.) in the previous autumn.

TABLE I. CONDITION OF RHIZOME AFTER EACH ROTARY CULTIVATION TO DEPTH OF BLADE ACTION (ABOUT 4 INCHES)

First Trial

| Dates of Rotary Cultivations | Total Length (in in.) per sq ft | Mean Length (in in.) of pieces | Percentage of rhizome in different length ranges in inches | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | < 4 | 4-8 | 8-12 | 12-16 | 16-20 | > 20 |
| 8th April | 799 | 6.6 | 18 | 32 | 22 | 5 | 11 | 12 |
| 16th April | 645 | 4.7 | 32 | 38 | 15 | 9 | 3 | 3 |
| 1st May | 717 | 5.1 | 24 | 30 | 25 | 16 | 5 | 0 |

Second Trial

A "Selectatilth Rotovator" (made by Rotary Hoes Ltd.) was used for the second trial and this had gears which could readily be changed to give a wide range of motor speeds of which 180 r p m was used at a forward speed of 2 mph giving a 'bite' of 3.7 in. It was mounted on a Fordson Major Diesel tractor which, for the initial treatments particularly, was used to work as deeply as practicable. The very dry conditions made it difficult to get adequate penetration. The trial followed a dried pea crop. Chemical treatments (amino triazole, dalapon and TCA) were applied on 31st July, 1959 and were followed by either no rotary cultivation, or one, two or three rotary cultivations at monthly intervals, the first being given on 7th August. A later application was made of each material to other plots on 1st September. Treatments are shown in Table II. Rainfall was as follows:

| | |
|---|---|
| July | 1.98 in. |
| August | 1.34 in. |
| September | .15 in. |
| October | 1.48 in. |
| November | .36 in. |

RESULTS

Second Trial

A fortnight after the last rotary cultivation soil samples were taken to the full depth of rhizome growth from unsprayed rotary cultivated plots. The effect on the couch rhizome is summarised in Table IV.

The trial area was subsequently ploughed to a depth of 9 in. about 4 in. below the depth of rotary cultivation, and drilled with wheat on 30th October.

Final assessments were made on the wheat stubble after the 1960 harvest (in late August and early September 1960). These are presented in Tables II, III and IV.

Unfortunately the ploughing in the previous autumn brought up an appreciable amount of couch rhizome which had been below the depth of rotary cultivation. Probably this could have been avoided by shallower ploughing. However it was thought essential to ensure that any rotary cultivation pan would be broken, although on soils of this type such a pan would be unlikely.

Yields were not obtained from the wheat crop; there was a clear visual response to the treatments controlling couch and no adverse effects were noted except damage to the wheat where TCA had been applied 8 weeks before sowing. (Rainfall during this period was very low).

Visual scorings were made after harvest on the whole trial area while couch leaf density and soil rhizome content were assessed on a more limited scale (Tables 2, 3 and 4 respectively).

TABLE II. SCORING FOR DENSITY OF COUCH LEAF GROWTH ON 29.8.60

(Mean of 3 observers, mean of 3 blocks, 10 = worst, 0 = complete absence)

(Second Trial)

| Chemical Treatments (lb/ac) | | No. of Rotary Cultivations Nil | One | Two | Three |
|---|---|---|---|---|---|
| Dalapon 3 | Sprayed on 31st July 7 days before first rotary cultivation | 7.2 | 6.8 | 6.2 | 4.4 |
| " 6 | | 6.2 | 6.3 | 4.9 | 3.3 |
| Not sprayed | | 9.6 | 8.8 | 7.7 | 5.3 |
| TCA 10 | | 8.6 | 6.2 | 5.7 | 4.1 |
| " 20 | | 8.0 | 5.2 | 4.8 | 2.4 |
| Not sprayed | | 9.6 | 9.2 | 6.7 | 4.2 |
| Activated amino triazole 2 | | 7.0 | 6.8 | 3.7 | 2.2 |
| Activated amino triazole 4 | | 6.0 | 4.3 | 2.7 | 1.4 |
| Not sprayed | | 9.7 | 8.0 | 5.7 | 4.8 |
| Dalapon 3 | Sprayed on 1st September 7 days before second rotary cultivation | 7.8 | 7.3 | 4.9 | 3.0 |
| TCA 10 | | 8.0 | 6.5 | 5.0 | 2.3 |
| Activated amino triazole 2 | | 8.0 | 6.2 | 5.0 | 2.6 |
| Not sprayed | | 9.6 | 8.5 | 5.8 | 3.9 |
| Mean unsprayed | | 9.6 | 8.6 | 6.4 | 4.6 |

TABLE III. COMPARISON OF SCORING (TABLE II) WITH ACTUAL STEM COUNTS (8.9.60) EXPRESSED AS PERCENTAGES OF NON-ROTARY CULTIVATED PLOTS

(Second Trial)

| Two Unsprayed Strips | No. of Rotary Cultivations | | | |
|---|---|---|---|---|
| | Nil | One | Two | Three |
| Scorings | 9.8 = 100 | 90 | 73 | 60 |
| Stem Counts | 70.2 = 100 (per sq ft) | 67 | 42 | 31 |

TABLE IV. WEIGHT OF COUCH RHIZOME (g/sq ft)

| | No. of Rotary Cultivations | | | |
|---|---|---|---|---|
| | Nil | One | Two | Three |
| Samples taken 20.10.59 | 58.6 | 11.5 | 2.3 | 1.4 |
| Samples taken 9.9.60 | 20.1 | 12.0 | 1.9 | 1.1 |

## DISCUSSION

Up to the present there have been four methods of couch control available to the farmer. Firstly for heavy land there is the summer fallow where the couch is killed by being dried out in largish clods; secondly there is the technique of working out the rhizomes and burning them. Thirdly, where depth of soil is sufficient, the couch may be killed by ploughing it down to a depth of about 14 in. Lastly there has been the possibility of using a herbicide.

On the farm in question the first three had been found ineffective; the soil was too light to dry out in clods, the infestation too heavy and deep to work out economically and there was insufficient depth of soil (11 in. over blowing sand) to kill by burying. TCA had not been tried and although preliminary experience with dalapon was unpromising its use was being contemplated on a large scale as the only possible solution.

Following upon the experience with the rotary cultivator in the first trial, unsuccessful though it was in the circumstances, the farmer purchased a more versatile model and, combined with adequate tractor power, has found it to be very effective in controlling couch, throughout the farm. The farmer has estimated that he can carry out the three rotovations at an overall cost, including tractor depreciation, of £4 per acre. Output he estimates at something like ½ acre per hour. So far as blade wear is concerned there is the advantage of a complete absence of stones so that a set of blades costing about £9 will deal with 200 acres.

In the second trial the scorings show that no chemical treatment by itself gave anything approaching a satisfactory control of couch and all were appreciably poorer than three rotary cultivations. The combination of chemical with rotary cultivation gave a rather better control than either alone although not to a degree which made the combined treatment worth while. The infestation did not increase on the rotary cultivated plots under the wheat crop (Table IV) but it appears to have fallen considerably on the untreated areas. It is of note that visual scorings tended to over-estimate leaf density on the cleaner plots and that leaf density in relation to rhizome was higher on the cleaner plots than on the untreated ones.

It would be unwise to draw general conclusions from these results since they are of only a single year's work on a single soil type and the reactions on different soils and in different weather conditions would seem likely to be variable. Clearly much more study is required on the subject although the trial obviously confirms the promise of Fail's work.

Acknowledgements

Particular thanks are due to the farmer, Mr. A. H. Cooke, who carried out all the rotary cultivations.

The assistance of members of the N.A.A.S. Holland Lincs. staff is acknowledged as is also the help received from Messrs. C. V. Dadd and E. R. Bullen.

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# AN IMPORTANT FACTOR AFFECTING THE MOVEMENT OF 2,2-DICHLOROPROPIONIC ACID (DALAPON) IN EXPERIMENTAL SYSTEMS OF AGROPYRON REPENS

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Summary. Two experiments are described which show that the extent of movement of dalapon when applied to experimental two shoot systems of *Agropyron repens* may be dramatically improved by covering the treated shoot with an opaque or transparent cover. The technique of autoradiography has been used and the dangers of extrapolating these observations into field practice are mentioned. If a treated shoot is shaded, then the radioactivity is distributed widely within the experimental system, whereas an unshaded shoot retains the herbicide to a far greater extent. It is suggested that a shade reduces the rate of movement of water in the xylem by increasing the humidity. Since dalapon is readily transferred from phloem to xylem, it is argued that the speed of downward movement of the chemical in the phloem will depend not only on the forces taking it down, but also on the rate at which the xylem draws it from the phloem. It seems likely that the faster the movement of water in the xylem, the more rapidly is the herbicide extracted from the phloem. It is suggested that humidity at the time of spraying and subsequently may be all important in determining the success or failure of dalapon applications in the field.

## INTRODUCTION

During the course of an investigation into the factors controlling the pattern of movement of 2,2-dichloropropionic acid (dalapon) in experimental systems of *Agropyron repens*, an attempt was made to determine how far the transport of dalapon could be correlated with supposed pattern of movement of metabolites. One of the more critical experiments to test such a hypothesis involves shading a part of a plant and demonstrating that a herbicide applied to another part of the same plant moves readily into the shaded portion.

## METHODS AND MATERIALS

### The production of the experimental systems

Lengths of rhizome were lifted from a garden at Headington, Oxford and transferred to the Department of Agriculture, Oxford. The rhizomes were then cut up into two node segments, the cut being made with scissors mid-way between nodes. The segments were planted in seed boxes placed in an incubator at a temperature of 25°C. 8 days later sprouts began to emerge and the boxes were transferred for 48 hr to a heated greenhouse at 20°C. When the sprouts measured

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ca. 5 cm in length they were lifted and washed in tap water prior to replanting. At this stage the segments were selected for uniformity and only those with a shoot at both nodes were used.

The plants were grown in procelain pots in gravel which had been sifted to remove particles which were less than 1/16th in. in diameter. The segments were planted 2.5 cm below the surface. The water table was maintained 10 cm below the surface of the gravel by means of reservoirs and a syphon device. Nutrient solution was added to each pot at three weekly intervals.

Each shoot tillered and produced rhizomes in the manner described by Palmer (1958), but during this period the experimental material became variable. Facilities did not permit any further selection to be made and the consistency of the results are therefore all the more remarkable.

Treatment

In both experiments sodium 2,2-dichloropropionate (2-$C^{14}$labelled) was used. The basic solution was of 1.65 mg/ml in water with 1 per cent carbowax 1500 added. The specific activity was approximately 1 millicurie/mM. 10µl of this solution was applied to the plant as a single drop placed in a lanolin ring sited midway along the upper surface of the lamina of the youngest unrolled leaf of one shoot. The plants were harvested 3, 10 or 17 days after treatment. Subsequent procedure was the same as that of Yamaguchi and Crafts (1958) except that dry ice was not used at harvest. The plants were freeze-dried for five days, mounted on lithograph paper, dried at 50°C for 24 hr, pressed and exposed to Kodirex X-ray film for 21 days. Terylene film was used to cover the specimens before they were exposed. The two node segments for Experiment I were collected on 30.11.59 and transferred to gravel in pots on 14.12.59. The pots were placed in a heated greenhouse at the Department of Agriculture, Oxford and auxilliary light was provided throughout the winter. The treatment was applied on 5.2.60. There were two replicates of each treatment and the plants were harvested 3 or 10 days after treatment. The variables were as follows:-

1. Treated shoot shaded.
2. Untreated shoot shaded
3. Both shoots shaded
4. Neither shoot shaded

The shades excluded all light from the selected parts of the plant from the moment that the treatment was applied up to the time of harvest.

For Experiment 2, two node segments were collected on 1.5.60 and planted out of doors at the University Field Station, Wytham on 11.5.60. One shoot of each plant was treated on 1.7.60 after being moved into an unheated greenhouse the day previously. Harvests were taken 10 and 17 days after treatment and there were again two replicates. The variables were as follows:

1. Treated shoot covered with a light-proof shade
2. Untreated shoot covered with a light-proof shade

3. Both shoots covered with light-proof shades

4. Neither shoot covered

5. Treated shoot enclosed by a transparent cover

6. Untreated shoot enclosed by a transparent cover

7. Both shoots enclosed by transparent covers

In this experiment the shades were of polystyrene, those designed to exclude the light being coated externally with four layers of a black cellulose paint.

RESULTS

No quantative data is available from these experiments at present and all the objections inherent in the autoradiographic technique may be quoted. However, the experimental plants are available for future studies.

Experiment 1: (All results after 10 days of treatment)

(a) Without shading, dalapon did not move from treated into untreated shoots. (b) Dalapon moved out of shaded into unshaded shoots. (c) Dalapon did not move from unshaded to shaded shoots. (d) Where both shoots were shaded movement did not occur into the untreated shoot. In one such case a rhizome tip erected outside the shades during the course of the experiment and this shoot accumulated the labelled material. (e) All the shaded shoots were moribund at the end of the experimental period (Fig. 1).

Experiment 2: (Results after 10 days of treatment)

(a) Where no shades were applied dalapon was not detectable in the untreated shoot (Fig. 2). (b) Dalapon moved out of a treated shoot that was covered by a transparent or an opaque shade (Fig. 3). (c) When the untreated shoot was covered it did not accumulate dalapon (Fig. 2). (d) If both shoots were covered by opaque shades, movement was most marked into actively growing rhizome tips, roots and young rhizome sprouts which grew up outside the shades (Fig. 4). (e) When both shoots were enclosed within transparent covers extensive distribution was seen throughout the entire experimental system (Fig. 4). (f) The shoots under the dark shades became moribund during the experiment. (g) Except where both shoots were shaded (see (d) and (e)), the pattern of movement of the labelled material is comparable no matter whether opaque or transparent covers were applied. There were, however, differences in the intensity of the pictures, more dalapon having moved from shoots covered by black shades than from those covered by the transparent.

DISCUSSION

It is most important that the shortcomings of the radioautographic technique should be fully understood before any attempt is made to extend the findings of this work to field practice. It is not intended to discuss this problem here, but to state simply that further experimental work using field doses of dalapon are necessary before recommendation can be made.

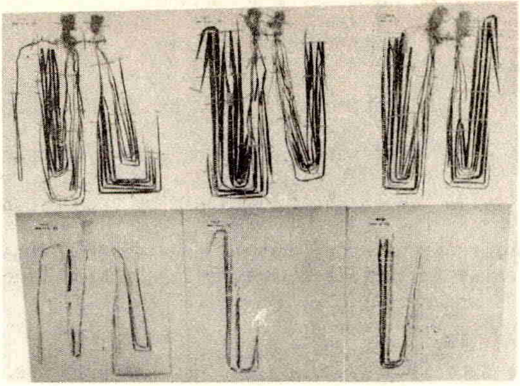

FIGURE 1. AUTORADIOGRAPHS (EXPERIMENT 1)

Lower series is of the plant systems. Upper series is of autoradiographs of corresponding plant systems. (Right hand shoot treated in each case with labelled material) All plants harvested 10 days after treatment (left) no shade applied; (centre) untreated shoot covered with an opaque shade; (right) treated shoot covered with opaque shade. Note the extended distribution of the labelled material when the treated shoot is covered.

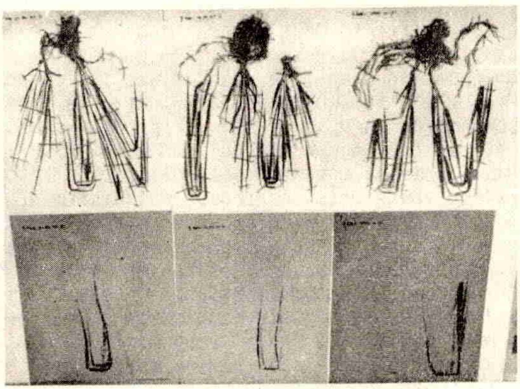

FIGURE 2. AUTORADIOGRAPHS (EXPERIMENT 2)

Lower series is of the plant systems. Upper series is of autoradiographs of corresponding plant systems. (Left hand shoot treated in each case) All plants harvested 10 days after treatment. (Left) no shade applied; (centre) untreated shoot covered with opaque shade; (right) untreated shoot covered by a transparent shade.

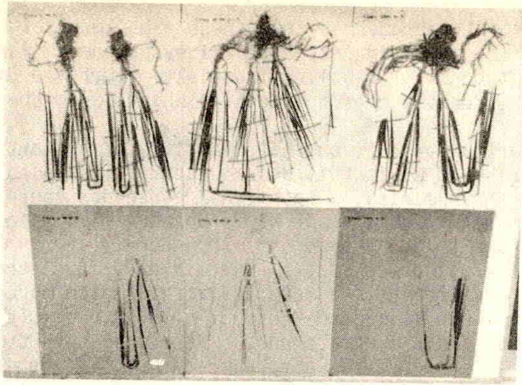

FIGURE 3. AUTORADIOGRAPHS (EXPERIMENT 2)

Layout as Fig. 2. (Left) no shade; (centre) treated shoot covered with an opaque shade; (right) treated shoot covered with a transparent shade. Note the greatly extended distribution of labelled material as a response to the opaque shade and to a lesser extent to the transparent cover.

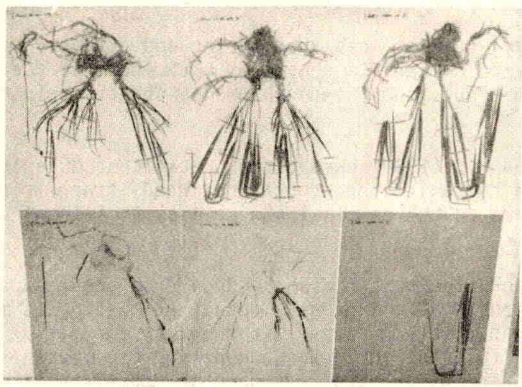

FIGURE 4. AUTORADIOGRAPH (EXPERIMENT 2)

Layout as Fig. 2. (Left) no shade; (centre) both original shoots covered by transparent shade; (right) both original shoots covered by opaque shade. Note (a) the excellent distribution of the labelled material as a response to covering both shoots with transparent shade and (b) the accumulation of labelled material in young aerial shoots and rhizome tips in the right hand picture.

The clear picture that emerges from these experiments is that the application of a shade or shades to the experimental system has a very marked effect on the extent of the movement of labelled material. Improved distribution of the chemical occurs consistently when the treated shoot is covered by a shade.

Shading has various effects on the physiology of a plant. Dark shades arrest photosynthesis and ultimately cause death. They also raise the humidity. Clear shades raise the humidity. Both types of shades cause temperature changes. The air under a dark shade warms up more slowly in sunlight than does free air which, in turn, lags behind the air under a clear shade. When direct sunlight ceases, free air cools faster than air under a clear shade, whereas the temperature of the air under a dark shade falls even more slowly. On a cloudy day, the amplitude of fluctuations of temperature is greatest under a clear shade and least under a dark shade. Since no attempt was made to record these changes during these experiments, temperature differences must not be neglected in any interpretation of the results. It is known, however, that the maximum temperature difference obtained in full sunlight was 5°C between a transparent and a dark shade, with free air intermediate.

In spite of the temperature differences, it is interesting to note that both opaque and transparent shades produce similar responses, although free air is frequently intermediate in respect of temperature fluctuations and extremes. In view of this, it is difficult to believe that temperature is the primary cause of the differences between shaded and non-shaded systems. It could, however, be important in explaining some of the differences between opaque and transparent shaded systems.

The most obvious feature that transparent and opaque covers have in common when placed over a green plant is that they both increase the humidity of the trapped air and, in consequence, tend to reduce the transpiration rate of the enclosed shoot.

Now, Crafts and Foy (1959) have demonstrated that dalapon shares with amitrole and maleic hydrazide the property of ready transference from phloem to xylem. This confers on the chemical the ability to 'circulate' within the plant system.

The single conclusion that I wish to draw from these experiments is that the increased movement that occurs as a result of shading is mainly due to the reduction in the transpiration rate. To draw any further general conclusions would be folly, but it is of interest to consider the mechanism by which transpiration rate might affect the speed of downward movement of dalapon in this experimental system.

Current interpretation of these experiments and others, (Sagar, unpublished), suggests that dalapon moves down the treated leaf and shoot into the rhizome system in the phloem and that this movement may be accelerated by the presence of actively growing rhizome tips which act as 'sinks' for the herbicide. In addition to this downward movement, it is suggested that dalapon may be constantly transferred from the phloem to the xylem at all stages during its passage down the plant. This transfer might be more readily effected in a monocotyledon where the xylem and phloem tissues are not separated by a cambium and where intercalary cambium is common. It is conceivable, and indeed probable, that the rate of movement of water in the xylem might affect the rate at which the dalapon is drawn from the phloem, less herbicide being removed as water speed decreases. The effect of a shade on a treated shoot would be to slow down or arrest the upward movement of water and in consequence increase the apparent rate of movement of material in the phloem.

At no stage in these investigations has it been possible to rule out the simplest explanation of all which would account for the observations. It is conceivable that at some stage or stages during the period from treatment to harvest, water movement in the xylem has been reversed and that in consequence water plus dalapon in the xylem and dalapon in the phloem have both moved in the downward direction for a greater or lesser length of time. Since much of the xylem tissue is dead and water movement may be regarded as a physical phenomenon, the movement of dalapon in xylem systems would be very much more rapid than its movement in the phloem. This simple interpretation of the results must not be forgotten in future experiments.

Nevertheless, the finding to be passed on to the field investigator is that the humidity at the time of spraying, and subsequently, may be the crucial factor in determining the success or failure of an application of dalapon.

Since amino triazole is even more readily transferred from phloem to xylem (Crafts, 1959) than dalapon, humidity acting on the transpiration stream might also be the key to the variability of the results obtained from the use of this chemical in the field.

Acknowledgments

Thanks are due to Dr. W. E. Ripper of Dow Agrochemicals Ltd., for financial assistance which made this investigation possible. It is a pleasure to record my thanks to Mr. R. G. Powell for making up the solutions; to Messrs. R. J. Bowerman and C. Donaldson for technical assistance, and to Mrs. S. W. Holmes for secretarial help. I am very grateful to J. Mattock, Esq., for a supply of rhizomes of *A. repens*. Dr. E. K. Woodford and all other members of A.R.C. Units at Oxford, Wytham and Begbroke receive sincere thanks for stimulating discussion, criticism and assistance at all times, I wish to thank Professor J. L. Harper for his critical reading of the manuscript.

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# THE EFFECTS OF ADDED PENETRANT AIDS AND WETTING AGENTS ON THE RESPONSE OF QUACKGRASS (AGROPYRON REPENS) TO DALAPON

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Summary: Tests using 2-$C^{14}$ labelled dalapon formulations with and without nonionic wetting agents resulted in a definite increase in the amount of dalapon 2-$C^{14}$ recovered from rhizomes, untreated shoots, and leaves when wetting agent had been added to the solution. These increases in the amount of dalapon translocated were measured on uniform plants under conditions which avoided such variables as differences in leaf area covered by droplets of equal volume but with different surface tensions, and differences in the amount of formulation applied per plant resulting from the influence of the wetting agent on retention of the formulation by the leaf. Erratic results have been obtained from time to time in field applications of dalapon. These tests, run under controlled conditions with uniform plants emphasize the need for a properly wetting formulation.

## INTRODUCTION

Since its introduction in 1953, 2,2-dichloroproprionic acid (dalapon) has been of considerable interest because of its practical selectivity with grasses. In addition to many field trials, a large number of more detailed experiments bave been conducted in attempts to determine its sites of action in plants, the method by which it is translocated in plants, and its ultimate fate in both plant tissue and soil. A number of experiments have been conducted with and without wetting agents. The present study was undertaken to determine the effect of some surface active agents on the translocation of a sodium dalapon into the rhizomes of quackgrass (Agropyron repens).

There is ample evidence in the literature that spray additives which have surface-active characteristics can increase the effectiveness of a number of herbicides. (Currier, H. B. 1954; Foy, C. L. 1958; Hamner, C. L. et al. 1947; Hitchcock, A. E. et al. 1948; Staniforth, D. W. et al. 1949; Woodford E. K. et al. 1958).

It has been pointed out (Ennis W. B. et al. 1952) that differences may exist in the effectiveness of herbicide formulations even with equal wetting, and that considerable care in the selection of a wetting agent is required.

Daniels (1953) refers to a relationship existing between the ionic character and the relative polarity of a compound which suggests that the addition of suitable surfactants to a strongly ionic, hydrophylic, polar compound such as sodium 2,2-dichloropropionate (sodium dalapon) might very well cause such a formulation to become more compatible with non-polar materials such as those found in the cuticle of plants.

Robbins et al. (1952) state that "increase in polarity enhances the apparent reactivity (of a herbicide) whereas increase in its oil-like (a-polar) properties promotes penetration".

They conclude that since the two processes are apparently opposed, there must be an optimum point in the balance between them; and this in reality represents a compromise between toxicity and compatibility with the cuticle.

Orgell (1957) has observed that cationic and anionic surfactants differ markedly in their effects on absorption of acidic compounds, and Staniforth (1949) states that non-ionic wetting agents differ in action from that of sodium laurel sulphate - an anionic wetting agent.

The observation by Currier (1954) that root absorption of dalapon is enhanced by the addition of a surfactant is of interest since roots are normally readily wetted by water, and thus perhaps confirms the earlier observation of Ennis et al (1952) by indicating some effect on root cell protoplasm. Present knowledge of the effect of surfactants in herbicidal solutions is far from complete; and a 1954 summary by Currier still represents the state of the art fairly well.

Foy (1958) using both $C^{14}$ and $Cl^{36}$ labelled dalapon demonstrated the advantages of using wetting agents with dalapon. For example, on the basis of growth inhibition, it appeared that as much dalapon was absorbed by corn in one hour from sprays containing a surfactant as in two weeks from a solution without a surfactant.

Jansen et al (1960) found a wide range in response to dalapon by both soybeans and corn in tests using 63 different wetting agents in combination with dalapon.

METHODS AND MATERIALS

Prior to the start of this experiment, Jansen's data had been reviewed, and on the basis of his results, a number of surfactants which had improved the herbicidal effects of dalapon on corn and soybeans were tentatively selected for use. Some of these were not readily available, so a further selection was made, and the following surfactants were obtained:

| Surfactant | Type | Produced by |
|---|---|---|
| Duponal WA Flake | Anionic | E.I. DuPont de Nemours and Company |
| Ethomeen S-15 | Cationic | Allied Chemical Corporation |
| Tergitol TMN | Non-ionic | Union Carbide Corporation |
| Polyglycol 26-2 | Non-ionic | The Dow Chemical Company |

Tests to determine retention on the leaves of quackgrass and tests to determine the required dose of dalapon-2-$C^{14}$ showed that the non-ionic surfactants were superior to both the ionic ones. Accordingly, Tergitol TMN and Polyglycol 26-2 were used in the rest of the experiments.

A formulation of the salt of sodium dalapon was sub-divided and each wetting agent was added to aliquots to give wetting agents concentrations of 0.2 per cent, 0.1 per cent and 0.05 per cent by weight and a concentration of the sodium salt of dalapon equivalent to 10 lb in 60 U.S. gal. These percentages are in the range of the concentrations of wetting agent which are used in field applications of dalapon at recommended rates.

This experiment was conducted with pot-grown plants of quackgrass (Agropyron repens). All test plants were grown from two node sections of quackgrass rhizomes which had been selected for uniform size and weight from a clone. The test plants were produced and held after treatment in a Percival controlled environment chamber with a day temperature of 78$^{o}$F and a night temperature of 66$^{o}$F having three four-degree temperature steps between the extremes. The plants were grown under a twelve hour day length with a maximum intensity of 3900 foot-candles at bench height. Light intensity was also regulated through three increments per cycle, with nine hours of maximum intensity light during each 24 hour period.

Plants were selected for uniformity of sprouts shortly after emergence, and again at the three leaf stage. A final selection made when the test was started resulted in an extremely uniform group of plants in the 6-leaf stage of growth, each having a second shoot in the 3-leaf stage of growth. Preliminary trials gave coefficients of variation of from 8 to 10 per cent for plant height, weight, and rhizome weights. Six replicates were used for each treatment.

Test solutions were prepared by dispersing the wetting agent in water, and diluting to the required concentration, then adding unlabelled dalapon-sodium to a concentration equivalent to 10 lb to 60 gal.

A sample of 2-$C^{14}$ labelled sodium salt of dalapon having a specific activity of 0.98 millicuries per millimole was used for the test. The solution employed contained 1.35 microcuries ml.

An area 5 mm by 50 mm on the upper surface of the third leaf of each test plant was walled with lanolin. This area was then supported in a horizontal position, and flooded with ½ ml of the proper dalaponwetting agent solution. A two hundred lambda aliquot of the 2-$C^{14}$ labelled sodium dalapon solution was added to the wetting agent solution on each leaf, after which the leaves were allowed to dry.

After five days, the plants were dissected and the individual leaves, stem, rhizomes, and roots were cut with shears into ½ in. segments. The various parts, except for the treated leaves were ground in a glass homogenizer. The pieces of treated leaf (with the lanolin wall) were placed into vials containing 5 ml of water containing sodium carbonate slightly in excess of saturation. The vials were heated to approximately 99C, placed in a freezer at 0C for 24 hr, and then crushed with a stirring rod. After grinding or crushing, each sample was centrifuged, and the supernatant liquid removed for analysis.

Counting was done in a Packard tri-carb automatic scintillation counter using a solvent system consisting of 70 per cent redistilled toluene and 30 per cent absolute ethanol and which contained 4 gm of 2,5-diphenyloxazole and 0.1 gm of 1,4-bis-2-(5-phenyloxazolyl)-benzene/l. A ½ ml of supernatant liquid from a sample preparation was added to nineteen and ½ ml of scintillation solution, dispersed by shaking, and counted at 50C for 30 min (or to a count of 100,000 if this was reached first.)

$C^{14}$ standard solutions and scintillation blanks were used, and the counting efficiency (which was determined for each counting run) varied from 54 per cent to 57 per cent.

Although other workers have reported that dalapon is easily leached from plant tissue, the sample preparation procedure was checked to determine whether or not a disproportionate amount of dalapon-2-$C^{14}$ remained in the solid portion. By successive extractions, it was determined that the dalapon-2-$C^{14}$ was readily equilibrated in the system.

It was also considered possible that the added wetting agent might affect the absorption of dalapon by the lanolin used to wall the application areas. This was checked, and found not to be a factor.

RESULTS AND DISCUSSION

Applications of the dalapon and surfactant formulations were made to the third leaf of quackgrass plants in the 6-leaf stage. After 5 days, the various plant parts were examined by liquid scintillation counting. The results obtained with dalapon alone are shown in Table I.

TABLE I. THE NET COUNTS PER MINUTE OBTAINED FROM VARIOUS PARTS OF QUACKGRASS PLANTS TREATED WITH $C^{14}$ LABELLED DALAPON IN WATER WITH NO ADDED WETTING AGENT.

(Background count = 28.3 cpm.)

| Replicate | First leaf | Second Leaf | Third Leaf* | Fourth Leaf | Fifth Leaf | Sixth Leaf |
|---|---|---|---|---|---|---|
| 1 | 26 | 37 | 8684 | 163 | 327 | 346 |
| 2 | 20 | 38 | 7872 | 216 | 355 | 337 |
| 3 | 25 | 37 | 7432 | 206 | 329 | 295 |
| 4 | 24 | 31 | 8425 | 189 | 273 | 332 |
| 5 | 27 | 40 | 6915 | 174 | 285 | 380 |
| 6 | 20 | 28 | 8439 | 225 | 286 | 256 |
| average | 23.7 | 35.2 | 7978 | 195 | 309 | 324 |
| standard deviation | 3.1 | 4.2 | 679 | 24 | 32 | 43 |
| C.V. (per cent) | 13.1 | 11.9 | 8.5 | 12.3 | 10.4 | 13.3 |

* Application made to third leaf

TABLE 1. (Contd.)

| Replicate | Stem | Untreated shoot | Old rhizome section | New rhizome | Roots |
|---|---|---|---|---|---|
| 1 | 36 | 409 | 20 | 82 | 24 |
| 2 | 26 | 470 | 17 | 76 | 18 |
| 3 | 30 | 456 | 21 | 60 | 22 |
| 4 | 33 | 439 | 26 | 69 | 27 |
| 5 | 29 | 552 | 24 | 67 | 19 |
| 6 | 33 | 472 | 16 | 70 | 23 |
| average | 32.2 | 466 | 20.7 | 70.7 | 22.2 |
| standard deviation | 3.3 | 48 | 3.9 | 7.6 | 3.3 |
| C.V. (per cent) | 10.2 | 10.3 | 18.9 | 10.8 | 14.9 |

The variation between replicates as shown in Table I is typical of that obtained with the other treatments. The results obtained using dalapon with two non-ionic wetting agents each in three different concentrations were compared with those shown for dalapon alone by calculating the per cent of applied dalapon-2-$C^{14}$ which was found in each of the several plant parts.

A number of comparisons are possible in this manner, some obviously of more interest than others. Translocation into new rhizomes and through old rhizomes into untreated shoots is of considerable importance in obtaining control of quackgrass. The effectiveness of the wetting agents in influencing movement into these parts is shown in Table II.

TABLE II. THE PER CENT OF APPLIED RADIO-DALAPON WHICH WAS FOUND IN THE RHIZOMES, ROOTS, AND UNTREATED SHOOTS.

(Application made on third leaf of 6 leaf plants of quackgrass)

| | | New rhizome | Old rhizome | Untreated shoot | Roots |
|---|---|---|---|---|---|
| Dalapon alone | | 0.74 | 0.22 | 4.9 | 0.26 |
| Dalapon with P-26-2. | 0.05 per cent | 1.35 | 0.53 | 7.3 | 0.28 |
| | 0.1 " " | 1.92 | 0.67 | 8.4 | 0.17 |
| | 0.2 " " | 2.94 | 0.81 | 10.5 | 0.24 |
| Dalapon with Tergitol TMN | 0.05 per cent | 1.43 | 0.49 | 6.9 | 0.22 |
| | 0.1 " " | 2.05 | 0.73 | 7.7 | 0.26 |
| | 0.2 " " | 3.65 | 0.94 | 9.4 | 0.31 |

These experiments clearly showed that the addition of selected non-ionic wetting agents to the formulation resulted in increased movement of dalapon into the rhizomes, and that the results obtained with the two wetting agents were quite similar.

The accumulation of dalapon in young tissue was also markedly increased by the addition of non-ionic wetting agents, and such increases are shown in Table III.

TABLE III. THE PER CENT OF APPLIED $C^{14}$ DALAPON WHICH WAS FOUND IN THE LEAVES ABOVE THE TREATED (THIRD) LEAF

| | | 4th leaf | 5th leaf | 6th leaf |
|---|---|---|---|---|
| Dalapon alone | | 2.0 | 3.2 | 3.4 |
| Dalapon plus P-26-2 | 0.05 per cent | 2.4 | 3.9 | 11.7 |
| | 0.1 " " | 3.9 | 5.6 | 16.5 |
| | 0.2 " " | 6.3 | 8.2 | 24.4 |
| Dalapon plus Tergitol TMN | 0.05 per cent | 2.2 | 2.6 | 9.2 |
| | 0.1 " " | 6.0 | 6.6. | 16.1 |
| | 0.2 " " | 10.8 | 11.9 | 26.2 |

Here, as shown before, the use of the wetting agents resulted in increased accumulation of dalapon-2-$C^{14}$.

The comparisons for lower leaves, stems and roots were also made, and in each instance the addition of wetting agent increased the amount of radio-activity. The differences were quite large in some cases, probably because the amount of radioactivity found in these plant parts was quite low when no wetting agent was used. In every instance, the amount of radioactivity which remained in the treated leaf was less when wetting agents were added than when dalapon alone was used.

These data show clearly that the addition of a non-ionic wetting agent to the formulation used in this experiment markedly increased the uptake and translocation of dalapon-2-$C^{14}$.

The amount of dalapon-2-$C^{14}$ translocated above and below the treated leaf was determined by computing the net count per minute for the appropriate plant parts (sample average net count per minute times the dilution factor used in preparing the sample) then comparing the count beyond the treated leaf with the total count. The per cent of applied dalapon translocated above the treated leaf and the per cent translocated below the treated leaf are shown in Table IV.

TABLE IV. THE TRANSLOCATION OF $C^{14}$ LABELLED DALAPON IN FORMULATIONS WITH AND WITHOUT ADDED WETTING AGENTS.

| | Dalapon alone | Dalapon with P-26-2 | | | Dalapon with Tergitol TMN | | |
|---|---|---|---|---|---|---|---|
| | | 0.05 per cent | 0.1 per cent | 0.2 per cent | 0.05 per cent | 0.1 per cent | 0.2 per cent |
| The per cent of applied dalapon translocated above the treated leaf. | 8.7 | 17.4 | 26.1 | 38.5 | 14.0 | 27.5 | 49.7 |
| The per cent of applied dalapon translocated below the treated leaf | 7.1 | 13.4 | 19.0 | 28.9 | 10.4 | 18.0 | 29.2 |

These data show several things in addition to the obvious influence of added wetting agent. First, although both non-ionic wetting agents performed similarly; when formulations containing the low rate of wetting agent were used, the use of Poyglycol 26-2 resulted in greater accumulation of $C^{14}$ dalapon in the various plant parts than did the use of Tergitol TMN. The reverse was true at the high rate. It would probably be difficult to establish the significance of this on the basis of these data alone, but the same trend existed in several preliminary tests using a number of different concentrations of both wetting agents. Surface tension measurements showed that at 0.2 per cent in the formulation, Tergitol TMN reduced surface tension more than did Polyglycol 26-2, while at concentrations of 0.05 per cent and less, the reverse was true.

This may indicate that penetration (as affected by surface tension) is a major factor influencing the results obtained.

A study of the amount of dalapon translocated into the new rhizomes shows that although the amounts accumulated increased with added wetting agent, there was a slight decrease in the percentage of translocated dalapon which moved to the rhizomes. This also would tend to support the hypothesis that the surface active agent influenced penetration more than translocation, and that whatever conditions limit the transport of dalapon-2-$C^{14}$ into the rhizome still appeared to be limiting when wetting agents are used in the formulation.

Second, significant amounts of dalapon-2-$C^{14}$ were translocated through the rhizome to untreated shoots. Not all shoots can be equally well covered by a field spray, and a number of quackgrass shoots are normally connected by rhizomes. The transport of dalapon from one shoot to another through the rhizome section may tend to equalize a less than perfect spray application. In these experiments, as little as 0.05 per cent of a non-ionic wetting agent in the formulation increased the movement of dalapon-2-$C^{14}$ into an untreated shoot by nearly 50 per cent, while 0.2 per cent in the formulation increased movement into an untreated shoot by nearly 100 per cent.

Movement into new rhizomes followed the same pattern, with the addition of 0.05 per cent wetting agent resulting in more than 80 per cent increase in accumulation of $C^{14}$-dalapon while the addition of 0.2 wetting agent resulted in at least four times the accumulation of radioactivity obtained with formulations containing no wetting agent.

Movement of dalapon-2-$C^{14}$ into the leaves was increased more by the addition of wetting agents than movement into and through the rhizomes, but it is felt that these movements (into rhizomes and through rhizomes to untreated shoots) are critical in evaluating the herbicidal effectiveness of dalapon on quackgrass.

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# DALAPON FOR THE CONTROL OF "COUCH" (AGROPYRON REPENS, AGROSTIS GIGANTEA AND AGROSTIS STOLONIFERA)

## (A Summary of Some N.A.A.S. Trials 1957-1959)

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Summary. Seventeen trials, in which treatment of couch or bent (*Agropyron repens*, *Agrostis Gigantia* and *A.stolonifera*) with dalapon, at doses falling within the range of 4-20 lb per acre, applied in all on 26 occasions, were carried out on farms by the N.A.A.S. in 1957-1959. Difficulty was encountered in making satisfactory assessments of the degree of control of grasses produced by chemical treatment. Results showed dalapon to be unreliable in its effects under the practical farm conditions encountered in the trials. The trials are not capable of indicating the reasons for the variable results. A little evidence on split applications of dalapon, pre-spraying treatment with nitrogen, and rolling pre- or post-spraying suggests that none of these techniques materially assists in the control of couch or bent with dalapon.

## INTRODUCTION

This report summarises various trials carried out on farms by members of the N.A.A.S. to investigate the efficiency of dalapon, at a range of doses and under varying conditions, in controlling couch and bent grasses (*Agropyron repens*, *Agrostis stolonifera* and *Agrostis gigantea*).

## METHODS AND MATERIALS

The trials, carried out from 1957 to 1959 were not standardised in treatments, layout or assessment. A sodium salt of dalapon containing 74 per cent a.e. and a wetting agent* was used in all trials. Two, three or four doses, between 4 and 20 lb of dalapon/ac, were included in each trial. Times of spraying ranged throughout the year and there was one or more dates of spraying in each trial. In addition, there were trials in which a single application of dalapon was compared with a split application of the same dose and trials to investigate the effect of treatment of "couch", by rolling or top dressing with nitrogen, on the degree of control achieved.

The layouts of the trials were, in each case, randomised blocks with usually three replicates. Plot size varied from 1/200 ac to 1/20 ac. Sites were usually selected where the infestation of couch or bent was heavy.

*The commercial product "Dowpon"

The varied type and timing of cultivations following spraying and the different cropping systems made standardised assessments for the trials impossible. One or more of four methods of assessment were carried out at convenient times following spraying. The methods were:

I. Score for the amount of foliage present on the scale 0-10 where 0 = no foliage present and 10 = maximum amount of foliage.

II. Counts of shoots per unit area.

III. Estimate of the percentage of ground area covered by "couch" foliage.

IV. Fresh weight of samples of rhizomes plus foliage.

Wherever possible assessments were continued into the second year. Details of each site are shown in Table I.

## RESULTS

In order to be able to present a mass detail in tabular form the results of all assessments have been transformed to the scale 0 - 100 with control plots as 100 in every case; the amount of grass in the control plots at the time of assessment is indicated where recorded (See Table I).

The three points that are immediately apparent in the results in Table I are (i) the higher the dose generally the better the control of the grasses (ii) the failure of treatment with dalapon in the majority of cases to eliminate, or reduce to less than 1/10 the amount on untreated areas, any species of "couch". Good results have generally been apparent only when the plots have been observed within a few months of spraying (iii) the variability of results from site to site (Figure 1 illustrates this). The three spray treatments that gave particularly poor control (Figure 1(a) "couch" at 60-70 compared with control at 100) were Cornwall (sprayed 3/1/58) Derby (sprayed 1/11/57) and Montgomery (sprayed 10/10/58). *Agrostis sp.* at Cornwall was regrowth after ploughing which was "not considerable" and results may be poor for this reason. At Montgomery rain fell four hours after spraying (the second spraying at Montgomery was followed by at least eight hours dry weather and gave a better but still poor control of couch) and the rainfall may have contributed to the poor control of *Agrostis stononifera*. The Derbyshire site on *Agrostis sp.* was sprayed fairly late in the autumn but whilst the couch was still green (the spraying carried out a month earlier gave somewhat better control of bent) and ploughing was not carried out until four months later.

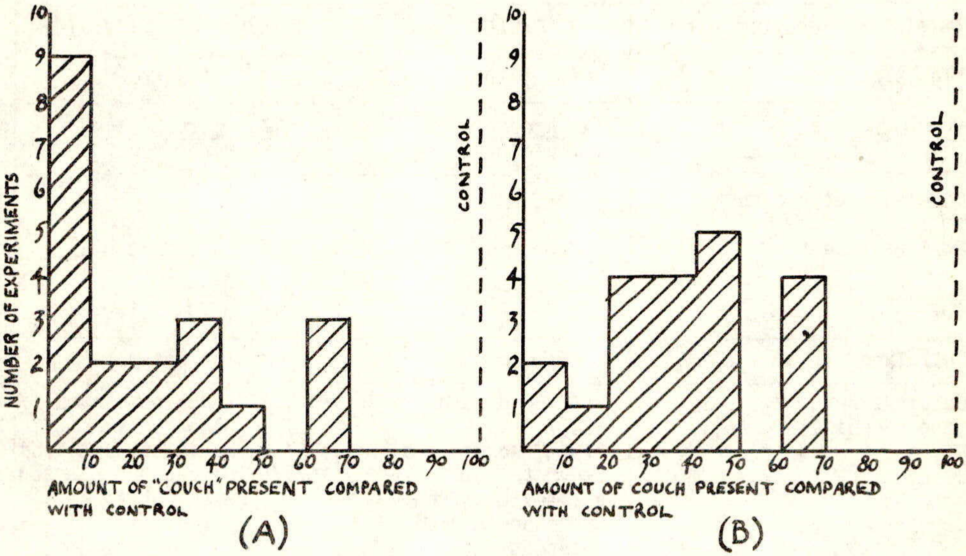


Fig. 1. The best (a) and poorest (b) control of couch recorded (at any time and by any method) from the same 20 treatments of not less than 13½ lb dalapon/ac.

TABLE I. DETAILS OF SITES AND SUMMARY OF CONTROL OF "COUCH" AND BENT

(Results of all assessments transformed to scale 0-100 with control plots as 100)

| Site | 1. Devon (I) | | 2. Flint | | | |
|---|---|---|---|---|---|---|
| Date(s) of Spraying | 4/6/57 | | 18/9/57 | | 16/10/57 | |
| Plot size (ac) | 1/100 | | 1/100 | | | |
| Couch species | Agrostis gigantea | | Agropyron repens | | | |
| Condition of "Couch"[x] | B | | A | | A | |
| Foliage height | 4-6 in. | | 6 in. | | 7-8 in. | |
| Density | - | | 17 shoots/ sq ft | | - | |
| Soil Type | culm shale | | medium heavy loam | | | |
| Cultivations and cropping | -/12/56 plough<br>6/857 "<br>-/9/57 worked and sown to kale<br>spring/58 worked and planted with potatoes | | -/11/57 twice rotovated<br>-/1/58 ploughed<br>-/4/58 heavy cultivations<br>16/4/58 ridged and planted with potatoes | | | |
| Dates of assessments | 20.7.57 | 20.3.58 | 27.7.58 | | 14.6.59 | |
| Months after treatments | 1½ | 9½ | 10 | 9 | 21 | 20 |
| Type of assessment* | IV | IV | II | II | III | III |
| 4-5 dalapon/ac | 66 | 95 | 44 | 73 | 95 | 78 |
| 6 lb " " | 64 | 53 | 38 | 51 | 86 | 63 |
| 9-10 lb" " | 39 | 29 | 44 | 51 | 26 | 60 |
| 13½ - 15 lb dalapon/ac | 33 | 8 | 0 | 22 | 44 | 29 |
| 20 lb " " | - | - | - | - | - | - |
| Infestation in control plots at time of assessment | 1.2 lb rhizomes / sq ft | 0.45 lb rhizomes /sq ft | 30 shoots/ sq ft | | 45 per cent ground cover | |

* I = score for abundance of foliage
II = shoot counts
III = ground cover of foliage
IV = fresh weight of shoots and rhizome.

[x] A = in cereal stubble, B = as regrowth following some cultivation treatment, generally ploughing

TABLE I (continued)

| Site | 3. Berks (I) | | | | |
|---|---|---|---|---|---|
| Date(s) of spraying | 19/9/57 | | 6/11/57 | | 6/3/58 |
| Plot size (ac) | 1/100 | | | | |
| "Couch" species | A. repens 75 per cent<br>Agrostis spp. 25 " | | 60 per cent<br>40 " " | | 55 per cent<br>45 " " |
| Condition of "Couch"[x] | A | | B | | B |
| Foliage height | 6-9 in. | | 4-5 in. | | 5-6 in. |
| Density | 45 per cent ground cover | | 20 per cent ground cover | | 30 per cent ground cover |
| Soil type | gravel loam | | | | |
| Cultivations and cropping | 4/10/57 plough | | 8/9/57 plough | | |
| | -/4/58 Seedbed prepared<br>12/4/58 Barley sown | | | | |
| Dates of assessments | 26.3.58 | | 16.10.58 | | |
| Months after treatments | 6 | 5 | 13 | 12 | 7 |
| Type of assessment* | II | II | IV | IV | IV |
| 4-5 lb dalapon/ac | 11 | 0 | 57 | 37 | 18 |
| 6 lb " " | - | - | - | - | - |
| 9-10 lb dalapon/ac | 9 | 0 | 32 | 48 | 9 |
| $13\frac{1}{2}$-15 lb " " | - | - | - | - | - |
| 20 lb " " | 2 | 0 | 25 | 33 | - |
| Infestation in control plots at time of assessment | 28 shoots/sq ft | | 0.95 lb rhizomes/sq ft | | |

* I = score for abundance of foliage
II = shoot counts
III = ground cover of foliage
IV = fresh weight of shoots and rhizome

[x]A = in cereal stubble, B = as regrowth following some cultivation treatment, generally ploughing

TABLE I (continued)

| Site | 4. W. Sussex | | | | | 5. Cornwall | | | |
|---|---|---|---|---|---|---|---|---|---|
| Date(s) of spraying | 20/9/57 | | | 13/2/58 | | 1/10/57 | | 30/1/58 | |
| Plot size (ac) | 1/20 | | | | | 1/25 | | | |
| "Couch" species | A.repens 25 per cent Agrostis spp. 75 per cent | | | 50 per cent 50 per cent | | Agrostis spp. | | | |
| Condition of "Couch"[x] | A | | | B | | A | | B | |
| Foliage height | 4-14 in. | | | 3 in. | | - | | - | |
| Density | 20-75 per cent ground cover | | | 10-15 per cent ground cover | | thick | | regrowth not considerable | |
| Soil Type | sandy loam | | | | | light loam | | | |
| Cultivations and cropping | 10/10/57 plough -/3/58 seedbed prepared 4/4/58 barley sown | | | | | -/10/57 ploughed | | 20/9/57 ploughed | |
| | | | | | | 7/4/58 worked and sown to barley | | | |
| Dates of assessments | 4.4.58 | 16.9.58 | | | | 12.11.58 | | | |
| Months after treatments | 6½ | 12 | | 7 | | 13 | | 9½ | |
| Type of assessment* | II | I | IV | I | IV | II | IV | II | IV |
| 4-5 lb dalapon/ac | 7 | 60 | 41 | 76 | 75 | 47 | 28 | 81 | 62 |
| 6 lb " " | - | - | - | - | - | - | - | - | - |
| 9-10 lb " " | 2 | 58 | 16 | 47 | 28 | 39 | 13 | 63 | 56 |
| 13½-15 lb " | - | - | - | - | - | - | - | - | - |
| 20 lb " | 1 | 46 | 24 | 20 | 10 | 48 | 36 | 70 | 62 |
| Infestation in control plots at time of assessment | 24 shoot/ sq ft | - | 0.6 lb rhiz/ sq ft | - | 0.6 lb rhiz/ sq ft | 12 sh. sq ft | 0.13 lb rhiz/ sq ft | 62 sh. sq ft | 0.13 lb rhiz/ sq ft |

* I = score for abundance of foliage
II = shoot counts
III = ground cover of foliage
IV = fresh weight of shoots and rhizome

[x] A = in cereal stubble, B = as regrowth following some cultivation treatment, generally ploughing

TABLE I (continued)

| Site | 6. Derby | | 7. Bucks | | 8. Northampton | |
|---|---|---|---|---|---|---|
| Date(s) spraying | 14/10/57 | 30/1/58 | 15/10/57 | | 21/10/57 | 12/11/57 |
| Plot size (ac) | 1/40 | | 1/20 | | 1/20 | |
| Couch species | Agrostis spp. | | A.repens 40 per cent A.gigantea 60 per cent | | Agrostis spp. | |
| Condition of "Couch"[x] | A | A | A | | A | A |
| Foliage height | - | - | 4-7 in. | | - | - |
| Density | - | - | 60 per cent ground cover | | - | - |
| Soil Type | sandy loam | | gravel loam | | medium loam | |
| Cultivations and cropping | -/3/58 plough | | 28/11/57 plough -/1/58 rotovate and harrow 25/2/58 sown to oats | | ploughed and sown to oats in 1958 | |
| Date of assessment | 5/5/59 | | 22.5.58 | 16.9.58 | 9.10.58 | |
| Months after assessment | 6½ | 6 | 7 | 11 | 12 | 11 |
| Type of assessment* | I | I | III | III | I | I |
| 4-5 lb dalapon/ac | 60 | 60 | 40 | 72 | 40 | 30 |
| 6 lb " " | - | - | - | - | - | - |
| 9-10 lb " " | 40 | 95 | 20 | 29 | 30 | 20 |
| 13½-15 lb " " | 50 | 70 | - | - | 40 | 20 |
| 20 lb " " | - | - | - | - | - | - |
| Infestation in control plots at time of treatments | - | | 75 per cent ground cover | 73 per cent ground cover | 65 per cent ground cover | |

* I = score for abundance of foliage
II = shoot counts
III = ground cover of foliage
IV = fresh weight of shoots and rhizomes

[x] A = in cereal stubble, B = as regrowth following some cultivation treatment, generally ploughing

TABLE I (continued)

| Site | 9. Staffs | 10. Denbigh | | 11. Kent |
|---|---|---|---|---|
| Date(s) Spraying | 23/10/57 | 5/4/58 | | 29/4/58 |
| Plot size (ac) | 1/50 | 1/100 | | 1/30 |
| "Couch" species | Agropyron repens | A.repens 60 per cent A.stolonifera 40 per cent | | A.gigantea A.stononifera |
| Condition of "Couch"[x] | B | B | | B |
| Foliage height | 4-6 in. | 5-6 in. | | 1-5 in. |
| Density | | 20 shoots per sq ft | | 34 per cent ground cover |
| Soil type | sandy loam | medium/heavy loam | | clay with flint |
| Cultivations and cropping | -/9/57 plough -/4/48 sown to ley | Barley 1957-stubble rotovated -/1/58 plough followed by further rotovation<br><br>16-20/8/58 plough and sown to rape 28/3/59 rotovated twice before plough & sowing to barley | | 30/5/58 plough 11/6/58 disc twice sown to kale |
| Date of assessment | Spring 1958 | 28.7.58 | 9.6.59 | -.11.58 |
| Months after assessment | c.5 | 3½ | 14 | 7 |
| Type of assessment* | IV | II | II | III |
| 4-5 lb dalapon/ac | 41 | 7 | 22 | 20 |
| 6 lb " " | - | - | - | - |
| 9-10 lb " " | 32 | 3 | 0 | 12 |
| 13½-15 lb " " | 30 | 0 | 7 | - |
| 20 lb " " | - | - | - | - |
| Infestation in control plots at time of treatments | 0.06 lb rhizomes/ sq ft | 16 shoots/ sq ft | 4.5 shoots/ sq ft | 83 per cent ground cover |

* I = score for abundance of foliage
II = shoot counts
III = ground cover of foliage
IV = fresh weight of shoots and rhizomes

[x] A = in cereal stubble, B = as regrowth following some cultivation treatment, generally ploughing

TABLE I (continued)

| Site | 12. Lincs | 13. Berks | | 14. Devon (II) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date(s) of spraying | 5/5/58 | 14/5/58 | | 8/6/58 | | | | | | |
| Plot size (ac) | 1/50 | 1/200 | | 1/200 | | | | | | |
| "Couch" species | A. repens 30 per cent Agrostis spp. 70 per cent | A. stononifera | | A. repens 70 per cent Agrostis spp. 30 per cent | | | | | | |
| Condition of "Couch"[x] | B | growing in peas | | B | | | | | | |
| Foliage height | - | - | | 5-6 in. | | | | | | |
| Density | 67 per cent ground cover | 40 per cent ground cover | | 80 per cent ground cover | | | | | | |
| Soil type | heavy boulder clay | chalk | | - | | | | | | |
| Cultivations and cropping | -/12/57 plough then untouched until assessment 25/8/58 | -/11/57 plough -/4/57 cultivated & sown to peas | | no crop 1958 20/9/58 plough | | | | | | |
| Date of assessment | 25.8.58 | 12.8.58 | 3.10.58 | 5.9.58 | | | | 17.12.58 | | |
| Months after assessment | 3½ | 3 | 4½ | 3 | | | | 6 | | |
| Type of assessment* | III | I | I | I | II | III | IV | I | II | III |
| 4-5 lb dalapon/ac | 25 | 8 | 20 | 68 | 57 | 31 | 43 | 36 | 44 | 36 |
| 6 lb " " | - | 7 | 12 | - | - | - | - | - | - | - |
| 9-10 lb " " | 12 | - | - | 38 | 31 | 37 | 39 | 39 | 40 | 44 |
| 13½-15 lb " " | - | - | - | 10 | 20 | 11 | 30 | 14 | 19 | 33 |
| 20 lb " " | 0 | - | - | - | - | - | - | - | - | - |
| Infestation in control plots at time of treatments | 80 per cent ground cover | 85 per cent ground cover | | 285 shoots/ sq ft 87 per cent ground cover 2.5 lb rhiz/ sq ft | | | | 10 shoots/ sq ft 23 per cent ground cover | | |

* I = score for abundance of foliage
II = shoot counts
III = ground cover of foliage
IV = fresh weight of shoots and rhizomes

[x] A = in cereal stubble, B = as regrowth following some cultivation treatment, generally ploughing

TABLE I (continued)

| Site | 15. Berks (III) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date(s) of spraying | 23/6/58 | | | | | 14/8/58 | | | | |
| Plot size (ac) | 1/30 | | | | | | | | | |
| "Couch" species | A. repens 70 per cent<br>Agrostis spp. 30 per cent | | | | | | | | | |
| Condition of "Couch"[x] | in clover ley | | | | | in clover ley | | | | |
| Foliage height | 4-6 in. | | | | | 8-12 in. | | | | |
| Density | - | | | | | - | | | | |
| Soil type | sandy loam | | | | | | | | | |
| Cultivations and cropping | 23/1/59 ploughed<br>24/3/59 worked and sown to barley | | | | | | | | | |
| Date of assessment | 21.1.59 | | 24.3.59 | | 2.10.59 | | 22.10.59 | | | |
| Months after assessment | 7 | 5 | 9 | 7 | $14\frac{1}{2}$ | $12\frac{1}{2}$ | 15 | | 13 | |
| Type of assessment* | I | I | III | III | I | I | III | IV | III | IV |
| 4-5 lb dalapon/ac | 29 | 11 | 9 | 25 | 66 | 66 | 65 | 52 | 46 | 58 |
| 6 lb " " | - | - | - | - | - | - | - | - | - | - |
| 9-10 lb " " | 26 | 9 | 10 | 7 | 60 | 53 | 42 | 55 | 35 | 61 |
| $13\frac{1}{2}$-15 lb " " | - | - | - | - | - | - | - | - | - | - |
| 20 lb " " | - | - | - | - | - | - | - | - | - | - |
| Infestation in control plots at time of treatments | - | | 85 per cent ground cover | | - | | 26 per cent gr. cover | 0.91b rhiz/ sq ft | 26 per cent gr. cover | 0.91b rhiz/ sq ft |

* I = score for abundance of foliage
II = shoot counts
III = ground cover of foliage
IV = fresh weight of shoots and rhizomes

[x]A = in cereal stubble, B = as regrowth following some cultivation cultivation treatment, generally ploughing

TABLE I (continued)

| Site | 16. Lincs (11) | | 17. Montgomery | |
|---|---|---|---|---|
| Date(s) of spraying | 2/10/58 | | 10/10/58 | 10/11/58 |
| Plot size (ac) | 1/50 | | 1/100 | |
| "Couch" species | A. repens dominant some Agrostis sp. | | Agrostis stolonifera | |
| Condition of "Couch"[x] | A | | A | A |
| Foliage height | 10-12 in. | | 5 in. | 5 in. |
| Density | 40- 70 per cent ground cover | | 100 per cent ground cover | 100 per cent ground cover |
| Soil type | clay | | - | |
| Cultivations and cropping | -/12/58 Plough<br>-/3/59 worked & sown to barley<br>-/10/59 Plough | | 13/12/58 Plough<br>-/4/59 harrow four times<br>20/4/59 sown to oats | |
| Date of assessment | 15.4.59 | 16.12.59 | 2.6.59 | |
| Months after assessment | 7½ | 14½ | 8 | 7 |
| Type of assessment* | I | I | II | II |
| 4-5 lb dalapon/ac | 17 | 40 | 60 | 67 |
| 6 lb " " | - | - | - | - |
| 9-10 " " | 8 | 28 | 47 | 42 |
| 13½-15 lb " " | - | - | - | - |
| 20 lb " " | 5 | 45 | 65 | 30 |
| Infestation in control plots at time of treatments | - | - | 13 shoots/sq ft | |

* I = score for abundance of foliage
II = shoot counts
III = ground cover of foliage
IV = fresh weight of shoots and rhizomes

x A = in cereal stubble, B = as regrowth following some cultivation treatment, generally ploughing

The value of a split application of dalapon was investigated in three trials but little advantage was shown by such an application compared to the same dose applied at a single time (see Table II).

TABLE II. A COMPARISON OF SINGLE V. SPLIT APPLICATION OF DALAPON

(Results of all assessments transformed to scale 0-100)

| Site | Bucks | | Lincs (II) | | Montgomery | |
|---|---|---|---|---|---|---|
| Dose (lb/ac). | 9 or 4½ + 4½ | | 10 or 7 + 3 | | 10 or 7 + 3 | |
| Interval between split appl. (days) | 9 | | 14 | | 7 | 7 |
| Date of assessment | 22.5.58 | 16.9.58 | 15.4.59 | 16.12.59 | 2.6.59 | 2.6.59 |
| Months after treatment | 7 | 11 | 7½ | 14½ | 8 | 7 |
| Type of assessment* | III | III | I | I | II | II |
| Single application | 40 | 29 | 8 | 28 | 47 | 42 |
| Split application | 20 | 25 | 5 | 42 | 49 | 40 |
| Control. | 100 | 100 | 100 | 100 | 100 | 100 |

* I = score for abundance of foliage
II = shoot counts
III = ground cover of foliage

The application of nitrogen to "couch" to encourage more vigorous growth in the hope that this may lead to better effect from a subsequent application of dalapon was investigated by Mr. R. G. Hughes S.E. region N.A.A.S. After a hay cut, a top dressing of nitrogen was applied and spraying carried out three weeks later. The unmanured plots had "couch" 4-6 in. high at the time of spraying whereas the nitrogen treated "couch" was 6-12 in. high. Results suggest that the nitrogen top-dressing may have improved the control slightly (see Table III).

TABLE III. The EFFECT OF NITROGEN ON THE CONTROL OF "COUCH" WITH DALAPON (BERKS III)

(Results of all assessments transformed to scale 0-100)

| Date of assessment | 21.1.59 | 24.3.59 | 22.10.59 | |
|---|---|---|---|---|
| Months after spraying | 7 | 9 | 15 | |
| Type of assessment* | I | III | III | IV |
| 5 lb dalapon/acre | 29 | 9 | 65 | 52 |
| " " " " + N | 32 | 5 | 46 | 39 |
| 10 lb " " | 26 | 10 | 42 | 55 |
| " " " + N | 22 | 6 | 35 | 39 |
| Control | 100 | 100 | 100 | 100 |

* I = score for abundance of foliage
III = ground cover of foliage
IV = Fresh weight of rhizomes and shoots

The effect of rolling was also investigated by Mr. Hughes. Plots on a cereal stubble were sprayed with 4½ and 9 lb dalapon/ac and rolled 9 days later on 24th October 1958. On the same day further plots were sprayed with 4 lb dalapon and rolled immediately before or after spraying. The rolling did not bruise the "couch" leaves to any extent but bent them over, exposing them more. Results, which are summarised in Table IV, provide no clear evidence but suggest that rolling may have improved the control of "couch" particularly with the lower doses of dalapon.

TABLE IV. THE EFFECT OF ROLLING ON THE EFFICIENCY OF DALAPON (BUCKS)

(Results of all assessments transformed to scale 0-100)

| Date of assessment | | 22.5.58 | 16.9.58 | |
|---|---|---|---|---|
| Months after treatment | | 7 | 11 | |
| Type of assessment* | | III | III | I |
| 4½ lb dalapon | sprayed 15.10.58 | 40 | 41 | 52 |
| 4½ lb " + roll 9 days later | | 26 | 34 | 46 |
| 9 lb " | | 19 | 12 | 18 |
| 9 lb " + roll 9 days later | | 10 | 17 | 31 |
| 4½ lb " | sprayed 24.10.58 | 26 | 31 | 46 |
| 4½ lb " + roll before spraying | | 16 | 29 | 36 |
| 4½ lb " + roll after spraying | | 16 | 26 | 41 |
| Control - rolled | | 92 | 81 | 108 |
| Control - unrolled | | 100 | 100 | 100 |

* I = Score for abundance of foliage
III = Ground cover of foliage

DISCUSSION

Satisfactory assessment of results proved difficult for several reasons. An effect of dalapon is to induce dormancy which may delay recovery of surviving rhizomes and too early an assessment may unduly favour dalapon; after recovery, differences in infestation between plots will begin to even out and too late an assessment may prejudice results against the chemical treatment. Infestations are always in a state of flux under the influence of seasons, weather, cultivations, competition from crops etc. and a difference in a few weeks in assessment may have a marked effect on results obtained. Different methods of assessment have given different results: this may be seen in Table I for the Devon (II) and Berks (III) experiments where different methods of assessment were carried out simultaneously.

Some of the variability in results can be attributed to these factors. A further factor may be that reinfestation is more probable, through the dragging of rhizomes by implements etc., on the smaller plots than on the larger plots used in the trials; this may have affected in particular some of the long-term results. Some possible factors contributing to the particularly bad results with three spray treatments (at Cornwall, Derby and Montgomery) are noted under "Results".

Ripper (1958) has stressed the value of ploughing in assisting the effect of dalapon. Control does not in general appear to have been substantially the poorer after treatment where ploughing was not carried out within two months of spraying, although often in such cases the spraying was in the spring with seed-bed cultivations following within a few months.

The trials do not indicate that any particular type of cultivation, crop, weather condition, etc. following spraying had any marked influence on results.

There is nothing in the few trials where stubble spraying was compared to spraying regrowth after ploughing, to suggest that there is particular advantage in either system and the results do not show whether there is any advantage in spraying in the spring or in the autumn. The natural fluctuation in the relative density of Agropyron repens and Agrostis spp. where they occur together (see for example Berks (I) and West Sussex sites, Table I) makes comparison of results, to obtain information on the relative susceptibility of species to dalapon, unreliable.

Thus the trials carried out under practical field conditions have shown dalapon, at doses in the range of 4-20 lb/ac, to be unreliable as a means of giving a persistant control, in the order of 80 - 100 per cent of couch or bent, but they have not been capable of satisfactorily indicating reasons for the inconsistent results. Split applications of dalapon, the use of a nitrogen top-dressing some weeks before spraying, and rolling of the "couch" about the time of spraying have not materially assisted in the control of "couch" with dalapon.

Acknowledgement

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# THE RESPONSE OF AGROPYRON REPENS TO AMINO TRIAZOLE

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Summary. In a series of pot experiments on *Agropyron repens* the 'activation' of amino triazole by $NH_4SCN$ (ammonium thiocyanate) was verified. Some evidence indicated that the effect of $NH_4SCN$ was not on penetration of amino triazole. A high degree of control was obtained with very low doses of amino triazole + $NH_4SCN$, but *A. repens* established from rhizomes from a second site was less susceptible. In field experiments this herbicide was not so effective as in the pot experiments.

## INTRODUCTION

The herbicidal properties of 3-amino-1,2,4-triazole were first indicated about 8 years ago (Behrens, 1953). There were many early reports of effectiveness for the control of *Agropyron repens*, but results were variable. In 1958 combinations of amino triazole and ammonium thiocynate ($NH_4SCN$) were found to give an enhanced effect on *Agropyron* in the U.S.A. (Anonymous, 1959). We have therefore investigated the effect of amino triazole both with and without $NH_4SCN$ on *Agropyron repens* in pots (K.H.) and in the field (R.J.C.) during the past two years.

## METHODS AND MATERIALS

For the pot experiments rhizomes were dug up from the field, cut into four-node sections and planted in moist sand. When shoots started to emerge, the rhizomes were washed out of the sand, selected and graded for evenness of sprouting, and five sections transplanted into a soil-sand mixture in a ten-inch earthenware pot. After growing-on in the open or the greenhouse to the appropriate stage of shoot-growth, they were sprayed by a specially constructed laboratory machine embodying a fan nozzle moving over the plants at a constant speed. Volume rates between 46 and 67 gal/ac were used. and the spray solutions contained 1.0 per cent v/v of a polyoxyethylene sorbitan monolaurate surface-active agent (Tween 20). Residues of herbicide on the foliage were washed off by simulated rainfall approximately 24 hr after spraying. All experiments included some treatments with dalapon as a standard grass killer. Technical grades of amino triazole and dalapon were used.

In the field experiments 0.005 acre plots were sprayed by Oxford Precision Sprayer at 20 gal/ac, using technical amino triazole and two commercial materials.+ No further surface-active agent was added. Assessment was by counting of shoots in random quadrats.

## RESULTS

In the first pot experiment the plants were sprayed when the shoots were mostly at the three-leaf stage and about 6 in. high in late December 1958. The plants were kept for the rest of the winter in the greenhouse with no

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\+ "Dowpon" and "Weedazol-T.L."

supplementary lighting, and moved into the open in April. In this instance amino triazole alone was compared with an already formulated mixture containing equal amount of amino triazole and $NH_4SCN$.* Some activation of amino triazole with pentachlorophenol had likewise been claimed (Constable, 1957) and a formulation containing an equal amount of sodium pentachlorophenate (PCP-sodium)** was also used. To investigate whether other contact herbicides gave the same effect, mixtures of amino triazole with equal amounts of pentachlorophenol as an emulsion, with one-quarter the amount of dinoseb-triethanolamine, and with one-eigth the amount of diquat, were also included. Doses are indicated in Table I.

TABLE I. PERCENTAGE OF ORIGINAL RHIZOME SECTIONS PREVENTED FROM PRODUCING VIABLE NEW SHOOT OR RHIZOME GROWTH DURING 247 DAYS FOLLOWING SPRAYING.

| Dose of amino triazole lb/ac | Amino triazole | Amino triazole + $NH_4SCN$ | Amino triazole + PCP-sodium | Amino triazole + PCP | Amino triazole + dinoseb-triethanolamine | Amino triazole + diquat | Dalapon-sodium |
|---|---|---|---|---|---|---|---|
| 1 | 87 | 93 | 10 | 40 | 67 | 73 | - |
| 2 | 100 | 100 | 54 | 80 | 100 | 66 | - |
| 4 | 100 | 100 | 67 | 87 | 100 | 60 | 0 |
| 8 | 93 | 100 | 93 | 100 | 100 | 100 | 0 |

Initial effect on the foliage was relatively slight, both from amino triazole and dalapon, except where diquat or high doses of the other contact herbicides were included. Ultimately there was some growth of new green shoots in dalapon pots, and of albino shoots in most amino triazole pots. There was a slight superiority of amino triazole with $NH_4SCN$ over amino triazole alone in killing the original shoots and reducing albino regrowth. At 136 days after spraying the rhizomes were removed for examination. Very few of the original rhizome sections were visibly dead but whereas there was vigorous growth of new rhizomes in the controls (20 g dry weight per pot) there was no new rhizome growth in any pot that had received an amino triazole treatment (except for a trace with the 1 lb/ac rate with PCP-dodium). Prevention of new rhizome growth was not quite so complete with dalapon, reduction in dry weight of new rhizome being 97 and 99 per cent at 4 and 8 lb/ac respectively. Original rhizome sections not producing new rhizome were replanted and re-examined 247 days after spraying. The proportion of the original rhizome sections which were then still inhibited from producing any new shoot or rhizome growth are given in Table I. Such rhizomes looked incapable of ultimate survival. The outstanding features shown by the data are the ultimate effectiveness of amino triazole with or without $NH_4SCN$, the dose range not going low enough to differentiate between these two series, and the reduced efficiency of amino triazole when a contact herbicide was present in the spray solution.

In the second pot experiment the shoots had three to four leaves when sprayed in mid-November 1959. The plants were kept in the greenhouse, with

* Amchem M 616
** Amchem M 617

supplementary fluorescent lighting to lengthen the photoperiod during midwinter, and moved into the open in April. Lower doses of amino triazole were used to show up any effect from the addition of $NH_4SCN$. An attempt was also made to determine whether the action of $NH_4SCN$ was due to its effect on the penetration of amino triazole. Three sets of plants were sprayed with amino triazole and $NH_4SCN$. One set received both in the same spray solution. The second set was first sprayed with $NH_4SCN$, this was washed off the foliage on the following day, and then, one day later, sprayed with amino triazole. In the third set the amino triazole was applied first, washed off after one day, and sprayed with $NH_4SCN$ on the second day. All the amino triazole applications were made on the same day. The plants sprayed with $NH_4SCN$ first, showed no visible effect when they came to be sprayed with amino triazole. Indeed, the only effect shown at any time by the $NH_4SCN$ controls was the development of a few small necrotic spots several days later.

The kill of shoots present at the time of spraying was greater than in the previous experiment with both dalapon and amino triazole. This effect was still greater if the plants received $NH_4SCN$ at any time, than if they were treated only with the amino triazole. This enhanced toxicity caused by the $NH_4SCN$ was still apparent 12 weeks after spraying. In all instances albino shoots were produced at low but not at high doses. After 223 days the rhizomes were washed free from soil, examined and the dry weight of new rhizome growth determined. At this time there was an average of 99 g of new rhizome per control pot. The percentage reductions in weight are given in Fig. 1. All amino triazole treatments were superior to dalapon, even doses as low as 0.25 lb/ac having a marked suppressive effect. The data verify the activation of amino triazole by $NH_4SCN$ and this activation occurs, though to a somewhat lesser extent, if the $NH_4SCN$ and amino triazole are applied separately and are never present together on the surface of the foliage.

Original rhizome sections which had not produced any new growth at this time were replanted and examined again 275 days after spraying. The proportion of sections which had not produced any new viable shoot or rhizome growth during this time are shown in Fig. 2. No sections treated with dalapon had died and all had shown regrowth by this time. The results with amino triazole were still good and if the results shown in Fig. 2 and Table I are compared it will be seen that the same doses in the two experiments produced remarkably similar results. Fig. 2. indicates that the addition of $NH_4SCN$ to the amino triazole solution increased the effectiveness by about four times, if the two components were applied separately the increase was about twice. The fact that one obtains any increase at all from separate applications, particularly when the $NH_4SCN$ is applied after the amino triazole, indicates that the effect of the former is not on penetration.

As a result of an observation by J. G. Elliott (unpublished) that amino triazole activated with $NH_4SCN$ gave superior effects on other grasses at low pH, solutions of amino triazole with and without $NH_4SCN$ and buffered at about pH 4 were also included. It was thought that the pH effect would be on the dissociable $NH_4SCN$ rather than on amino triazole itself. However, in this instance on <u>A. repens</u>, lowering the pH reduced the phytotoxic effect at all stages of the experiment and irrespective of whether $NH_4SCN$ was present.

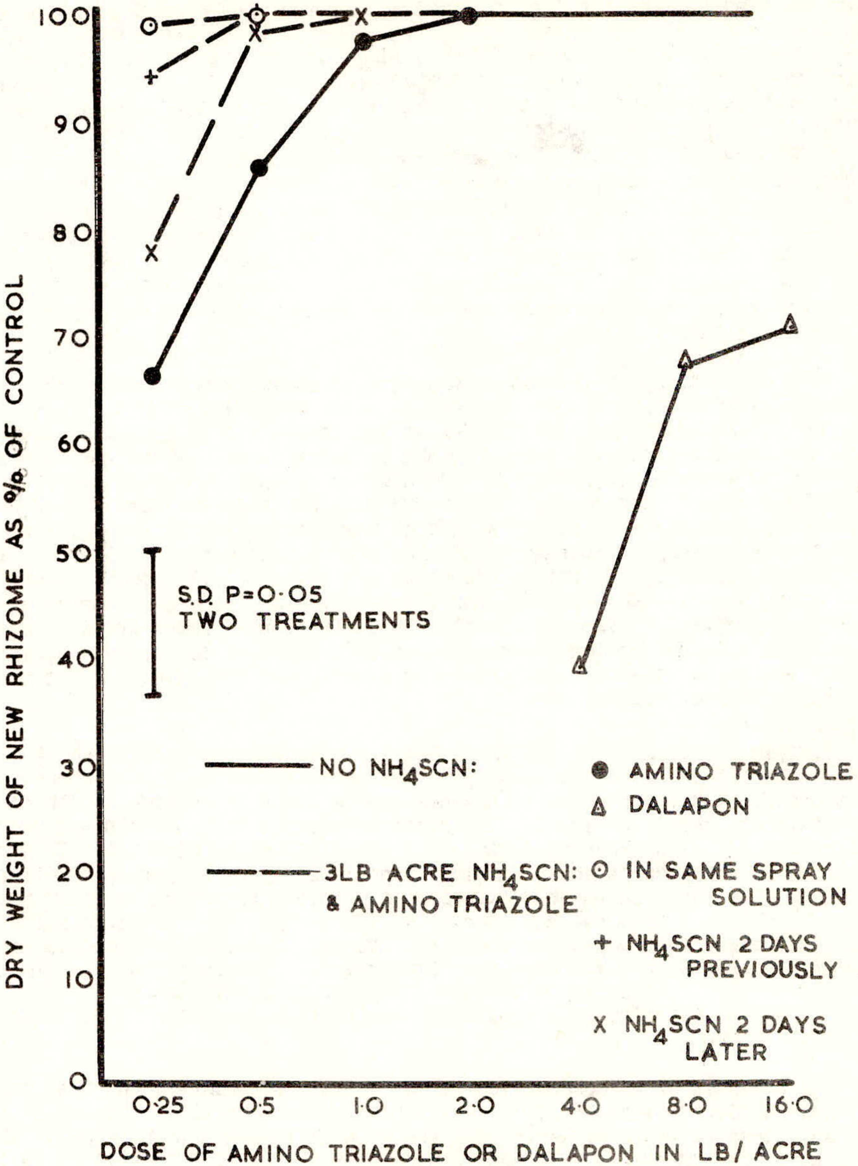


Fig. 1. REDUCTION IN DRY WEIGHT OF NEW RHIZOME PRODUCED DURING 223 DAYS FOLLOWING SPRAYING.

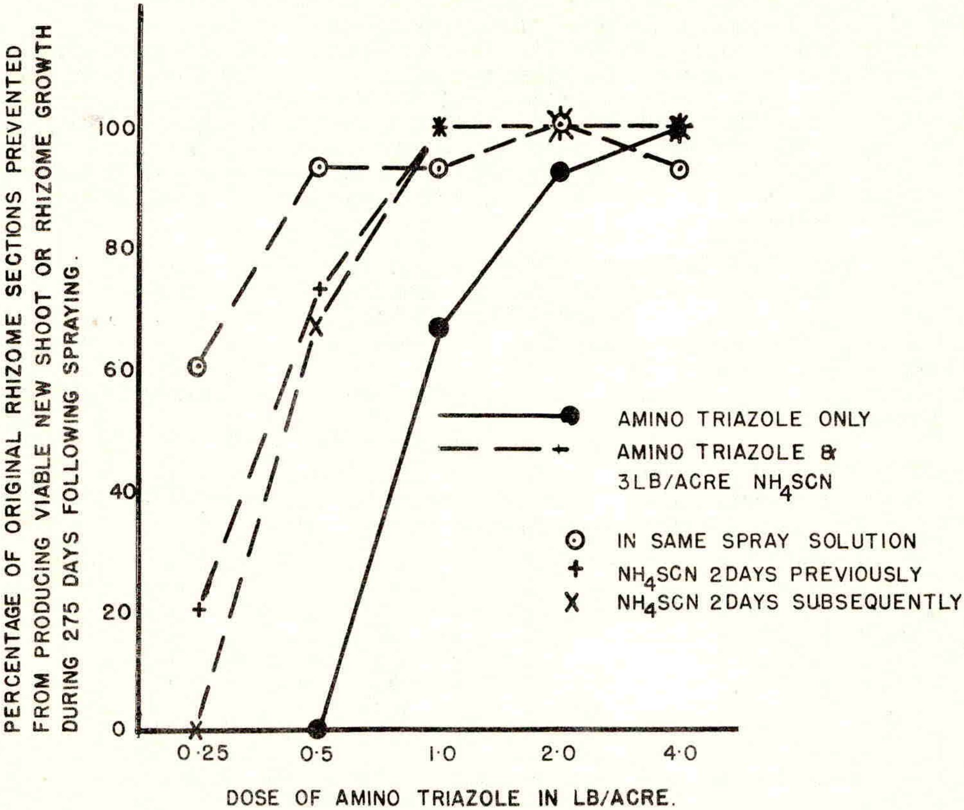


Fig. 2. EFFECT OF AMINO TRIAZOLE IN PREVENTING NEW GROWTH BY RHIZOMES.

A third experiment was designed to ascertain whether activation and a high level of effectiveness was obtainable under summer conditions. Shoots had mainly three leaves at the time of spraying in mid-June, 1960, and the plants were kept in the open. In addition to $NH_4SCN$, thiourea was also tested as an activator in view of its chemical similarity ($NH_4SCN$ is converted to thiourea by heating) and physiological activity. Rhizomes for this experiment were obtained from Headington, about five miles from the previous source of supply at Wytham. However, to provide continuity, amino triazole with $NH_4SCN$, and dalapon were also applied to a set of plants raised from Wytham rhizomes.

$NH_4SCN$ and thiourea alone were without effect. Detailed observations made on vegetative growth 28 and 78 days after spraying indicated a relatively small effect from dalapon and amino triazole treatments and an absence of activation by $NH_4SCN$ or thiourea on the Headington material. There was a greater response to amino triazole + $NH_4SCN$ but not to dalapon, with the Wytham material.

Dry weights of new rhizomes were determined 79 days after spraying, when the controls gave an average 35 g per pot. These data are presented in Table II. The main set of results on the Headington material show: (1) a smaller effect from both amino triazole and dalapon treatments compared with the previous experiments; (2) less activation with $NH_4SCN$; (3) an absence of activation with thiourea. Some additional treatments not reported in the table indicated that there was no activation of dalapon by $NH_4SCN$ or thiourea. The most striking feature of the results was the greater effect of amino triazole with $NH_4SCN$ on the A. repens from Wytham, as compared with that from Headington. On the other hand, the A. repens from Wytham was not more susceptible to dalapon.

TABLE II. INHIBITION OF GROWTH OF RHIZOME PRODUCED IN 79 DAYS FOLLOWING SPRAYING, EXPRESSED AS PERCENTAGE REDUCTION IN DRY WEIGHT OF NEW RHIZOME

| Source of Agropyron | Headington | | | Wytham | | Headington | Wytham |
|---|---|---|---|---|---|---|---|
| Dose of amino triazole (lb/ac) | Amino triazole only | Amino triazole + $NH_4SCN$* | Amino triazole + thiourea* | Amino triazole + $NH_4SCN$* | Dose of dalapon (lb/ac) | Dalapon-sodium | Dalapon-sodium |
| 0 | - | 0 | 6 | - | | - - | - |
| 0.33 | 35 | 52 | 46 | 62 | 2 | 47 | 19 |
| 1.0 | 53 | 73 | 53 | 91 | 6 | 59 | 40 |
| 3.0 | 99 | 98 | 97 | 100 | 18 | 54 | 51 |

S.D. (P = 0.05). Two treatments: Headington 16; Wytham 28.
* 3 lb/ac in all cases.

Two field experiemnts, one in Berkshire, the other in Oxfordshire, were sprayed in 1959. The results one year after treatment are set out in Table III. Experiment A was in a fallow and there was a dense cover of Agropyron shoots, mainly with three to four leaves, when sprayed in early May. There was an appreciable kill of foliage, increasing with dose in each case, and little regrowth probably because of the dry season. The foliage remaining was resprayed with the same treatments at the end of July. There were no cultivations until early 1960 when the field was ploughed and sown to a spring cereal. In this instance both amino triazole with $NH_4SCN$ and dalapon at the highest dose performed well. Technical grade amino triazole alone was less effective.

TABLE III. REDUCTION IN NUMBER OF SHOOTS IN THE YEAR FOLLOWING SPRAYING, IN TWO FIELD EXPERIMENTS

| | Experiment A | | | Experiment B | | |
|---|---|---|---|---|---|---|
| | Dose: lb/ac* | per cent reduction | shoots/ sq yd | Dose: lb/ac | per cent reduction | shoots/ sq yd |
| Amino triazole | 4 | 73 | 9.2 | 2.5 | 43 | 6.4 |
| | 8 | 87 | 6.5 | 5 | 35 | 6.8 |
| | | | | 10 | 58 | 5.4 |
| Amino triazole + $NH_4SCN$** | 4 | 95 | 3.7 | 2.5 | 40 | 6.5 |
| | 8 | 99 | 2.2 | 5 | 54 | 5.7 |
| | | | | 10 | 57 | 5.5 |
| Dalapon-sodium | 2 | 35 | 14.3 | 5 | 5 | 8.2 |
| | 4 | 71 | 9.3 | 10 | 29 | 7.1 |
| | 8 | 94 | 4.3 | 20 | 53 | 5.7 |
| S.D. P = 0.05. | | | 4.1 | | | 1.1 |

* This dose on each of two occasions.

** $NH_4SCN$ in amounts 95 per cent of those of amino triazole.

Experiment B was in a cereal stubble and there was a strong dense growth of Agropyron shoots six to eight inches high when sprayed in mid-September. The experiment was ploughed in mid-November, cultivated in the spring and mangolds were drilled in late April. The level of control obtained was not as high as in Experiment A. Amino triazole at 5 lb/ac + $NH_4SCN$ and dalapon at 20 lb/ac gave comparable results, and the difference between amino triazole alone and the 'activated' formulation was slight.

## DISCUSSION

The pot experiments verify the activation of amino triazole with $NH_4SCN$ with respect to its effect on Agropyron repens, but suggest that the magnitude of this effect may vary with conditions. The results indicate that this activation is not due to some effect of $NH_4SCN$ on the penetration of amine triazole into the plant, but is concerned with some later phase in the exertion of its phytotoxic action.

The most striking feature of the pot experiments was the high degree of effectiveness of amino triazole + $NH_4SCN$ even at doses as low as 0.25 lb/ac. Ultimate results were superior to those from dalapon at far higher doses. However, it must be borne in mind that these experiments were carried out under a specific set of conditions with only short rhizome sections, and therefore it is not possible to extrapolate them to all field conditions. The dalapon effect might have been improved by a treatment simulating ploughing at a suitable time after spraying, although this is not always necessary in the field. Such a treatment might, of course, equally well benefit an amino triazole application.

In the pot experiments there was some variation in degree of control obtained from amino triazole according to conditions, and the results in field experiments were markedly inferior, when allowance is made for much higher doses in the latter. The salient point is therefore that amino triazole + $NH_4SCN$ possesses a very considerable potential for the control of Agropyron repens but the conditions enabling it to produce its maximum effect and the reasons for variable results must be elucidated, so that it can be used reliably in the field. The present experiments provide certain 'leads'. Firstly, in all the pot experiments dormant pieces of rhizome had produced shoots but had not yet produced new rhizomes at the time of spraying. It may be that the treatment is less effective once an extensive new rhizome system is present. Therefore some suitably timed cultivations to reproduce these pot conditions may be necessary prior to spraying to produce good results in the field. Some of the factors which must be evaluated in order to define such a treatment are being investigated in current pot experiments. These include the length of rhizome fragment from which shoots are produced, the depth in the soil from which the rhizomes sprout, and the stage of plant development with respect to both shoot and new rhizome growth.

The difference in response of rhizomes derived from two separate sources suggests a reason for variable results in the field. The untreated controls from the two sites showed certain morphological differences in the shoot when growing under the same conditions. There is an obvious need for an investigation of possible correlations between morphological features and high susceptibility and of the relative frequency of occurrence of extremely susceptible or resistant clones. Their existence implies the possibility of a build-up of more resistant populations, in this connection it is slightly reassuring that clonal differences in response to amino triazole and dalapon were not identical.

Finally, the fact that results from the summer pot experiment were slightly inferior to those of the earlier experiments, even on the Wytham material, suggests that some environmental factors may be important. In this connection, it could be postulated that the relatively poor results from the field experiments are attributable to their being sprayed in an unusually dry season. It may be relevant that in the summer pot experiment over 1.5 inches of rain fell on the third day after spraying, which may have led to considerable leaching through the pots. This may be important if appreciable amounts of amino triazole are taken up from soil. Occurrence of soil uptake would widen the number of environmental variations which may be of importance, compared with the situation where only foliar entry is involved. Work has already been started to investigate some of these possibilities.

Acknowledgements

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# THE CONTROL OF PERENNIAL GRASSES WITH DIPYRIDYL HERBICIDES ALONE AND IN MIXTURES

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Summary: Greenhouse and box tests indicated that mixtures of the dipyridyl herbicides with dalapon or amitrol gave initially quicker top kill of the existing foliage than dalapon alone and better translocation of the chemicals. Subsequent field trials confirmed the quicker initial effects from the mixtures but these mixtures did not appear to have any greater effect on the regrowth than did dalapon alone. The addition of wetters improved the action of the dipyridyl herbicides but did not have any marked effect on the other treatments.

## INTRODUCTION

In the study of the herbicidal activity of the dipyridyl herbicides, greenhouse and field trials were conducted to evaluate their effects on couch grasses (*Agropyron repens* and *Agrostis* spp.). These herbicides were tested alone and in combination with established grass killing chemicals such as 2, 2 dichloropropionic acid (dalapon) and 3-amino-1,2,4-triazole.

## METHODS, MATERIALS AND RESULTS

### Greenhouse Trials

These trials had two main objects:-

(a) to compare translocation of the mixtures with that of the pure chemicals

(b) to give some indication of the field performance of these mixtures as sprays.

Rhizomes of couch, *Agropyron repens*, each 10 in. long were collected in the field and planted in John Innes Compost in seed boxes. Each rhizome produced from 3 to 12 green shoots and these were ready for treatment in the translocation tests when they had reached the 2-3 leaf stage and when they had reached the 4-6 leaf stage for the spraying tests. The two dipyridyl herbicides, diquat (1,1'-ethylene-2,2'-dipyridylium dibromide) and PP.910 (1,1'-dimethyl-4,4'-dipyridylium dimethosulphate) were tested alone and in mixtures with dalapon (sodium) and amino triazole. Dalapon and amino triazole were also included on their own.

In tests to compare the translocation of these mixtures, all the leaves on one shoot at one end of the active rhizome were painted with the appropriate chemicals alone or in combination. The treatments and results are set out in Tables I and II.

TABLE I. AERIAL SHOOTS PRESENT 3 MONTHS AFTER TREATMENT AS PERCENTAGE OF THOSE ORIGINALLY PRESENT

(UNREPLICATED TEST)

| Diquat gm/100 ml \ Dalapon gm/100 ml | 0.0 | 2.5 | 5.0 | 7.5 |
|---|---|---|---|---|
| 0.0 | 100 | 50 | 67 | 63 |
| 0.25 | 100 | 40 | 40 | 22 |
| 0.5 | 67 | 13 | 0 | 0 |
| 1.0 | 83 | 67 | 0 | 0 |

TABLE II. AERIAL SHOOTS PRESENT 39 DAYS AFTER TREATMENT AS PERCENTAGE OF THOSE ORIGINALLY PRESENT

(MEAN OF THREE REPLICATES)

| Dipyridyl gm/100 ml \ Amino triazole gm/100 ml | 0 | 1.25 | 2.5 |
|---|---|---|---|
| 0 | 100 | 69 | 73 |
| 0.5 Diquat | 64 | 72 | 0 |
| 0.5 PP.910 | 14 | 31 | 36 |

The spray trials were carried out on rather older plants and the following treatments were applied at the equivalent of 40 gal/ac: diquat 1 lb/ac, PP.910 1 lb/ac. dalapon 5 and 10 lb/ac and amino triazole 2.5 and 5 lb/ac. The boxes were sprayed with the chemicals alone and with combinations of diquat or PP.910 with dalapon or amino triazole. An area measuring 2 x 2 yd was marked out in the open in which the boxes of couch grass were placed, the whole area then being sprayed. Observations were then made to determine speed of kill and of subsequent regrowth.

Two days after spraying the dalapon/diquat treatments had caused severe scorch of all aerial growth while diquat alone produced only very slight tip scorch on 50 per cent of the plants. The dalapon treatment caused some scorch effects six days after spraying. Ten weeks after spraying all the shoots sprayed with the dalapon/diquat mixtures had been killed and there had been no regrowth; with dalapon alone all the sprayed shoots had been killed but there was regrowth which was slightly inhibited. The shoots treated with diquat alone had by this time recovered completely from the initial scorch and were growing normally.

The behaviour of shoots sprayed with dalapon/PP.910 in mixture followed much the same pattern as those sprayed with dalapon/diquat mixtures:- complete kill of aerial growth, with no regrowth up to 7 months after spraying. At this time slight regrowth had occurred on shoots treated with dalapon alone. PP.910 alone initially gave a good kill of aerial shoots but subsequently regrowth took place.

Spray applications of diquat, PP.910/amino triazole gave similar results to diquat, PP.910/dalapon mixtures, in so far as initial scorch, followed by kill of shoots was much more rapid than when the chemicals were applied alone. A good kill of plants was obtained 22 days after spraying with PP.910/amino triazole mixtures, whereas few shoots were killed by PP.910 alone, or by diquat/amino triazole mixtures. No kill of plants with diquat or amino triazole applied alone was obtained at this time.

Five months after spraying excellent kill of top growth was obtained with PP.910 alone and in mixture with amino triazole. After one year plants sprayed with PP.910 alone produced some regrowth, as did those sprayed with PP.910 plus the low rate of amino triazole. The high rate of the PP.910/amino triazole mixture gave 100 per cent kill and no regrowth occurred. Plants treated with diquat alone and in mixture with the low rate of amino triazole were making good recovery from the initial scorch and had produced much new growth a year after treatment. A good initial kill was also obtained with amino triazole alone, the plants not killed being severely affected. A year after treatment there was 100 per cent kill with no regrowth.

## Field Trials

A randomized block design with four replicates was used in all trials. The plot size was either 6 yd x 4 yd, or 6 yd x 6 yd. Eight trials were laid down in the autumn of 1959 and four in the spring of 1960. No cultivations prior to spraying were carried out on the trials.

A standard rate of 1 lb/ac of both diquat and PP.910 was used alone and in mixture with dalapon or amino triazole. Dalapon was used at 5 and 10 lb/ac of the sodium salt and amino triazole was used at 5 lb/ac in these mixtures. A split application with a 10 day interval between applications of 7 + 5 lb/sodium salt of dalapon/ac was also included. A wetter (Lissapol NX) at 0.1 per cent vol/vol was used in some trials.

The chemicals were applied in water with an Oxford Sprayer calibrated to deliver 20 gal/ac.

The damage was graded by eye. Initial top kill was graded 0 - no kill 10 - complete kill and regrowth was graded 0 - complete regrowth, 10 - no regrowth.

## TABLE III. DIQUAT, PP.910, DALAPON AND AMINO TRIAZOLE

| Number | | 1 | | | 2 | | | 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Site Details | Grasses | Agropyron repens | | | Agropyron repens agrostis stolonifera | | | Agrostis stolonifera | | |
| | Date sprayed | 17.9.59 | | | 16.11.59 | | | 23.9.59 | | |
| | Date ploughed | 23.10.59 | | | December 59 | | | 30.10.59 | | |
| Assessment | Top kill days after spraying | 11 | 35 | | 11 | 36 | | 9 | 29 | |
| | Regrowth weeks after spraying | | | 26 | | | 22 | | | 31 |
| Treatment | | | | | | | | | | |
| Diquat 1 lb/acre | | 8.0 | 6.0 | 0.5 | 4.0 | 0.5 | 1.0 | 8.0 | 3.0 | 1.0 |
| Diquat 1 lb/ac + wetter | | | | | | | | 8.5 | 2.0 | 2.0 |
| PP.910 1 lb/ac | | 9.0 | 7.5 | 2.5 | 5.0 | 2.5 | 2.0 | 8.0 | 5.5 | 2.0 |
| PP.910 1 lb/ac + wetter | | | | | | | | 9.5 | 8.5 | 3.5 |
| Dalapon 5 lb/ac | | 7.0 | 7.5 | 6.0 | 1.0 | 3.0 | 6.5 | 4.5 | 6.0 | 9.0 |
| " 10 lb/ac | | 7.5 | 8.0 | 7.5 | 1.5 | 4.0 | 9.0 | | | |
| " 5 lb/ac + wetter | | | | | | | | 5.0 | 5.5 | 8.0 |
| " 10 lb/ac + wetter | | | | | | | | | | |
| " 7 + 5 lb/ac | | 8.0 | 8.5 | 8.5 | 1.5 | 4.0 | 8.5 | 4.5 | 7.5 | 9.0 |
| " 7 + 5 lb/ac + wetter | | | | | | | | | | |
| Amino triazole 5 lb/ac | | 8.5 | 8.5 | 2.5 | 1.0 | 0.5 | 4.5 | | | |

Top Kill 0 = No kill 10 = complete kill
Regrowth 0 = complete regrowth 10 = no regrowth

(78178)

TOP KILL AND CONTROL OF REGROWTH ASSESSMENTS, AUTUMN SPRAYED TRIALS

| 4 | | | 5 | | | 6 | | | 7 | | | 8 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agrostis gigantea | | | Agropyron repens Agrostis stolonifera | | | Agrostis stolonifera | | | Agropyron repens Agrostis Stolonifera | | | Agropyron repens Agrostis stolonifera | |
| 2.10.59 | | | 13.10.59 | | | 24.11.59 | | | 29.10.59 | | | 10.11.59 | |
| 30.10.59 | | | 13.11.59 | | | Spring 1960 | | | December 59 | | | April 1960 | |
| 7 | 20 | | 3 | 20 | | 13 | 27 | | 4 | 35 | | 7 | 42 |
| | | 30 | | | 23 | | | 21 | | | 21 | | |
| 8.0 | 3.0 | 1.0 | 8.5 | 5.0 | 1.5 | 4.0 | 0.5 | 1.0 | 4.0 | 2.5 | 3.0 | 5.0 | 4.0 |
| 9.0 | 3.5 | 1.5 | | | | | | | 6.0 | 4.0 | 3.5 | 5.0 | 4.5 |
| 9.0 | 7.0 | 5.0 | 9.0 | 7.0 | 0.5 | 5.0 | 2.5 | 2.0 | 5.0 | 6.0 | 5.5 | 5.0 | 6.0 |
| 9.5 | 8.5 | 6.5 | | | | | | | 6.5 | 7.5 | 6.0 | 5.0 | 6.5 |
| 6.5 | 4.0 | 8.0 | 6.0 | 6.0 | 7.0 | 1.0 | 0.5 | 2.5 | 3.0 | 4.0 | 9.0 | 3.0 | 5.0 |
| | | | 6.5 | 6.0 | 8.5 | 2.0 | 1.0 | 7.0 | 2.5 | 3.5 | 9.0 | 3.0 | 5.0 |
| 7.0 | 4.5 | 8.0 | | | | | | | 3.5 | 4.0 | 9.0 | 3.0 | 6.5 |
| | | | | | | | | | 2.5 | 4.0 | 9.5 | 3.0 | 5.5 |
| 7.0 | 5.0 | 8.0 | 5.5 | 7.0 | 9.0 | 1.0 | 1.0 | 8.5 | 3.0 | 4.5 | 9.0 | 3.0 | 6.5 |
| | | | | | | | | | 3.0 | 5.0 | 9.5 | 2.5 | 6.5 |

## TABLE IV. MIXTURES OF DIQUAT OR PP.910 WITH DALAPON OR AMINO TRIAZOLE

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Number | | 1 | | | 2 | | | 3 | | |
| Site Details | Grasses | Agropyron repens | | | Agropyron repens Agrostis stolonifera | | | Agrostis stolonifera | | |
| | Date sprayed | 17.9.59 | | | 16.11.59 | | | 23.9.59 | | |
| | Date ploughed | 23.10.59 | | | December 59 | | | 30.10.59 | | |
| Assessment | Top kill days after spraying | 11 | 35 | | 11 | 36 | | 9 | 29 | |
| | Regrowth weeks after spraying | | | 26 | | | 22 | | | 31 |
| Treatment | | | | | | | | | | |
| Diquat 1 lb/ac + Dalapon 5 lb/ac | | 6.0 | 6.5 | 6.0 | 3.5 | 3.0 | 6.0 | 5.0 | 4.5 | 7.5 |
| " " " 10 " | | 8.0 | 8.0 | 7.5 | 4.5 | 5.0 | 8.0 | | | |
| " " " 5 + wetter | | | | | | | | 6.5 | 6.0 | 8.0 |
| " " " 10 + wetter | | | | | | | | | | |
| " " Amino triazole 5 lb/ac | | 9.0 | 8.5 | 1.5 | 2.5 | 2.0 | 4.0 | | | |
| PP.910 1 lb/ac + Dalapon 5 lb/ac | | 8.5 | 7.5 | 6.0 | 5.0 | 5.0 | 6.5 | 7.5 | 6.5 | 5.5 |
| " " " 10 " | | 8.5 | 8.0 | 7.5 | 4.5 | 3.5 | 7.5 | | | |
| " " " 5 + wetter | | | | | | | | 9.0 | 8.5 | 6.0 |
| " " " 10 + wetter | | | | | | | | | | |
| " " Amino triazole 5 lb/ac | | 9.0 | 8.0 | 2.5 | 5.0 | 4.5 | 4.0 | | | |
| Control | | 2.5 | 3.5 | 1.0 | 1.0 | 0.0 | 0.0 | 2.5 | 1.5 | 1.0 |

Top kill 0 = No kill 10 = complete kill
Regrowth 0 = complete regrowth 10 = no regrowth

TOP KILL AND CONTROL OF REGROWTH ASSESSMENT, AUTUMN SPRAYED TRIALS

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | | | 5 | | | 6 | | | 7 | | | 8 | |
| Agrostis gigantea | | | Agropyron repens Agrostis stolonifera | | | Agrostis stolonifera | | | Agropyron repens Agrostis stolonifera | | | Agropyron repens Agrostis stolonifera | |
| 2.10.59 | | | 13.10.59 | | | 24.11.59 | | | 29.10.59 | | | 10.11.59 | |
| 30.10.59 | | | 13.11.59 | | | Spring 1960 | | | December 59 | | | April 1960 | |
| 7 | 20 | | 3 | 20 | | 13 | 27 | | 4 | 35 | | 7 | 42 |
| | | 30 | | | 23 | | | 21 | | | 21 | | |
| 6.5 | 4.0 | 8.0 | 6.5 | 7.0 | 5.5 | 1.5 | 1.0 | 4.0 | 3.5 | 5.0 | 8.0 | 3.5 | 6.0 |
| | | | 6.5 | 7.0 | 8.0 | 1.5 | 2.0 | 7.0 | 3.0 | 5.5 | 9.0 | 4.0 | 6.0 |
| 7.5 | 6.5 | 7.5 | | | | | | | 3.5 | 4.5 | 8.0 | 4.0 | 6.5 |
| | | | | | | | | | 4.0 | 6.0 | 9.0 | 3.5 | 6.0 |
| 8.5 | 7.0 | 8.0 | 8.0 | 7.5 | 6.0 | 2.5 | 2.0 | 6.0 | 4.0 | 7.0 | 8.0 | 3.5 | 6.0 |
| | | | 8.0 | 8.0 | 8.5 | 2.0 | 2.5 | 7.5 | 4.0 | 7.0 | 9.0 | 3.5 | 7.0 |
| 9.0 | 9.0 | 8.0 | | | | | | | 4.5 | 8.5 | 8.5 | 4.5 | 6.5 |
| | | | | | | | | | 5.0 | 9.0 | 8.0 | 3.5 | 8.0 |
| 5.0 | 1.0 | 1.0 | 5.5 | 3.0 | 0.5 | 1.0 | 0.5 | 0.5 | 2.5 | 1.0 | 1.5 | 2.5 | 2.0 |

TABLE V. DIQUAT, PP.910, AND DALAPON ALONE AND IN MIXTURE.
TOP KILL ASSESSMENTS, SPRING SPRAYED TRIALS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Number | | 9 | | 10 | | 11 | | 12 | |
| Site Details | Grasses | Agropyron repens | | Agrostis stolonifera | | Agropyron repens agrostis stolonifera | | Agropyron repens agrostis stolonifera | |
| | Date of spraying | 24.3.60 | | 13.4.60 | | 21.4.60 | | 7.4.60 | |
| Assessment | Top kill days after spraying | 7 | 42 | 7 | 22 | 8 | 35 | 12 | 26 |
| Treatment | | | | | | | | | |
| Diquat 1 lb/ac + wetter | | 4.5 | 1.0 | 6.5 | 1.5 | 7.5 | 1.5 | 5.5 | 1.0 |
| PP.910 1 lb/ac + wetter | | 5.0 | 5.0 | 8.5 | 7.5 | 8.0 | 7.5 | 9.0 | 9.5 |
| Dalapon 5 lb/ac | | 0.5 | 2.5 | 0.0 | 2.0 | 0.5 | 2.5 | 0.5 | 1.0 |
| " 5 lb/ac + wetter | | 0.5 | 2.5 | 0.0 | 2.0 | 1.0 | 3.5 | | |
| " 10 lb/ac | | 0.5 | 3.0 | 2.5 | 1.0 | 1.0 | 4.5 | 1.0 | 2.0 |
| " " + wetter | | 0.5 | 3.0 | 2.5 | 1.0 | 1.0 | 5.0 | | |
| Diquat 1 lb/ac + dalapon 5 lb/ac | | 1.0 | 2.5 | 4.5 | 3.5 | 2.0 | 3.0 | 3.0 | 3.0 |
| " " 10 lb/ac | | 1.0 | 5.0 | 4.5 | 4.0 | 2.0 | 4.5 | 3.0 | 3.5 |
| PP.910 1 lb/ac " 5 lb/ac | | 4.0 | 8.0 | 7.5 | 8.0 | 6.5 | 7.5 | 8.0 | 9.0 |
| " " 10 lb/ac | | 5.0 | 9.0 | 8.0 | 8.0 | 7.0 | 9.0 | 6.5 | 8.5 |
| Control | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Top kill 0 = No kill
10 = Complete kill

In general the dipyridyl herbicides either alone or in mixture with dalapon or amino triazole gave the best top kill in the two weeks after spraying. PP.910 was rather more effective than diquat in the majority of trials. This initial top kill was not so marked in those trials sprayed late in the year (November) and early in the spring (March) when the air temperatures were low.

The top kill from dalapon on its own a month after spraying was in general not quite as good as that from the mixture including PP.910 but there was little difference in those mixtures containing diquat. Plots treated with diquat alone were showing signs of recovery at this stage but on those treated with PP.910 there was little recovery especially in the spring-sprayed trials. The addition of a wetting agent appeared to improve the long term effect of PP.910 but had only a slight effect on the other treatments.

Data on regrowth from the spring-sprayed trials are not available but data regrowth from the autumn-sprayed trials indicate that there is little difference between the results from the mixture treatments relative to dalapon and amino triazole on their own. Diquat and PP.910 alone did not give an adequate control of Agropyron repens but there was an indication in trials No. 4 and 7 that PP.910 at 1 lb/ac plus a wetting agent did give a useful partial control when Agrostis stolonifera and Agrostis gigantea were present.

DISCUSSION

There is a clear indication from the greenhouse tests that the kill of Agropyron repens due to translocated herbicide is greater with the dipyridyl mixtures with dalapon than it is with either component alone. Field trials confirmed that there was a more rapid initial top kill with these mixtures, but subsequent regrowth on the mixture treated areas was no less than on those treated with dalapon alone. This decrepancy is of sufficient interest to justify speculation.

The development of Agropyron repens in the field has been reviewed by Sagar (1960). The growth is mainly from the apical bud of the rhizome; in detached rhizomes equivalent to those used in the greenhouse tests an indefinite number of auxiliary buds also develop. Developing buds provide metabolic sinks in the sense used by Crafts (1959). However, many buds remain dormant unless the rhizomes are cut into 1 node segments. The translocated herbicide would normally travel to the metabolic sinks provided by the developing buds and this would show as a kill in the greenhouse trials. In the field the killing of the developing buds may only encourage the development of buds normally dormant and these would only be killed by further movement of active herbicidal chemicals from the developing buds which had been killed or other tissue. Dalapon may be capable of this further movement while the dipyridyls may not, hence long term assessments in the field would only detect the effect of the mobile dalapon. The advantage of the initial kill of active buds would not be appreciable in the field where adequate reserves of dormant buds are present to maintain a full stand of grass and as long as an excess of formant buds exists dipryridyl/dalapon mixtures are unlikely to show any appreciable practical advantage.

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# RESIDUAL PHYTOTOXICITY OF AMINO TRIAZOLE AND DALAPON TO BARLEY AND KALE

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Summary: In a series of field experiments a study was made of the relative phytotoxicity and persistence in the soil of amino triazole and dalapon under different soil and climatic conditions. This showed that, at recommended rates of application, the residual toxicity of dalapon was considerably greater to barley and kale than amino triazole. For example, barley and kale planted 5 weeks after spraying dalapon were slightly damaged, whereas no injury occurred following amino triazole treatment. Despite dry weather, the experiments also showed that rotary cultivation was more effective than ploughing in accelerating the breakdown of residues of amino triazole though the reverse may be true of dalapon. However, it must be borne in mind that couch control with amino triazole is more effective if coupled with ploughing.

## INTRODUCTION

Chemical treatments have certain advantages over cultural methods for the eradication of couch, (Agropyron repens) and other perennial grasses from arable land. Firstly, successful fallowing is dependent upon dry weather to kill the exposed rhizomes, whereas the action of herbicides is influenced to a much less extent by climatic conditions. Secondly, land under fallow is unproductive, whereas little or no alteration to the cropping programme is necessary where chemical methods of control are used. Amino triazole or dalapon applied to the land in the autumn can be planted with complete safety in the following spring. On heavy land, however, farmers frequently desire to sow a winter cereal shortly after the previous crop has been harvested, or alternatively, they may wish to spray in the spring prior to sowing. Thus the period of time available for the control of perennial grassy weeds is much restricted and a knowledge of the residual life of the herbicides under field conditions on different soil types from spring, summer and autumn applications is of considerable importance. Furthermore, ploughing should be compared with rotavation as a method of affecting rate of breakdown of chemical residue.

It was with the object of finding the information on these problems that this series of experiments was carried out.

## METHODS AND MATERIALS

Three split-plot experiments with randomized block layouts were carried out on light, medium and heavy soils. Each site was in fallow at the time of treatment and contained a mixed flora of perennial and annual weeds in cereal stubble.

Main treatments were amino triazole at 3, 4 and 6 lb/ac, dalapon at 7.4 and 11.1 lb/ac and an untreated control. The amino triazole contained ammonium thiocyanate as an activator. For convenience, results have been quoted in this paper in terms of the mean of the doses applied, (i.e. 4.3 lb/ of amino triazole and 9.25 lb of dalapon/per ac) and these approximate to the rates recommended in general practice for the control of perennial grasses. An Oxford Precision Sprayer was used to apply the herbicides in a volume of 30 gal of water/ac at 30 psi.

At each site, the treatments were applied in March, May and August in order to determine the effect of climatic conditions on the persistence of the chemicals measured by crop response.

Each main treatment was divided into three sub-plots which were cultivated at intervals of one, two and three weeks after spraying. Half of each sub-plot was rotavated with a Howard "Gem" and the other half ploughed with a single furrow plough pulled by a capstan winch on the front of a Land Rover. Owing to the very dry conditions during the early part of the year, it was not always possible to cultivate to a depth of more than 3-4 in, but during the late summer and autumn penetration was increased to a maximum of 8 inches.

In order to prepare a seed bed the ploughed plots were raked before drilling but there was a sufficiently fine tilth on the rotavated plots to make this unnecessary. Rika barley, dressed with liquid seed dressing, and thousand-headed kale were drilled immediately after cultivation and at weekly intervals thereafter in order to ascertain the length of time chemical residues persisted in phytotoxic quantities in the soil under varying climatic conditions and cultural treatments.

Crop damage was assessed by a scoring technique, observations being made by three independent assessors whose mean score was recorded. The scoring system was as follows:-

0 - no crop damage
1 - slight crop damage or retardation of growth
2 - severe damage
3 - crop killed or damaged beyond recovery

Amino triazole showed up as a chlorosis which turned the leaf white and later pink. Symptoms of dalapon damage were retardation in growth, necrotic leaf spots leading to die-back of the leaf apex and eventual death of the plant.

On each of the three sites a total of 216 separate observations were recorded by each assessor and thus, a reasonably high degree of accuracy was obtained.

RESULTS

Relative phytotoxicity of herbicides to test crops

In order to reduce the standard error the results of all three experiments have been combined in table I.

TABLE I. CROP DAMAGE AT MEAN OF 1-5 WEEKS AFTER TREATMENT - MEAN SCORE OF PLOUGHED AND ROTAVATED PLOTS

| Treatment | Barley | Kale |
|---|---|---|
| Control | 0 | 0 |
| Amino triazole | 0.48 | 0.07 |
| Dalapon | 2.59 | 0.62 |
| Significant difference (P = 0.01) | 0.45 | 0.51 |

Dalapon was thus considerably more phytotoxic to both barley and kale than amino triazole at application rates recommended for couch control during the period of these observations. These differences are highly significant. Kale is much more tolerant of residual amounts of both chemicals than barley, but it should be noted that, despite its selectivity to dicotyledons, dalapon has caused more damage to kale than amino triazole under conditions of the experiment.

Methods of Cultivation

One of the reasons for carrying out cultivations following treatment with dalapon and amino triazole is to accelerate the breakdown of chemical residues in the soil. A study was made of the best method of achieving this and table II shows the mean score for damage to barley drilled on rotary cultivated and ploughed land at a mean of 1-5 weeks after spraying.

TABLE II. DAMAGE TO BARLEY ON TREATED LAND SUBSEQUENTLY ROTARY CULTIVATED OR PLOUGHED

| Treatment | Rotary cultivated | Ploughed |
|---|---|---|
| Control - no herbicide | 0 | 0 |
| Amino triazole | 0.35 | 0.60 |
| Dalapon | 2.78 | 2.40 |
| Significant difference (P = 0.01) | 0.10 | |

On soil treated with amino triazole rotavation has resulted in significantly less damage to the following crops than ploughing; on the other hand, ploughing has produced less damage to crops where dalapon is concerned.

As stated previously, kale is less sensitive to residues of these herbicides than barley, and thus the differences between rotavated and ploughed land are not as great in the case of kale, (See Table III.)

TABLE III. DAMAGE TO KALE ON TREATED LAND SUBSEQUENTLY ROTARY CULTIVATED OR PLOUGHED

| Treatment | Rotary cultivated | Ploughed |
|---|---|---|
| Control - no herbicide | 0 | 0 |
| Amino triazole | 0.05 | 0.09 |
| Dalapon | 0.60 | 0.64 |
| Significant difference (P = 0.01) | 0.36 | |

The differences between rotary cultivation and ploughing are not significant owing to the relative tolerance of the indicator crop of kale to herbicidal residues.

Interval between spraying and planting

Barley and kale were drilled at weekly intervals after spray treatments applied in March, and crop damage was recorded in Table IV.

TABLE IV. BARLEY AND KALE - MEAN SCORE FOR DAMAGE PER PLOT

barley

| Herbicide | No. of weeks between spraying and drilling | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Amino triazole | 0.58 | 0.42 | 0.47 | 0.29 | 0 |
| Dalapon | 2.31 | 2.27 | 2.24 | 2.17 | 1.71 |

kale

| Herbicide | No. of weeks between spraying and drilling | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Amino triazole | 0.17 | 0.17 | 0.07 | 0.02 | 0 |
| Dalapon | 0.75 | 0.74 | 0.75 | 0.59 | 0.19 |

These results cannot be analysed statistically owing to a considerable number of missing plots in which the test crops did not germinate, nevertheless there is a consistent reduction in crop damage as the interval between spraying and sowing is increased.

DISCUSSION

During early and mid-summer there was very little rainfall and the soil became so dry, particularly on the medium and heavy land, that efficient and thorough cultivations at regular weekly intervals became difficult. Consequently germination was often poor owing to lack of soil moisture and the difficulties of obtaining a good tilth on the seed beds. The minor crop injury recorded to barley 3 weeks after the application of amino triazole is most probably due to the dry conditions not only affecting germination, but also increasing the persistence of the chemical in the soil. Similar damage was not observed after subsequent applications in more favourable conditions for breakdown during May and August. Indicator crops sown 5 weeks after the amino triazole treatment were unaffected, whereas dalapon severely damaged barley and slightly retarded the growth of kale sown after the same interval.

Under the conditions of the experiment, dalapon residues were significantly more phytotoxic to barley and kale than amino triazole. The damage to kale, however, was minor and can be attributed to high residual concentrations of the chemicals in the soil affecting the early drillings. Despite its selectivity to dicotyledons, however, dalapon residues caused significantly more damage to kale than amino triazole.

A comparison of ploughing and rotary cultivation for accelerating the breakdown of chemical residues in the soil showed that, in the case of the amino triazole rotory cultivation was the more effective method of cultivation. The most probable explanation for this is that the herbicide was leached to plough depth and by inversion of the furrow brought to the surface again where a sufficiently high concentration was left to be toxic to the indicator crops. Rotary cultivation, on the other hand, thoroughly incorporated and diffused the chemical residues throughout the cultivated layer, so that significantly less crop damage was recorded. In the case of dalapon, ploughing resulted in less damage than rotary cultivation and the explanation does not appear to be so straightforward. Whilst its greater solubility would tend to give a more even and rapid distribution in the soil which would favour breakdown in undisturbed soil, as in a furrow slice, where mechanical mixing as in rotary cultivation is applied, it might be expected that breakdown would be even more rapid, but this is not so. Ploughing is significantly better and no satisfactory explanation can be found at present.

It should be noted, however, that although less crop damage results after rotary cultivation of amino triazole treatments, other experiments have shown that ploughing gives more efficient control of couch grass.

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Discussion of preceding eight papers

M. J. Zwijns. Is there any evidence of differences in field results, with both amino triazole and dalapon, between 1959 and 1960 due to great difference in rain fall in these two years?

Dr. G. R. Sagar. The results of spraying dalapon during 1960 will not be available until next year because the dormancy caused by dalapon does not permit valid assessments until 12 months after spraying. No comparison is therefore possible until 1961.

Dr. C. C. McCready. I should like to ask Dr. Sagar one question about his experiment in which he found that the export of dalapon from a treated shoot of *Agropyron* was promoted by both an opaque cover and a transparent cover. Could the common factor here be the prolongation of absorption by the increased humidity under the covers?

Dr. G. R. Sagar. Under the opaque cover I would expect the stomata to be closed and under the transparent cover to be open. Therefore, if penetration is a major factor operating through the stomata, I would expect a bigger difference than I in fact obtained between these two treatments.

Mr. R. W. Sidwell. Has Dr. Sagar proved that no translocation takes place to older rhizomes? If so, how is dormancy maintained in axillary buds?

Dr. G. R. Sagar. I do not believe I have proved anything. Various workers have shown that mineral status may affect bud dormancy and I prefer to think that dormancy is maintained in *Agropyron* by the mineral nutrient status of the dormant buds being too low to allow dormancy to be broken, rather than by diffusion of specially produced chemicals to rhizomes, one chemical to keep the rhizome growing horizontally and another to keep the buds dormant.

Dr. R. K. Pfeiffer. Could Mr. Evans tell us something about the experience of the N.A.A.S. with TCA, which can now almost be regarded as the classic method of chemical couch control?

Mr. S. A. Evans. The results of some N.A.A.S. experiments with TCA are contained in previous Conference Proceedings. TCA has not been experimented with in recent years and no direct comparison with dalapon has been made.

Dr. G. R. Sagar. A chemical applied to the aerial parts of a plant depends for its movement to below-ground organs on a variety of environmental and internal factors, none of which we understand properly. There is no doubt in my mind that we can be far more certain that a chemical which enters the roots will be distributed extensively throughout a plant system via the xylem. There are two problems. First, farmers are not inclined towards soil incorporation, since it is more expensive and relies on soil conditions being suitable for using machinery to effect the incorporation. Second, plant physiologists cannot agree as to how any natural metabolite moves in the phloem and yet here we are introducing a foreign substance into that tissue and attempting to explain its pattern of movement. This is in fact the main problem.

Dr. W. Ripper. With reference to Mr. Evans' paper, I would like to point out that of the 17 reported experiments, 9 did not comply with the maker's recommendations. Mr. Evans pointed out his variable results. I have been under the impression that the industry has asked farmers to follow the maker's recommendations and I am surprised that Mr. Evans has not done so. The N.A.A.S. should have more uniform experimentation. If maker's instructions had been carried out, the results would have been very different.

Is Dr. Sagar happy to draw conclusions about the application of very small quantities of labelled dalapon? In fact we saturate the plant with a tremendous quantity which may give different methods of translocation. All he says of our lack of knowledge of translocation is quite true. It is also true that systemic insecticides have been used very successfully within the last six years.

Dr. G. R. Sagar. As far as insecticides are concerned I will agree that we could usefully work in closer harmony with those concerned with these substances. I would however point to one danger. It would seem likely that many of our herbicides are closely related chemically to natural plant metabolites whereas many insecticides, particularly systemic types, are not. The point regarding application of small quantities of marked dalapon is very relevant. In my paper I pointed out the deficiencies in my technique and repeatedly warned that the observations are very preliminary. I agree that it is important that we bear in mind that the experimental dose is something like 1/300th of the dose in the field. This is a good point and must be considered together with the possibility of snags arising from the use of radioautographic techniques.

Mr. S. A. Evans. In reply to Dr. Ripper's reference to the N.A.A.S. experiments, the remaining experiments that presumably did comply with the manufacturer's instructions also did not give very good control of couch.

Mr. G. B. Lush. I would like to ask Dr. Leasure two questions. What was the significance of the relatively high greenhouse temperature under which the pot experiments reported were conducted? Has the improved control of couch resulting from the addition of these non-ionic wetters been confirmed in the field?

Dr. J. K. Leasure. The temperatures used in this test were settled on after about 3½ months of attempting to grow couch grass from two-node rhizome segments. The temperatures chosen gave the best growth of secondary rhizomes. With regard to field tests, these tests are being undertaken on a wider scale. Half a dozen tests were put out in the United States last year and it appears to us worth while following these up on a larger scale this year.

Mr. W. H. Salmon. I speak as a farmer and after listening to the manufacturers of various chemicals it would seem the control of couch grass is not difficult. Listening further to the speakers who have conducted experiments, I do not feel so happy and it does seem that conditions of growth, temperature etc. have to be just right to give even partial control. The cost is still high, more so than rotary cultivation. My impression is that farmers do not feel that spraying is really successful in eliminating couch grass.

30 or 40 years ago, a product called Gas Lime was much used by market gardeners. Spread on the ground in the autumn and worked in the soil it actually sterilised and killed all the vegetation and weeds. The great drawback was the toxic effect which prevented any cropping for six months. I do not think this by-product of the gas works is still available. Much of our arable land is dormant from October to February and soil conditions being suitable I would go to a lot of trouble during this period to eliminate couch grass. It should not be difficult for the agricultural chemists to produce a product of

similar properties and much less bulky, which could be applied during this dormant period and probably with less toxic persistency. It might even destroy wild oat seeds!

(Editors note: See "An assessment of the new herbicide 2,6-dichloro-benzonit benzonitrile" by G. E. Barnsley in Session 10)

Dr. W. van der Zweep. I am impressed by Dr. Leasure's data on the translocation of radio-active material to non-treated plant parts. We are trying to do this type of work at Wageningen. We realise the difference between these conditions and field conditions. Has Dr. Leasure any data on different treatment times? Do amounts of dalapon to which no wetting agents have been added finally have the same amount of radio-activity in the rhizome system as when wetting agents added? Perhaps the initial amount of radio-activity in the rhizome is higher but does it equalise later?

May I ask Dr. Sagar if there is any difference between treatment of lower leaves against treatment of higher leaves on the same shoot, and between shoots that have tillers and those that don't have tillers? Are there different means of translocation through the aerial system?

Dr. J. K. Leasure. With regard to the first question, I have really no data to support an answer. I have some observations which bear on this point. A test was run not merely with small amounts of tagged dalapon but also with a herbicidal dose of untagged dalapon plus the labelled dalapon. At the end of a period, plants having additional wetting agent already showed effects of the herbicidal action but plants receiving dalapon without the wetting agent did not show herbicidal effects at this time. In fact a few plants remaining, treated with dalapon alone, did not continue to deteriorate and never did show the same degree of effect as those treated with dalapon plus a wetting agent. Although analyses were made at only one time, I do not think it is a matter simply of initial increase as suggested by Dr van der Zweep.

Dr. G. R. Sagar. I tried treating the youngest or oldest leaves and using only visual assessment for radioautographs, there was very little difference between these. This would appear to be contrary to the general hypothesis of mass flow and I may suggest that the major factor influencing the movement of one herbicide is not necessarily the same one for any other herbicide. I believe that Craft's view of herbicide movement may be too simplified. In my other experiments which I have not reported here, the comparative vigour of the two shoots determined the pattern of movement of dalapon. Movement of the labelled material was almost invariably from the "weaker" to the "stronger" shoot and not vice-versa.

CONTROL OF REEDS (PHRAGMITES COMMUNIS) IN ARABLE LAND WITH DALAPON

J. M. Proctor

National Agricultural Advisory Service Eastern Region

Summary. Reeds (Phragmites communis) are troublesome weeds in some arable fen fields. Limited trial and field experience suggests that dalapon can be expected to give a very effective control. 15 lb/ac would appear to be a satisfactory dose in most circumstances. Application should be made when there is good growth of leaf. Control would seem most practicable in cereal stubbles but potatoes and sugar beet may be suitable alternatives.

INTRODUCTION

Reeds (Phragmites communis) occur commonly in dykes in the fens and often invade arable fields. Infestations are normally most serious along headlands but may extend over a large proportion of the field, interfering with hoeing and presumably reducing crop yields by competition.

METHODS AND MATERIALS

Two trials were carried out with dalapon.* The first of randomised block design (plot size 1/100th ac) was laid down on a cereal stubble on 30th September, 1958 when most reed re-growth was 9-12 in. high with occasional plants up to 30 in. high. The field was cropped with potatoes in 1959 and sugar beet in 1960. The second was sprayed by logarithmic sprayer on a cereal stubble on 1st September, 1959 when reed re-growth was 3-16 in. high. The field was cropped with potatoes in 1960. The results of farmer usage of dalapon on reeds is also considered.

RESULTS

Results are summarised in Table I and Fig. 1

TABLE I. ASSESSMENTS OF EFFECTS OF TREATMENTS ON REED NUMBERS, ONE AND TWO YEARS AFTER SPRAYING

TRIAL 1

| Dosage of dalapon (lb /ac.) applied 30.9.58 | Reed Counts 14.8.59 | | Reed Counts 27.9.60 | |
|---|---|---|---|---|
| | Numbers AC | per cent control | Numbers AC | per cent control |
| 0 | 10,000 | 0 | 129,450 | 0 |
| 10 | 100 | 99 | 15 ,750 | 88 |
| 20 | 300 | 97 | 7,550 | 94 |
| 30 | 150 | 98½ | 8,750 | 93 |
| 40 | 100 | 99 | 2,700 | 98 |

*Used as the commercial formulation "Dowpon"

(78178)

The apparent build up of the reed population on the controls may be due to a poorer cultural control having been obtained under the sugar beet crop (1960) than under potatoes (1959). In any case, it is not easy to count dense reed infestations under a crop and the 1959 figure for the untreated plots was estimated only.

TRIAL 2

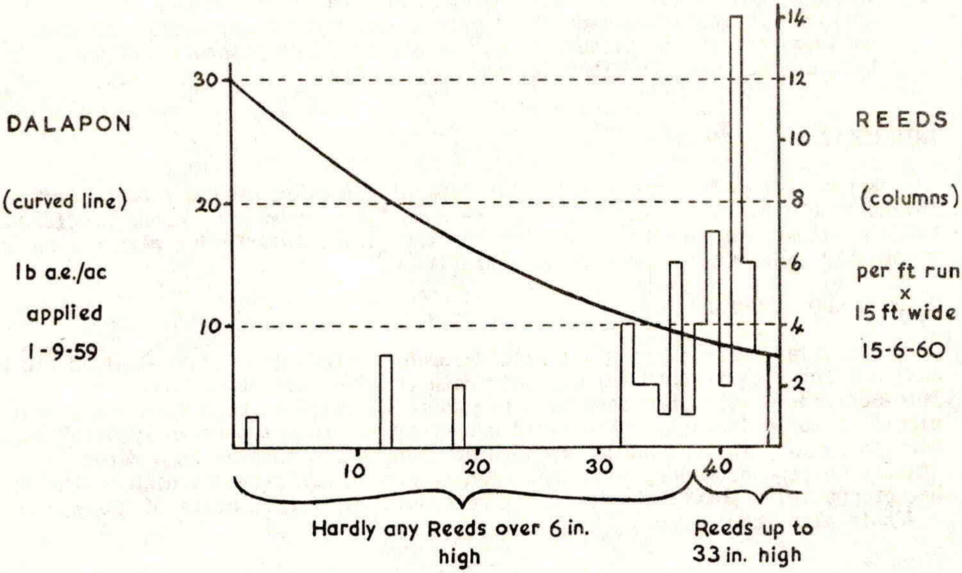


Fig. 1. Assessment of Effects of Treatments in year after spraying (Log. Plot).

Failure to control every reed at the higher doses may have been due to the spray having been applied too early so that the area of leaf receiving the spray was very small.

Farmer Experience

Virtually complete kills of reed have been obtained in the past two years with dalapon by a number of farmers. In several cases it has been possible to establish the rates applied. These were as follows (dalapon as lb/ac):- (a) 25 lb (150 gal water/ac, 1958); (b) 11 1/3lb (30 gal/ac. 1959); (c) 15 lb (25 gal/ac. 1958 (1 field ), 1959 (2 fields)); (d) 17 lb (1959). In some cases the applications were split.

In most cases the chemical was applied on reed regrowth in cereal stubble. There were three cases where flowering reeds were treated. One was a potato crop treated after the haulm had died back; another was a dyke adjoining a treated field and the third a sugar beet headland adjoining a treated stubble field. In the last case kill was better on the sugar beet area where the reeds were flowering than on the stubble land, although the latter received two applications of 8½ lb while the sugar beet strip received only a single application of 8½ lb per ac.

DISCUSSION

In the past, invasion of the reed into arable land has been accepted as one of the difficulties of farming in certain areas of fen, there being no practical method of control.

The trials showed that dalapon rapidly killed leaf growth but the rhizome showed no very definite signs of having been affected when examined prior to summer emergence of the shoots.

While the weed on the first trial did appear to be coming back in the second season, this is likely to be at least partly due to rhizomes having been dragged onto the small plots from adjoining untreated areas by cultivations.

Further work is clearly necessary to determine the most effective stage of application and to assess optimum dosage more critically. It would appear, however, that 15 lb /ac of dalapon can be expected to give a very good control of reed, provided it is applied when there is a good growth of leaf present.

SESSION 7

Chairman: Mr. D. Lowe

## WEED CONTROL IN HORTICULTURAL CROPS

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### WEED CONTROL IN HORTICULTURAL CROPS - PRESENT AND FUTURE

P. H. Brown

Director, Efford Experimental Horticulture Station

In attempting to review the subject of weed control in the wide and diverse field of horticulture a tremendous number of aspects call for consideration. Time, however, will only permit but a few of the more important of these to be taken into account. I therefore propose to discuss the following three aspects only:

(1) The extent of the need for herbicides to assist horticultural production.

(2) Is the present supply of herbicides and more particularly the method and means of applying them satisfactory?

(3) Is the extent of present day research, field experimentation and advice sufficient to meet the needs?

#### Is the horticultural industry in need of herbicides to assist its production?

This would sound to be an unnecessary question, yet it is one which should be examined and answered, and in so doing the facts must be faced fairly and squarely. The industry at the present time is none too confident of the advantages chemical weed control supposedly offers for the simple reason that performance of many materials is still too uncertain under this or that set of circumstances. Despite this, the answer to the opening question must clearly be "Yes". Firstly because adequate manual labour is becoming an ever-increasing problem and is already, let alone in the future, far too expensive a means of securing weed control in our crops. Let there be no doubt that the economics of the immediate future will no longer permit weed control by manual means, except possibly in the case of a few very high-value crops. I believe we have to envisage the position in the very near future of fewer but higher paid workers on both horticultural and agricultural production - a situation which thus demands a much changed production technique, in which the worker will need to be much more of a technician. A second factor, again for economic reasons, is the need to increase yield per acre as one of the contributing factors towards a lower production cost per unit of produce. In this connection it should be realised that each hour's delay in destroying competing weeds in the crop significantly depresses the ultimate yield of that crop. Therefore as time is the limiting factor chemical control, which is speedier and less disturbing to the young plant, obviously has its necessary and rightful place. The grower, in order to "acclimatise" himself to future requirements, must be prepared to do two things:-

(a) He must adopt a far less conservative attitude in regard to his methods of crop production. For example, chemical weed control both in regard to materials used and more particularly methods of application and the equipment to do so, may necessitate the changing of row-spacings and other cultural practices. If he is to gain the advantages that herbicides can offer he must be prepared to accept new ideas perhaps far removed from current practices.

(b) He must learn to be more precise, for the use of herbicides calls for a precision approach. This requirement, coupled with the necessity for precision approach in other matters concerned with crop production, will increasingly require technicians rather than manual workers to form the spear-head of his staff.

Equally, to further assist the producer, much will be required of the chemical industry, the research worker, the field experimenter and the adviser.

Is the present supply of herbicides and means of applying them satisfactory?

The first point is whether the chemical industry is producing and meeting the needs of the horticultural industry. Could it in fact be that they are producing too many materials, or of the wrong type? Opinion in many quarters suggests that too many chemicals are being put onto the marker as herbicides and for two main reasons. Firstly, it is often suggested many appear to be offered to the horticultural industry because, having been developed for agricultural crops or other purposes, an additional sales outlet would be an obvious advantage. This may or may not be true. It is, however, probably true to say that few herbicides have been developed to specifically meet horticultural needs. The admittedly small and diverse horticultural market does not and possibly cannot interest the larger chemical companies who, because of the potentially small market, are not prepared to infuse money into the development of herbicides for horticultural crops when a very much larger market awaits them for herbicides for agricultural use both in this country and more particularly overseas.

The second reason that causes opinion to suggest too many herbicides are being put onto the market is that these materials are not being sufficiently tested beforehand and in consequence their effects on crops and reaction to soil and climate are not sufficiently known and the user is too often left to find out for himself.

This present position can be summarised thus:-

(1) The lack of sufficient knowledge too often places the adviser in the position of not being able to make positive or sound recommendations to the grower. This is indeed an unfortunate situation.

(2) Variable results, apparently due to differences of soil, climate, conditions of crop and possibly other factors unknown, are all too common.

(3) These variable results, due to lack of sufficient knowledge of their performance often puts the herbicide into disrepute when it might, in fact, be

extremely valuable if more information concerning its behaviour were known and understood.

(4) In the absence of sufficient knowledge the risks of residual effects may be quite considerable. Are not such risks being taken to a considerable extent at the present time?

(5) The same case could be argued in respect of risk of toxicity to humans and, possibly, off-flavour in crops.

So far I have said nothing about the application aspect. I fear there is little on which to congratulate ourselves in regard to the present methods of application, apart from the fact that many spraying machines being used are of doubtful design and performance for the application of herbicides. We should seriously ask ourselves questions such as these:

(1) Is surface application of sprays, which has many drawbacks, the only way? Are other methods seriously being explored? Most crops on the horticultural holding are extremely sensitive to spray-drifts and for this reason alone methods of application other than spraying are needed. Granulated herbicides exist, and we are told, in wide use in the United States. Surely this form and the technique of application should be investigated with the maximum of effort.

(2) Is complete spraying of the land occupied by the crop necessary, sensible or economical? - if not why has the technique of band-spraying and equipment to do so not been developed to any extent?

Would it be true to say that the main deterrent to progress in such directions is the relatively low sales-potential of both materials and equipment specifically developed for the horticultural need? I suspect this is the case. It might, for example, be argued that the demand for equipment to apply a band of granular herbicides is too small to interest the manufacturer. But let it be remembered that the use of granulated forms of other materials is also receiving attention - for example granulated systemic insecticides and these will require very similar equipment. The demand may thus not be so small as might be imagined.

<u>Is the extent of present day research, field experimentation and advice sufficient to meet the needs?</u>

It is always too easy, as an excuse for other deficiencies, to cry for more and more research and one must not fall into this trap without being sure the needs exist. I therefore propose to start at the field end to examine the situation. What is the position today? Briefly I would describe it as the grower, anxious to reduce his weed control costs by the use of herbicides but uncertain of which of the many materials the trade offers him he can use with certainty of success and no crop loss. In an effort to find an answer he seeks advice. In turn the adviser finds himself in similar difficulties because so much of his knowledge has necessarily to be based on little more than observations in the field. That is to say his ability to give thoroughly sound advice and recommendations is limited by insufficient factual information from field experiments, both adequate in number and scope. In case I should be misunderstood, please note that I am not saying that no field experiments are undertaken, but that much more is need in this respect, for how little we really know concerning the variable behaviour of many of the present day herbicides. Again in case I am misunderstood, let me hasten to say that within the limitations already indicated, everything possible is being done to acquaint the adviser with all the information available. I refer to the N.A.A.S. Horticultural Herbicides Committee, who collect and review the knowledge available concerning each crop, each year, and issue advice to the advisory officers as to the recommendations they can safely make to the grower. My point, however, is that this knowledge is still far too limited and the advisory officer thus too hampered in his job. So many materials appear to behave in so many contradictory ways and we lack precise information not only of the extent of this but more important still the types of soil (particularly organic soils) and climatic conditions under which these variable performances occur.

And what are we do do about this situation? Here, I think, is a case where field experimentation is the real need as the necessary follow up to the research and development that has already taken place. Aware that what I am about to suggest is no mean task, I am nevertheless of the opinion that full scale field experiments on the maximum number of soil types coupled with a range of climatic conditions and embracing a comprehensive list of horticultural crops is needed. Only in this way do I feel we are likely to acquire the information from which sound and reliable advice can be given to the grower.

Now what do we require from research?

The horticultural industry requires more selective herbicides to meet its particular needs - and their full testing before release. This is certainly the greatest need so far as materials are concerned. I have previously made a brief reference to the risks of residual effects. Whilst some work is going on in this connection much more is needed in order to assure that the residual period of all the materials we use is known and their use can take this knowledge into account.

I have attempted, no doubt quite inadequately, to review the position and needs of the horticultural industry in regard to chemical weed control. I have intentionally tried to do so from the user's angle as I am quite sure the wealth of scientific and technical talent present here at this conference can, and will, fully cover the other aspects of the subject in the course of the deliberations to follow. I have drawn attention to deficiencies - that has been intentional and, if by so doing, it stimulates discussion and consideration during the rest of the conference my objective will have been fulfilled.

May I, in conclusion, summarise.

The horticultural industry must, for economic reasons, make even greater use of herbicides.

This calls for development of new herbicides, and particularly selective herbicides, in new forms such as granulated, and with the need for much fuller testing before release. The existing and future residual types must be investigated much more in regard to their residual period and risks.

Coupled with new materials is the need to develop equipment for their application in which respect band spraying and band application of granulated forms would appear to be high on the priority list.

Advice to the grower must be improved. The prerequisite to this is much more factual knowledge concerning the performance and behaviour of herbicides under a wide variety of conditions, obtained from a much increased field experimentation programme covering the whole country.

Lastly, for the efforts of the chemical industry, the research worker, field experimenter and the adviser to achieve the desired end, the grower must be more liberal in outlook, accept new ideas in place of current practices and above all cultivate a precision outlook, for precision it must be in all matters connected with herbicides.

# THE USE OF SIMAZINE IN STRAWBERRIES

D. van Staalduine

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Summary: The most important weeds in strawberry plantings in the Netherlands are *Poa annua*, *Senecio vulgaris* and *Stellaria media*. Seedling development of these weeds can be prevented by applications of 0.50 - 0.75 kg simazine/ha. Healthy established plants of all the varieties studied can stand post-harvest applications of 0.50 - 0.75 kg simazine/ha. Applications in early spring may cause damage to the crop. Variety, rate applied, soil type, and amount of rainfall determine the extent of the damage. Strawberry plants are susceptible to simazine applied just before and after planting. Some months after planting, however, treatments seem to be possible again. On runner beds a striking tolerance to simazine has been observed in young plants shortly after treatment.

## INTRODUCTION

Keeping strawberry plantings free from weeds commonly entails high expenditure. This is particularly so if the plantings are maintained for some years as beds of about 3 feet wide, as is the case with the varieties Jucunda, Madame Moutot and Oberschlesien. Moreover, because strawberries are at certain times of the year not of such immediate importance as compared to other crops on farms, frequently sufficient labour for hand-weeding is not available at the most desirable moments.

Although the system of growing strawberries in beds is gradually being replaced by the row system, also in this system a weed control technique less expensive and labour dependent than hand-weeding would be very welcome. For this purpose herbicides have been investigated at many places. The results of our own investigations with propham (IPC), chlorpropham (CIPC), 2,4,-D and 2,4-DES were published previously (Van Staalduine, 1957). Although this work did not result in official recommendations for the use of the mentioned herbicides, we tend to agree with the instructions on autumn and early winter applications of chlorpropham, given in the Handbook of the British Weed Control Council (1958).

Since 1956 simazine has been included in our experiments and the results of 4 subsequent years are now available. Initially, major stress was laid on applications in strawberry beds, but with the extension of the experiments to more varieties, also other growing systems were included.

The major weeds occurring in strawberry fields are *Poa annua*, *Senecio vulgaris* and *Stellaria media*. All three species are able to germinate and develop during the greater part of the year. Consequently except for the period from flowering to picking applications were made and studied during the entire growing season. The applications of simazine after picking and in early spring were studied most intensively.

## METHODS AND MATERIALS

The experiments were carried out in various centres of strawberry culture. Consequently all soil types on which strawberries are grown were represented. The most important varieties studied were Jucunda, Madame Moutot, Oberschlesien, Senga sengana, Talisman and Deutsch Evern.

A 50 per cent wettable powder formulation was used, but in this report all doses indicated refer to kg of active material per hectare (= 0.89 lb/ac) applied in 1000 l/ha (about 90 gal/ac). The plot size usually was 10 $m^2$ (= 12 sq yd) and there were 3 replicates of each treatment. The application usually was made on previously weeded plots.

The effects of treatment on weed growth were assessed by estimating the weed coverage on the treated and non-treated plots. In most experiments yields per plot were determined. For comparison hand-weeded plots were also taken up in the experiments. The spread in yield data within one treatment was usually rather great. Data on rainfall were collected. In order to characterize rainfall in the Netherlands the monthly figures for 1956-1960 and the monthly average values for 1921-1950 are plotted in figure 1.

## RESULTS

### Influence on the strawberry plants

#### Established strawberry beds

Post-harvest applications of 0.5-0.75 kg simazine/ha were made in July - August under varying conditions of soil type, age of the crop and rainfall. In all experiments with Jucunda on sand and clay soil (12 experiments) no yield depressions were observed in the year following application. The rather great variation occurring usually in the yield data from replicate plots did not allow a statistically significant conclusion to be made. In 4 experiments with Madame Moutot, applications of 0.375-0.75 kg/ha were investigated in post-harvest treatments. Also with these experiments no yield reductions were observed in the year following application. With Oberschlesien (2 experiments) on sandy soil poor in organic matter, similar applications again caused no production losses. The yields of one of these experiments with Madame Moutot and with Oberschlesien are given in table I.

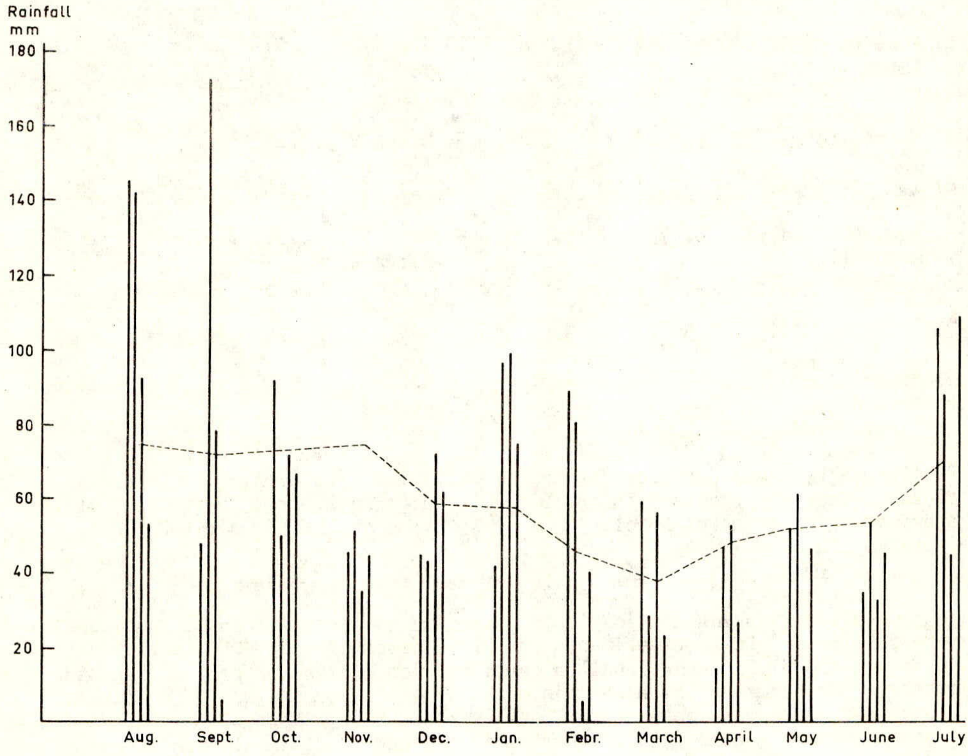


Fig. 1. THE MONTHLY RAINFALL DURING 1956-1960, AND THE AVERAGE MONTHLY VALUES FOR 1921-1950 (DOTTED LINE)

The four vertical lines for each month represent from left to right: 1956-1957, 1957-1958, 1958-1959 and 1959-1960.

TABLE I. EFFECT OF SIMAZINE ON STRAWBERRIES

| Variety Madame Moutot Planted spring 1956, sandy soil, 3 per cent o.m. | | | Variety Oberschlesien Planted spring 1955, sandy soil, 1½ per cent o.m. | | |
|---|---|---|---|---|---|
| Date of application | Dose kg/ha | Yield in kg/10 $m^2$ (mean of 3 replicates) | Date of application | Dose kg/ha | Yield in kg/10 $m^2$ (mean of 3 replicates) |
| 1) Aug. 6, 1958 | 0.375 | 21.5 | 1) Aug. 7, 1958 | 0.375 | 23.4 |
| 2) " | 0.75 | 23.1 | 2) " | 0.75 | 21.2 |
| 3) March 16, 1959 | 0.375 | 12.9 | 3) March 20, 1959 | 0.25 | 22.5 |
| 4) " | 0.50 | 8.2 | 4) " | 0.50 | 17.1 |
| 5) Aug. 6 + March 16 | 0.375 + 0.375 | 11.9 | 5) Aug. 7 + March 20 | 0.375 + 0.25 | 21.3 |
| 6) " " | 0.75 + 0.375 | 12.5 | 6) " | 0.75 + 0.25 | 22.5 |
| 7) " " | 0.75 + 0.50 | 9.2 | 7) " | 0.75 + 0.50 | 14.5 |
| 8) Hand-weeded | | 22.5 | 8) Hand-weeded | | 21.6 |
| Treatments 1, 2 and 8 differ significantly from treatments 3, 4, 5, 6 and 7 at the 1 per cent level. Expt IBS 214 | | | Treatments 1, 2, 3, 5 and 6 differ significantly from treatment 7 at the 1 per cent level. Expt IBS 218 | | |

With early spring applications of simazine on Jucunda inconsistent results were obtained. In 11 experiments out of 19 doses of 0.25-0.50 kg/ha resulted in damage and yield reductions, in particular on clay soils poor in organic matter. On sandy soils, higher in organic matter, damage was less common. The same results were obtained with the variety Madame Moutot. From table I it appears that in spring 1959 (rather humid weather conditions) even a dose of 0.375 kg/ha caused a significant yield reduction (treatments 3, 5 and 6). In another experiment in spring 1958 under less humid weather conditions on the same soil a statistically significant difference from the yields of hand-weeded plots could only be observed at 1 kg/ha. Data on an experiment on sandy soil with the variety Oberschlesien are also presented in table I. Early spring applications of 0.25 kg/ha did not result in a statistically significant influence on the yield, but at 0.50 kg/ha important yield reductions may occur (see treatment 7). The same observation has been made in 1960 in the same soil under rather dry weather conditions.

With all varieties simazine symptoms following spring treatments did not occur before the plants had developed a considerable amount of foliage (4-6 weeks after treatment). The oldest leaves showed marginal yellowing, followed by entire browning.

## Annual cropping system

In these experiments more recently developed varieties (Talisman, Senga sengana and Macherachs Frühernte) and Deutsch Evern were included. The planting usually takes place in August. Autumn and spring applications of simazine were investigated.

In table II the results are presented of an experiment with Senga sengana and Talisman on an organic sandy soil. Autumn applications of rather high amounts of simazine did not cause significant yield reductions. Rather dry weather conditions in autumn and especially in spring have to be taken into consideration, however (see fig. 1).

TABLE II. EFFECT OF SIMAZINE ON STRAWBERRIES

(Planted Aug 1959, sandy loam soil, 10 per cent organic matter)

| Dose kg/ha on Oct 19, 1959 | Yield in kg per 10 $m^2$ (mean of 3 replicates) | |
|---|---|---|
| | Senga sengana | Talisman |
| 0.5 | 17.5 | 16.8 |
| 1.0 | 18.5 | 16.9 |
| 1.5 | 16.0 | 16.7 |
| Hand-weeded | 18.0 | 17.1 |

All plots were hoed on March 24 and May 25, 1960
Expt IBS 557

In another experiment on sandy soil with a lower content in organic matter neither autumn nor spring applications of 0.25-0.75 kg/ha influenced the yields (table III). This was also observed in Macherach Frühernte. In this case too the rather dry weather situation in spring has to be considered.

TABLE III. EFFECT OF SIMAZINE ON STRAWBERRIES

(Planted Aug 1959, sandy soil, 4.5 per cent organic matter)

| Date of application | Dose kg/ha | Yield in kg/10 $m^2$ (mean of 3 replicates) | |
|---|---|---|---|
| | | Senga sengana | Talisman |
| Sept 29, 1959 | 0.25 | 14.1 | 9.8 |
| | 0.50 | 13.3 | 9.9 |
| | 0.75 | 13.4 | 9.6 |
| Nov 9, 1959 | 0.25 | 13.2 | 11.3 |
| | 0.50 | 14.7 | 10.1 |
| | 0.75 | 14.1 | 9.5 |
| March 14, 1960 | 0.25 | 14.5 | 10.0 |
| | 0.50 | 14.6 | 10.7 |
| | 0.75 | 13.5 | 11.0 |
| Hand-weeded | - | 13.9 | 9.8 |

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Comparing spring applications in Senga sengana and Deutsch Evern on clay soil, in 1959 under rather humid weather conditions Senga sengana did not react on doses of 0.75 kg/ha, but Deutsch Evern already showed severe damage at 0.25 kg/ha. In Deutsch Evern autumn applications caused less damage than spring treatments.

## Runner beds

With the variety Jucunda runner beds are started in spring, with other varieties mother plants are planted in summer. In the following summer runner formation and the development of young plants takes place. Hand-weeding is very difficult, in particular during and after the period in which the young plants become established.

In Jucunda in April 1958 especially pre-planting, but also early post-planting applications of 0.5-1 kg simazine/ha caused considerable growth retardation and the death of plants. With the same variety on sandy soilapplications in June, early in the period of runner formation, were investigated in 1958 and 1959. In addition to simazine also propazine, neburon and chlorpropham were studied. A dose of 0.5 kg simazine/ha (and in 1959 even higher doses, up to 1 kg/ha) did not damage the mother plants or the runners. The young plants becoming established on the treated soil grew normally and a satisfactory weed control was obtained. Propazine and neburon also caused no damage; chlorpropham however, caused considerable growth retardation in the young plants.

With Talisman, Senga sengana, Macherachs Früherne and Deutsch Evern too an application at the rate of 0.5 kg simazine/ha in the period of runner formation (June-- July) was not harmful to the production of young plants.

Influence on the weeds.

Generally speaking applications in our experiments took place on previously hand-weeded plots, as at the low doses investigated unsatisfactory results would have been obtained with established weeds. Consequently in the experiments reported on, only the residual effect on germinating weeds has been followed. The following tables indicate what may be expected under these circumstances.

Table IV shows the effect of some post-harvest applications of simazine on a sandy soil poor in organic matter. On this soil low rates from 0.25 kg/ha resulted in satisfactory control of the major strawberry weeds during a period of 3 months, although the weather conditions were rather dry (see fig. 1). In the following spring the activity of the chemical on young weeds appeared to have ceased almost completely.

TABLE IV. EFFECT OF SIMAZINE ON WEEDS

(Poa annua Senecio, vulgaris Stellaria, media on sandy soil with 1.5 per cent organic matter)

| Dose kg/ha on July 30, 1959 | Mean estimation of weed coverage on | |
|---|---|---|
| | Sept 11, 1959 | Nov 2, 1959 |
| 0 | 7.8 | 6.8 |
| 0.25 | 1.1 | 2.1 |
| 0.50 | 1.0 | 2.3 |
| 0.75 | 0.1 | 0.4 |
| 1.00 | 0.2 | 0.0 |

Three replicates; 0 = no weeds; 10 = complete coverage
All plots were hoed on Sept 12, 1959
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TABLE V. EFFECT OF TIME OF APPLICATION OF HERBICIDES ON WEEDS

(On sandy soil with 4.5 per cent organic matter)

| Dose kg/ha | Mean estimation on May 16, 1960 after application on | | |
|---|---|---|---|
| | Sept. 29, 1959 | Nov 9, 1959 | March 14, 1960 |
| Simazine, 0.25 | 5.0 | 2.3 | 0.9 |
| Simazine, 0.50 | 3.8 | 0.9 | 0.2 |
| Neburon, 1.50 | 3.8 | 3.3 | 7.0 |
| CIPC , 1.60 | 4.3 | 4.0 | - |
| None | 7.8 | 7.8 | 7.8 |

Three replicates; 0 = no weeds; 10 = complete coverage All plots were hoed on April 4, 1960 IBS 352

The effect of the moment of application on weed control obtained by simazine is shown in table V, which also gives some results with chlorpropham and neburon. In this experiment the main weeds were Apera spica-venti, Chenopodium album, Poa annua, Polygonum convolvulus and Viola arvensis. The application in September 1959 of simazine, neburon and chlorpropham appeared to have lost its residual effect by May 1960. Applications of 0.25-0.50 kg simazine/ha in November 1959, however, still gave satisfactory weed control in May 1960 and the same was true for treatments applied in March 1960, although weather conditions in spring were dry. The results obtained with simazine were better than with neburon.

According to our experience the effect of summer applications of 0.50 kg simazine/ha has usually worn off in the spring following. Therefore repeated applications (summer and spring) were investigated as well. In table VI the results of such an experiment are indicated. The major weed present in this case was Senecio vulgaris. Also here the residual effect gradually disappeared, although some effect could still be observed after 10 months. In other experiments too the great susceptibility of Senecio to simazine has been noticed. A twofold application in summer and spring of 0.5 kg/ha gave a perfect control of this weed. In this experiment rainfall was rather high (see fig. 1).

TABLE VI. EFFECT OF SIMAZINE ON SENECIO VULGARIS

(On clay soil)

| Time of application | Dose kg/ha | Mean estimation of area covered on | | |
|---|---|---|---|---|
| | | Nov. 12, 1957 | May 31, 1958 | July 30, 1958 |
| Aug. 1, 1957 | 0.50 | 3.0 | 3.8 | 5.7 |
| Feb 21, 1958 | 0.50 | 8.5 | 1.5 | 3.3 |
| Aug 1, 1957 + ) Febr. 21, 1958 ) | 0.50 + 0.50 | 3.0 | 0.2 | 1.3 |
| None | none | 8.5 | 8.0 | 6.3 |

Three replicates; 0 = no weeds; 10 = complete coverage
All plots were hoed on Nov. 13, 1957, and June 2, 1958
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DISCUSSION

In our experiments with strawberries grown according to various systems (picked for one or more seasons) a striking difference showed up between the susceptibility of strawberry plants to applications of simazine in summer or early autumn to those sprayed in early spring. Whereas during 4 years of experimental work post-harvest applications of up to 0.75 kg simazine/ha did not cause any depression in yield the next year, applications in spring, of doses as low as 0.25 kg/ha caused damage to the crop. The relative resistance of strawberries to summer applications of simazine was also mentioned by Campbell (1957), who reports that doses of 1 lb/ac caused little or no damage to 3-year old plants, 2 lb/ac gave considerable damage, however.

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Rainfall probably is not a factor of importance in causing these differences. After summer and autumn applications precipitation is usually higher than in spring; still the occurrence of reactions to simazine is more frequent after applications in spring. Although no data are available on differences in root development during the different parts of the growing season for the varieties included in our experiments, according to Mann and Ball (1926, 1928) root formation and extension of the root system in the variety Royal Sovereign is more intensive in summer and autumn than in the same plants in spring. Therefore a closer contact between the root system of the strawberries and the simazine present in the top-soil might explain this higher susceptibility of the plants in spring.

The extent of damage occurring after applications of simazine in spring is determined by several factors. First of all varietal differences exist. In our experiments Senga sengana and Talisman were the least susceptible varieties; Jucunda, Regina and Oberschlesien take an intermediate place and Deutsch Evern and Madame Moutot proved to be very susceptible. Varietal differences in susceptibility to simazine were also mentioned by White (1958). They are known as well from experiments with chlorpropham (Van Stallduine 1957; Robinson 1958). Secondly a group of environmental factors determining the amount of simazine available to the root system of the strawberry plants influences the extent of damage. In addition to the dose of simazine applied, the influence of soil type, in particular the content of organic matter, and the amount of rainfall after applying the chemical appear to be of importance. In particular, doses higher than 0.5 kg/ha may cause considerable damage. After applications of 2 lb/ac in spring Hemphill (1957) has also observed serious damage and yield reduction.

The relative resistance to simazine observed in young strawberry plants on runner beds is striking. This phenomenon has also been observed by Wood and Sutherland (1960). The fact that young plants may development normally in simazine-treated soil can best be understood by assuming a prolonged physoi - logical dependence of the young plants on the mother plants. This theory is supported by the observation that if a mother plant shows simazine symptoms, reactions may also be noticed in the already well-rooted runner plants. Under normal conditions the mother plants do not react to the simazine, however.

In the experiments reported on, a satisfactory weed control was obtained with doses of 0.25 - 1 kg/ha. This low level is caused by several factors. Strawberries are usually grown on soils rather low in organic matter content (5%). The inactivation of simazine observed on soils high in organic matter and the required increase in the dose needed for a satsifactory weed control consequently is of no great importance for applications in strawberries. Good effects are usually assured because of sufficient rainfall during the entire growing season (see figure 1). Applications on humid soil surfaces are to be preferred; this situation appears to promote a good effect of the application. As has been indicated all treatments in our experiments were carried out after removing all established weeds. Weeds germinating subsequently are easily controlled by the doses indicated. Under humid weather conditions small established weeds will also be killed. The applications are rather effective because of the high susceptibility of _Poa annua_, _Senecio vulgaris_ and _Stellaria media_ to simazine.

Since applications of simazine are possible in established strawberry plantings and in addition the use of simazine in the annual growing system is promising, only the problem of weed control in spring remains. There are indications, that applications of 0.5 kg simazine/ha in October - November may result in good weed control until picking next year. It seems to be justified to continue research in this direction. In addition, however, we shall have to continue our search for other selective herbicides which will be tolerated by strawberries under spring conditions and allow a greater safety at other moments of the year. The use of simazine reported on may result in a considerable alleviation of weed control porblems in strawberry plantings, but has not to be looked upon as the most desirable solution or the final word in this aspect.

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# FURTHER PRELIMINARY TRIALS OF CHEMICAL WEEDKILLERS IN RASPBERRIES AND STRAWBERRIES

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Summary: This paper reports small preliminary trials on the control of annual weeds in established raspberries and strawberries, on the control of *Agropyron repens* in raspberries and on the effect of spraying a prepared soil surface with herbicides shortly before planting strawberries. Simazine and atrazine, used at low rates, gave promising results against annual weeds in established plantations of both fruits. In the work with *Agropyron repens*, dalapon gave the best results and amino triazole severely damaged the raspberries. Soil-surface sprays of simazine (2 lb/ac), atrazine (4 lb/ac), monuron ((3 lb/ac), diuron (4 lb/ac) and fenuron (0.5 lb/ac) all caused the death of strawberries planted by trowel two days later.

## INTRODUCTION

Herbicide "screening" trials of the type previously reported by Wood and Sutherland (1960) have been continued at Mylnefield as a means of selecting the most promising materials for use in longer-term experiments. The work now described was done on well-drained light or medium loam soils, largely free from perennial weeds but productive of a dense growth of mixed annuals. The application rates for materials are given as weights of active ingredient per acre.

## I. A trial of eight herbicides in raspberries in 1959.

### METHODS AND MATERIALS

This trial was planted in late March with canes of the variety Malling Jewel, spaced at 6 ft x 3 ft. Plots, two for each treatment, were marked out across the direction of the rows. The ground was rotavated on 9 April and the herbicides were applied by Oxford Precision Sprayer two days later, at a standard liquid volume rate of 40 gal/ac.

### RESULTS

(i) Untreated plots

By 29 April these plots carried large seedling populations of *Stellaria media*, *Senecio vulgaris* and *Spergula arvensis*. Other species included *Chenopodium album*, *Poa annua*, *Lamium amplexicaule*, *Fumaria officinalis* and *Galeopsis tetrahit*. Weed-cover was complete soon after mid-May.

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(ii) 3Y9 (Falone 2,4-DE Phosphite) (3 lb and 6 lb)

This material gave inadequate weed control, especially of Stellaria media and Poa annua. Chenopodium album and Senecio vulgaris were fairly well controlled at both rates and Fumaria officinalis and Spergula arvensis were possibly reduced in numbers at the 6 lb dose: but the estimated weed cover on 29 May was 40 per cent and 20 per cent at the two rates respectively. The raspberries showed no injury.

(iii) Atrazine (2 lb and 4 lb)

Although weed seedlings were numerous on 29 April on the plots treated with atrazine at 2 lb, nearly all had died by 11 May. None were present on the 4 lb plots. Weed control in late spring was excellent at both rates, the cover on 11 June being below 1 per cent. After being rotavated in late June along with others, these treatments continued very clean for the remainder of the season, the 4 lb-treated plots until as late as November. The raspberries showed no injury.

(iv) Simazine (6 lb)

Few seedlings were present on the plots of this treatment on 29 April, and most of them were dying. The plots then remained clean throughout the summer and were still 95 per cent free from weed cover in early November. The raspberries showed no injury.

(v) Monuron (5 lb)

This gave a good general control of weeds - Senecio vulgaris and Stellaria media, the main species, were completely suppressed - but did not adequately control Fumaria officinalis, Polygonum aviculare, Veronica hederifolia and V. persica. The raspberries in late May showed interveinal leaf chlorosis and necrosis, but the canes were not killed and eventually grew well.

(vi) Diuron (2 lb, 4 lb and 6 lb)

Weed control by diuron at the 2 lb dose was quit inadequate. A dense weed cover which formed in May and June was dominated by Fumaria officinalis, Senecio vulgaris and Galeopsis tetrahit. Although better, the 4 lb dose still left a weed cover in late May of about 15 per cent, composed mainly of Fumaria officinalis with some Senecio vulgaris and occasional plants of Lamium amplexicaule, Chenopodium album and Veronica spp. The 6 lb dose gave the best control but still did not adequately control Fumaria officinalis. The raspberries were apparently uninjured at the 2 lb and 4 lb dose but showed slight marginal leaf chlorosis in early June at the 6 lb dose. After rotavation of the plots in mid-June the 6 lb dose continued to give a moderate degree of weed control during the summer and autumn.

(vii) Fenuron (0.5 lb and 1.0 lb)

Fenuron at these doses failed to give a useful control of weeds. The raspberries showed no injury.

(viii) EPTC (5 lb and 10 lb)

EPTC at 5 lb was almost without effect. The 10 lb dose gave a good control of Stellaria media until the end of May, but Senecio vulgaris was no more than checked and a general and rapid growth of weeds occurred in June. The raspberries grew normally.

(ix) Neburon (2.5 lb)

This treatment also was ineffective. There was some control of Stellaria media but little or none of Senecio vulgaris, Lamium amplexicaule, Fumaria officinalis or Galeopsis tetrahit. The raspberries grew normally.

II. A trial for the control of Agropyron repens in raspberries in 1959.

METHODS AND MATERIALS

This was a trial made on a 5-year-old plantation of seedling rapberries (Malling Jewel x Burnetholm Seedling) of varying habit and vigour, the rows of which were heavily infested with A. repens. The following treatments were applied on 23 March, when the couch grass was starting into growth but the raspberry buds were still unopened: dalapon (8.5 lb), amino triazole ( 5 lb), atrazine ( 5 lb), TCA (18.6 lb), and dalapon (4.25 lb) + amino triazole (2.5 lb). Each was applied at a liquid volume rate of 50 gal/ac. No cultivations were given before or afterwards.

RESULTS

(i) Dalapon (8.5 lb)

By 5 April to A. repens foliage was becoming grey and brownish, and by the end of the month had turned completely brown. Poa annua also looked unhealthy and showed some abortion of the growing tips, but dicotyledonous annual weeds grew normally. There was no sign of injury to the raspberries until early June, when the foliage of the young current-season canes was pale in colour. Some regrowth of A. repens began in mid-June.

(ii) Amino trizole

This treatment produced severe chlorosis and pink colouration of the foliage and growing apices of A. repens and of all other weeds present, and the stand of A. repens was much reduced by mid-April. Similar severe effects were produced in the fruiting laterals and new canes of the raspberries, and by 30 April there was scarcely any green growth on the treated plots. Many raspberry canes were killed by the end of May, but there was then a slight re-growth of A. repens.

(iii) Atrazine (5 lb)

This gave a good kill of established Poa annua by the end of April and controlled all germinating annual weeds until autumn: but A. repens was only slightly checked in growth. The raspberries showed no injury.

(iv) TCA (18.6 lb)

With this treatment the leaves of A. repens turned greyish in April, with necrotic tips, but re-growth had begun by the end of the month. Although the vigour of growth was reduced during May, coverage of the rows remained complete. The raspberry foliage developed the severe interveinal chlorosis typical of TCA injury.

(v) Dalapon (4.25 lb) + Amino triazole (2.5 lb)

This mixture gave as good a control of A. repens as amino triazole at 5 lb, with less damage to the raspberries: but the control was rather poorer than with dalapon at 8.5 lb. The raspberries showed chlorosis patchily until mid-June.

## III. Effects of spraying a soil surface with herbicides before planting strawberries in 1959.

METHODS AND MATERIALS

Immediately after being prepared for the spring planting of strawberries, areas of soil surface were sprayed on 17 April with the herbicides listed below, at the rates shown and each at a volume rate of 30 gal/ac. Strawberries (variety Redguantlet) were planted with trowels on 20 April.

RESULTS

All the strawberries were killed on plots which had been sprayed with monuron (3 lb), simazine (2 lb), atrazine (4 lb), and diuron ( 4 lb).

Injury on the monuron and diuron plots first appeared as a marginal leaf chlorosis and developed into an interveinal necrosis leading to a complete collapse of the plants. Most plants on the monuron plots were dead by 11 May, but some on the diuron plots survived for a week or two longer. The plants on the simazine and atrazine plots developed a severe general necrosis and were dead by the end of May.

An almost complete loss of plants also occurred on plots pre-sprayed with atrazine at 2 lb or with a mixture of 2,4-DES (3.6 lb) and fenuron (0.5 lb). The mixture produced leaf symptoms indistinguishable from those of monuron injury. On plots pre-sprayed with 3Y9 (2 lb and 4 lb) or with a mixture of 2,4-DES (3.6 lb) and propham (5.0 lb) there was a temporary distortion of the young leaves. No damage occurred on plots treated with EPTC (8 lb), but this treatment gave the poorest weed control. Weed control on the 3Y9 plots was also poor, and similar to that obtainable with 2,4-DES alone.

## IV. Trials of herbicides on established strawberries in 1959 and 1960.

Applications of simazine at rates of 1.5 lb and 3.0 lb were tested in an initial trial in 1959 of a fifth-season Talisman plantation, in which the plants had been maintained separately at their original spacing of 36 in x 18 in. The treatments were applied on 16 March after the rows had been hoed and lightly rotavated. The 1.5 lb dose gave insufficient weed control, but the plots treated at the 3 lb dose remained clean until autumn. Some of the older strawberry foliage on the 3 lb plots showed a marginal chlorosis and necrosis, and severe injury occurred to small runners of the previous year left loosely rooted after the cleaning; but the new season's growth on the established plants was normal and vigorous.

In 1960 the following treatments were tested in a 6 x 6 latin square design on part of the same plantation: monuron (3 lb), simazine (2 lb), atrazine (2 lb), diuron (3 lb), chlorpropham (2.5 lb) + monuron (1.0 lb), and control (normal cultivation). The herbicides were applied on 4 March by Oxford Precision Sprayer at a working pressure of 25 psi, each at a volume rate of 30 gal/ac. The plantation was clean and the foliage dry.

The simazine and atrazine treatments caused no injury to the established plants, although loosely rooted runners of the previous year again showed necrosis. The monuron treatment was disappointing: Stellaria media and Senecio vulgaris were poorly controlled and chlorosis appeared on some of the mature strawberry foliage in April. By mid-May, however, most of the new growth was normal. Diuron gave rather similar effects - a poor control of Senecio vulgaris and Veronica spp. and some interveinal chlorosis of the older strawberry leaves. Both of these treatments slightly depressed vigour as compared with the simazine, atrazine and control treatments. The chlorpropham/monuron mixture controlled weed growth well, except for Senecio vulgaris, but severely stunted the strawberry plants.

The fruit yields from the six treatments (Table I) were in close relation to the effects on growth. The simazine, atrazine and control plots significantly outyielded those treated with monuron and chlorpropham/monuron, and the simazine plots also significienty outyielded the diuron plots.

TABLE I. FRUIT YIELDS OF TALISMAN STRAWBERRIES IN 1960.

| Treatment | Yield per plot (lb) | | |
|---|---|---|---|
| | Sound | Blemished | Total |
| Simazine (2 lb) | 20.5 | 2.7 | 23.2 |
| Atrazine (2 lb) | 19.6 | 2.3 | 21.9 |
| Diuron ( 3 lb) | 17.1 | 1.7 | 18.8 |
| Monuron (3 lb) | 15.0 | 1.6 | 16.6 |
| Chlorpropham + (2.5 lb) Monuron (1.0 lb) | 14.4 | 1.4 | 15.8 |
| Control (normal cultivation) | 19.9 | 2.0 | 21.9 |
| | Sig. diff. (P = 0.05) 3.4 | | |

## DISCUSSION

These trials provided only very introductory information on the possible usefulness of the materials tested, since they left almost untouched the variations in rates and times of application that can be considered for perennial fruit crops, particularly deciduous crops like the raspberry. There are also wide possibilities in the use of mixtures of herbicides for these crops. The present results are reported, however, as a contribution to work which is being continued at Mylnefield and elsewhere.

The first trial, with raspberries, gave further promising results from simazine used at a low dose as a residual herbicide. It also showed the possible value of atrazine, which may be the more effective of the two under dry conditions. EPTC and 3Y9 gave disappointing results, and further work is required to determine the value of fenuron, neburon and diuron as herbicides for soft fruit. Monuron can be injurious to raspberries, and probably even more so to strawberries, if applied in spring at rates sufficient to destroy *Senecio vulgaris*, but its use at other times of the year may repay investigation.

Of the five treatments applied against *Agropyron repens* in raspberries, dalapon at 8.5 lb seemed the most successful, and slightly better than amino triazole at 5 lb. Damage to the raspberries was greatest where amino triazole was used. With all the treatments there was some re-growth of *A. repens* by mid-June, and better control may have been achieved if the use of herbicides had been combined with cultivations.

The third trial showed that sprays containing simazine, atrazine, monuron, diuron or fenuron, applied to a prepared soil surface, can destroy strawberry runners planted into the site shortly afterwards. This is presumably because the chemicals are mixed into the rooting zone by the act of planting.

The last of these trials showed promising results from the spring use of simazine and atrazine on established strawberries. It is important to follow-up this work with experiments combining repeated applications of these herbicides with assays of their persistence and movement in the soil, because the value of substituted triazines will depend largely on whether their accumulation in harmful concentrations can be avoided. The possibility of such a build-up makes it still more important to select a range of herbicides suitable for use in any given crop, so that changes can from time to time be made.

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