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# CHEMICAL TREATMENT OF BRACKEN

A review of recent experimental work on the reactions of the common Bracken Fern (Pteridium aquilinum) to foliar and soil applications of some chemical herbicides.

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## Summary

During the summers of 1955 and 1956, a survey has been made of the reactions shown by the bracken fern (Pteridium aquilinum) to treatment by some of the herbicides recognised as effective on plants with rhizomatous stems. The following substances have been used: ammonium sulphamate, the growth-regulating phenoxy - compounds (in acetic and butyric formulations) amino-triazole, maleic hydrazide, trichloracetic acid and monuron. Application was made in some cases as foliar sprays, and in others as soil applications. Two growth-stages of the plant were used (a) 1-year old plants growing in garden beds; and (b) mature stands of field bracken.

As a result of these tests, it is suggested:

(1) that actively developing young tissues of the bracken fern show translocation of such chemical compounds as the growth-regulating herbicides and (to a lesser degree) ammonium sulphamate. Ammonium sulphamate may kill off young tissues after translocation; but the growth-regulating herbicides (both in acetic and butyric formulations) produce systemic effects and these are seldom lethal.

(2) that in mature bracken there is little evidence of such extensive translocation: herbicides of the growth-regulating types can induce morphological changes on the fronds; but there is no evidence that organs other than the fronds are affected by the treatment.

(3) that at the rates tested ammonium sulphamate and amino triazole are powerful agents of frond destruction, but there are no signs that they are translocated within the mature plant body. In the case of ammonium sulphamate, even after two years treatment there are no obvious signs of deterioration of the underground stem.

(4) that we have little evidence at present that any chemical herbicide can be more effective on field bracken than cutting or crushing treatments.

## Introduction

Purpose of the experimental work. It is now generally accepted that the traditional ways of treating land infested with bracken (by cutting or crushing the fully mature fronds) may serve to check the plant; but that the massive underground stem in well established stands is seldom killed by starvation through removal of the photosynthetic organs, the fronds: such treatment may fail to eradicate the weed even after years of frond removal. Probably the only effective mechanical treatment is ploughing (8); and even on lands where the bracken has been brought under control, there is often need to "mop up" areas in difficult terrain which, if left, would act as centres of new growth.

With the recent increase in the number and our knowledge of the action of chemical herbicides, particularly translocated herbicides, it may be postulated that if such compounds are applied to the fronds of bracken (the only easily available organ of the plant) they might be carried down to act as agents of attack on the underground stem; and that such a mode of attack would be particularly useful on un-ploughable land. To test this idea, experimental work has been carried out during the past two summers on the morphological reactions of bracken to various compounds, particularly ammonium sulphamate, amino-triazole and some of the growth-regulating phenoxyacetic compounds. The opportunity has also been taken to test the effect on bracken of the butyric formulations of some phenoxy compounds (7,25).

The chemicals under review. (a) Ammonium sulphamate is known as a contact herbicide which is also said to be translocated (4,10,20). Reports exist that it has been tested on bracken (22); but no real details are known of its action. It is, however, said to have been used with success on such plants as morning glory (*Ipomoea lacunosa*) and field bindweed (*Convolvulus arvensis*) where it is said to have induced dormancy which persisted until the starch reserves of the storage organ were exhausted and the plants died (20). Ammonium sulphamate has three characteristics which make it more acceptable than many contact herbicides: for instance, sodium chlorate. (a) It is said to break down to ammonium sulphate, and could therefore act as a soil fertiliser in the later stages of treatment. Little is known of the rate of breakdown; but it has been reported that the chemical is effective in the soil for one or two months and that it is then decomposed by soil bacteria (12,20). (b) It is reported as being translocated downwards through the plant system and as being effective on roots when applied as a foliar spray (20). (c) It is non-toxic to animals.

(b) Amino-triazole is known to be readily absorbed by the roots and foliage of plants and translocated through the plant system (1,2,13). Treated plants frequently become chlorotic, and subsequent growth is often devoid of chlorophyll (2,13). Further, it is reported (2) that mixtures of amino-triazole and 2,4,5-T were more toxic to seedlings of mesquite (*Prosopis juliflora*) than either compound by itself. It has been found effective on couch grass (*Agropyron repens*) at 4,8, and 16 lb/ac (18); and complete eradication of creeping thistle (*Cirsium arvense*) was obtained using 4 lb/ac. (6). It is also reported that amino-triazole gives control of *Typha spp.* (3), also rhizomatous plants; and that it has been tried on bracken where the effects produced "appeared promising" (21).

(c) It has already been reported that the growth-regulating compounds MCPA and 2,4-D induce systemic effects on young plants of bracken (8); inhibitory effects such as reduced frond formation, curvatures of young tissues and increased dormancy of apices have been seen after foliar treatment with certain doses. One of the effects of treatment with growth-regulating compounds which is now recognised is a disturbance of the starch metabolism and of the amount of starch stored up (14,15,19). Any agent which could induce a disturbance in the storage of the underground stem of bracken might effectively lessen the resistance of the plant and hasten its starvation; but earlier work with MCPA, 2,4-D and 2,4,5-T (8) suggested that these compounds were acting only on the fronds (8).

The main interest of the butyric compounds lies in their selective herbicidal actions; and though no such selective use is envisaged in the case of bracken, the opportunity has been taken to see the effects of some of the butyric formulations on sporelings (7), and also on field bracken since MCPB is reported to give control of rhizome development in creeping thistle (1).

(d) Other compounds which have been tested in the field are 3-(p-chlorophenyl)-1,1-dimethylurea (monuron), maleic hydrazide (MH) and trichloroacetic acid (TCA) all of which have been reported as effective on field weeds with underground stems (1,13,20). Monuron has previously been tried on bracken with inconclusive results (16,22,26).

General design of the experiments. Tests have been made of the reactions of the bracken plant to foliar or soil sprays at two growth stages: (a) young plants during their first year of development these being grown in garden plots; and (b) stands of field bracken with a density of 30-40 fronds to the square yard, each frond being 4-5 ft high when fully unfurled. The chosen area was on Drumclog Moor, Dunbartonshire, where the soil is a heavy loam with top layer of 1.5 in. of litter.

The effects of treatment have been assessed by analysis of fronds and rhizomes at the end of the growing season - i.e. in September. The nature of the plant precludes experimental work with large numbers of replicates at one time; and experiments call for repetition over several seasons. The results here presented are largely observational.

Application of the chemicals was made by aqueous sprays directly on the foliage or the soil. In the case of young plants, a fine nasal spray was used; in field tests, a knapsack spray with a single jet lance and a spraying pressure of 30 lb/sq. in. was used; or for the smaller field trials, a watering can with a fine rose nozzle gave most even distribution. The volume used in all cases was equivalent to 100 gal/ac of water.

Part I of this paper describes the effects of ammonium sulphamate and growth-regulating compounds on young plants of bracken, and part II gives the effects of these and other chemical herbicides on field bracken.

## Reactions of young plants to chemical sprays

A. Ammonium sulphamate. Preliminary tests on fronds of young bracken plants in pots established (a) that single drop foliar treatment of weak solutions of ammonium sulphamate had little effect; but that in high concentrations, single drops caused local effects which were seen as dark coloured, shrivelled areas of tissue, and a tendency for the apex of a young treated frond to droop. (b) Spraying (i.e. the contact of numerous small droplets) caused drooping and death of a treated frond within 10-12 days. Similar drooping and later death followed in adjoining fronds which had been protected from contact during the initial spraying: that is, the effects of chemical treatment appeared to have been transmitted through the plant system. The effect seen above ground on the second affected frond was a deterioration from the apex downwards, suggesting that the destructive factor had been carried to the frond apex in the xylem and that the effects spread slowly downwards towards the frond-base.

Experimental procedure. Experiment 1. Three young, established plants in a garden bed were treated on August 7th with 10.5 ml of ammonium sulphamate at a concentration of 25 parts per thousand: this rate is equivalent to a field rate of about 25 lb in 100 gal of water. Each of the selected plants showed 15-20 fronds in addition to a central group of very juvenile ones, many of which were dead. The heights of the mature fronds were 20-25 in. An analysis of one of these plants seven weeks later is shown in table 1. This suggests that (a) ammonium sulphamate is a powerful agent of attack on young frond tissues, thereby restricting markedly the growth of the whole plant; (b) this restriction is seen particularly in the lessened development of the rhizome; (c) an attempt to re-establish growth is seen in the development of an increased number of active frond-buds.

These results were confirmed by further similar experiments in a second growing season.

Table 1

Analyses of young bracken plants treated with ammonium sulphamate as a foliar spray

| Form of plants 7 weeks after treatment | Control | Plants treated in August with solution at concn. 25 parts per thousand |
|---|---|---|
| Fronds: | | |
| no. active | 27 | 0 |
| no. moribund or dead | 7 | 37 |
| max. height developed by individual fronds (cm) | 41.9 | 24.1 |
| Frond-buds: | | |
| no. of living buds per plant | 32 | 58 |
| Length of rhizome developed (cm) | 114.3 | 58.4 |
| dry weight of plants (g) | 56.6 | 21.8 |

Experiment 2. A further experiment was carried out on young potted plants in a greenhouse to see the extent of development when solutions were applied to the fronds or to the roots - i.e. through the soil. The results of analyses made seven weeks after treatment are shown in table 2. This suggests that very dilute solutions of ammonium sulphamate applied to the foliage may be stimulatory, but that strong solutions are extremely harmful to frond tissues; and that inhibitory effects on growth can be brought about through soil treatment, though the required dose is considerably greater.

Table 2

Analyses of very young bracken plants under treatment with ammonium sulphamate as foliar or soil spray

| Form of plants 6 weeks after treatment | Control | 1 ml Foliar 0.5% | 1 ml Foliar 5% | 2 ml Soil 5% | 2 ml Soil 50% |
|---|---|---|---|---|---|
| Fronds: | | | | | |
| no. active | 5 | 5 | Plant | 8 | 1 |
| no. moribund or dead | 2 | 3 | | 2 | 3 |
| height of tallest frond (cm) | 14 | 12 | quite dead | 5.5 | 4 |
| Frond-buds: | | | | | |
| no. living | 1 | 3 | | 2 | 0 |
| no. dead | 0 | 0 | | 0 | 2 |
| length of rhizome developed (cm) | 5.5 | 13 | | 5.0 | 4.5 |
| dry weight (referred to control as 1 g) | 1 | 1.1 | 0.05 | 0.175 | 0.05 |

Conclusions. Thus, ammonium sulphamate appears to be an effective inhibitory agent on young bracken plants, its action being particularly destructive on frondular tissues. Almost certainly there is some translocation through young developing organs; but as collapse of the tissues occurs rather readily, this suggests that the compound acts primarily as a contact herbicide.

B. Growth-regulating compounds. It has already been reported that the growth-regulating compounds MCPA and 2,4-D can produce systemic effects in young bracken plants (8). It is also known that these two compounds produce inhibitory and even lethal effects when used on sporelings in high concentrations; but in low concentrations, their action may be stimulatory. In 1955, a series of young plants sprayed with 2,4,5-T at a concentration of 500 p.p.m. showed marked restriction of rhizome development; and so, in 1956, a comparative test using 4 phenoxyacetic acids was set up.

Experiment 3. A series of young plants, in replicates of four, was grown in a garden plot. At the 5-6-leaf stage, each plant was treated with 10 ml of a 500 p.p.m. solution of the diethylamine salt of each of the following compounds: MCPA, 2,4-D, 2,4,5-T and 4-CPA. When harvested seven weeks later, all the plants showed systemic effects. These were more readily appreciated in the form and appearance of the plants than by a count of the organs, for with all treatments the young plants showed some degree of (a) pinnule reduction and contortion of the frond rachises, and a general hardening of the young fronds to give a "wiry" appearance; (b) reduction in the extent of rhizome development; (c) contortion and dormancy of the rhizome tips, a point in marked contrast to the very active state of the rhizome apices in the control plants; and (d) marked proliferation of small roots round the tips of the dormant rhizomes. The later formed fronds showed much less reaction, suggesting a lessening potency of the activating agents with time.

Table 3

Analyses of young bracken plants after treatment with MCPA, 2,4-D, 2,4,5-T and 4-CPA (all at the concentration of 500 p.p.m. of the diethylamine salt)

| Form of plants 7 weeks after treatment (means of 4 plants) | Control | MCPA | 2,4-D | 2,4,5-T | 4-CPA |
|---|---|---|---|---|---|
| No. of fronds | | | | | |
| (a) active | 9 | 7 | 6 | 8 | 8 |
| (b) moribund or dead | 1 | 5 | 3 | 1 | 6 |
| No. of frond-buds | | | | | |
| (a) active | 14 | 3 | 9 | 17 | 7 |
| (b) dormant | 0 | 3 | 1 | 0 | 2 |
| Length of rhizome developed (cm) | 34.0 | 24.85 | 24.25 | 9.63 | 10.8 |

Experiment 4. A repeat of experiment 3 above was made to test the effects on young bracken plants of the butyric formulations MCPB, 2,4-DB, 2,4,5-TB and 4-CPB. As before, plants at the 5-6-leaf stage were sprayed with 10 ml of the diethylamine salts at concentrations of 500 p.p.m. After seven weeks, the plants in all series were affected to some degree: the MCPB and 2,4-DB series showed growth effects similar but rather less marked than those caused by the acetic homologues except at the rhizome apices, which were all markedly contorted, showing effects as great as under treatment with the phenoxyacetic compounds. Plants of the 4-CPB series showed marked pinnule reduction and contortions of stem and rachis; but the elongation of the rhizome was markedly greater than in the 4-CPA series. Probably the least effect on above ground was shown by plants in the 2,4,5-TB series: when dug up, these plants showed quite extensive rhizome development (in marked contrast to the stem inhibition resulting from treatment with 2,4,5-T), but the tips of the rhizome branches were again markedly coiled and contorted and were in a dormant condition.

Table 4

Analyses of young bracken plants after treatment with MCPB, 2,4-DB, 2,4,5-TB, and 4-CPB (at the concentration of 500 p.p.m. of the diethylamine salt)

| Form of plants 7 weeks after treatment (means of 4 plants) | Control | MCPB | 2,4-DB | 2,4,5-TB | 4-CPB |
|---|---|---|---|---|---|
| No. of fronds | | | | | |
| (a) active | 9 | 5 | 5 | 9 | 12 |
| (b) moribund or dead | 1 | 2 | 2 | 3 | 3 |
| No. of frond-buds | | | | | |
| (a) active | 14 | 8 | 17 | 17 | 6 |
| (b) dormant | 0 | 0 | 2 | 1 | 0 |
| Length of rhizome developed (cm) | 34.0 | 32.9 | 31.0 | 27.4 | 25.9 |

Conclusions. Thus the butyric compounds can induce systemic effects on young plants of bracken, and these seem to be mainly displayed in differentiating apical tissues. This suggests either that the butyric compounds undergo a $\beta$-oxidation in active apical tissues, or that they stimulate the development of natural hormones which cause curvaturss and contortions in young organs.

These experiments all suggest that the young developing rhizome of bracken is an organ which can be markedly affected by translocated chemical substances. Probably the morphological effect of most interest in the present tests is the restricted rhizome development which appears to be a feature of treatment with 2,4,5-T and 4-CPA, and the correspondingly marked internodal elongation on the rhizomes of plants treated with 2,4,5-TB. Since the underground stem is the main focus of any attack on the bracken plant, further information as to the behaviour of these translocated herbicides in relation to the development of the rhizome would be of the greatest interest: we know nothing of the path of their movement into the rhizome, the rate or place of their breakdown (if any) or their effect on the starch metabolism.

## Chemical treatment of field bracken

### 1. Foliar applications

#### (a) Ammonium sulphamate

Experiment. A limited amount of ammonium sulphamate was available in 1955, and four plots, each of 4 x 8 yd, were laid out and treated with ammonium sulphamate at the following rates: (a) 150 lb/ac applied as a split application in July and August; (b) 75 lb/ac applied in July; and (c) 75 lb/ac applied only in August. Treatment was made during a spell of bright weather and no rain fell for some weeks.

Experimental results. Three days after the first spraying in July, the treated plots could be detected by eye from more than 200 yd away. The fronds were brown and seemed to be dying off very quickly. Four weeks after treatment, the July-treated plots showed more than 90% kill of the fronds. New fronds replaced the dead ones only slowly; and by the middle of August there were 6 young fronds on one plot and 20 on the other. On September 26th, rhizome samples were taken from unit areas of 1 sq. ft and they were examined for the state of the frond-buds, the state of the rhizome apices and the dry weight of the rhizome from the unit area. No clear evidence could be obtained of any difference between the rhizome of the control or the treated plots. At that time, the fronds on all the treated plots were shrivelled, quite brown and completely dead. On the control plots at the same time, fronds were still green and vigorous and showed a good deal of soral maturation. The plot with split application and the August-treated plot carried 100% dead fronds; the plot treated in July only had 6 small, green fronds among the dead ones.

In August 1956, the three plots were again treated, this time with ammonium sulphamate at the rate of 35 lb/ac. Again the fronds were quickly killed; but rhizome samples taken in mid-September showed no significant differences from the control samples.

In field bracken, then, there are no signs of translocation of ammonium sulphamate, and the compound does not appear to attack the deep-seated rhizomes of mature field bracken. The effect on the plant of the rapid killing off of the fronds would be similar to one year's cutting treatment, though the extent of the frond removal was probably more efficient than any which could be obtained by cutting or bruising machines.

(b) MCPB (sodium)

Experiment. Plots of 4 x 2 yd were laid out and treatments replicated three times. MCPB was applied at rates of 2 lb, 4 lb and 8 lb/ac a.e. on June 29th, 1956 during a period of bright weather which was followed by light rain 10 hours later. At the time of spraying, the bracken fronds were not fully expanded: in most cases, the upper 5-6 pinnae were still to unfurl.

Experimental results. Two weeks after treatment, those fronds which were partially unfurled at the time of treatment all showed typical growth-regulating effects - i.e. reduction of lamina in the pinnule segments, epinastic curvatures of the rachis and general brittleness of the fronds. These effects were most marked on plots which received the highest rates of treatment, 8 lb/ac a.e. Four weeks after treatment, the affected fronds were still green, but they seemed to be more easily detached and pulled out of the ground than is usual in untreated bracken. In September, unit samples of the rhizomes were dug up and analysed in the same way as the ammonium sulphamate samples. No differences from the control samples could be found.

Thus, there appears to be no evidence of any translocation of the butyric compound into the rhizome of field bracken; and this is true of other tests with growth-regulating compounds on field bracken (22). The compounds are able to effect reactions in the tissues of the fronds, but there are no signs that these compounds can pass out of the fronds; nor have we any evidence of the site of the breakdown of the butyric compounds - if, in fact, such breakdown does occur in the fronds.

(c) Amino-triazole.

Experiment. In an experiment similar in design to that of MCPB, amino-triazole was tested alone and in combination with 2,4,5-T (ester). The compound was used at the rates of (a) 10 lb, 20 lb and 40 lb/ac when alone; and (b) in combination at rates of 5 lb amino-triazole + 2,4,5-T (ester) at 1 lb/ac a.e. and 5 lb amino-triazole + 2,4,5-T (ester) at 2 lb/ac a.e.

Experimental results. Treatment was given on June 29th, 1956, and early in August all the plots were covered with dead fronds. No chlorosis was observed on the bracken fronds on the plots, but chlorotic fronds were found in the areas bordering the experimental quadrats: this effect may have been caused by drift of the amino-triazole during treatment. There was little visual difference between plots which had received amino-triazole alone or in combination with 2,4,5-T; and analysis of the rhizome in mid-September gave no marked differences from the controls for any of the treated samples. Chlorosis and stunted growth was marked on the following angiospermic species which were found in September, on the plots which had been treated with amino-triazole alone: creeping soft grass (Holcus mollis); creeping bent (Agrostis stolonifera); greater woodrush (Luzula sylvatica); violet (Viola canina) and sneezewort (Achillea ptarmica).

Thus, at the rates used, amino-triazole, alone or in mixtures with 2,4,5-T, gives no evidence of action on the underground stem of bracken: the effects appear to be restricted to destruction of the fronds.

(d) Maleic Hydrazide

In an experiment similar in set-up to that of ammonium sulphamate, one treatment of a 40% wettable powder formulation of MH was applied to field bracken at a rate of 15 lb/ac. Treatment was given on June 29th, 1956, and a few days afterwards, signs of slight scorching were seen on some of the fronds. This did not increase, however, and at harvesting in mid-September, no effects could be seen either on fronds or rhizome.

2. Soil applications

Experiment. A series of plots, each 4 x 2 yd and replicated three times, were treated with the following compounds: (a) ammonium sulphamate at 75 lb/ac; (b) TCA (sodium) at 75 lb/ac; (c) amino-triazole at 20 lb/ac; (d) MH at 15 lb/ac, and (e) monuron at 60 lb/ac. Treatment was applied directly on to the soil in the spring before any of the bracken fronds were showing above ground. All treatments were made on April 24th, 1956 except monuron, which was applied on May 6th. In each case, the area was lightly burned before treatment in order to remove dead bracken litter of the previous year.

Experimental results. (a) Ammonium sulphamate. Twelve weeks after treatment, the plots carried green fronds; but these were sparse, and the frond density almost 50% less than on the control plots. This may be explained by the fact that the first developing frond-buds appeared to have been killed by the early treatment. Their replacement, however, appeared to be very much less than would happen if the first formed fronds are removed by cutting (8). Even with this visible decrease in the number of fronds developed, no effects could be traced in the rhizome samples taken in September from the treated plots, and there was no increase in the amount of dead tissue resulting from one year's treatment. It will, however, be desirable to check through a second or third season to see if any accumulated effects become visible later.

(b) Amino-triazole. Chlorosis was first noticeable on the creeping soft grass present on the plots; later, a few of the developing bracken fronds also showed chlorosis. It is worthy of comment, however, that this effect was observed only on fronds growing out from patches of grass: and on one replicate where the soil was bare, the emerging bracken fronds showed no chlorosis. It is possible that an explanation for this lies in the rate of leaching or break-down of amino-triazole in bare soil. Analysis of the rhizomes from these plots in September showed no difference from the controls.

(c) Trichloroacetic acid. Three weeks after treatment, the pinnules of developing fronds appeared to droop, and they had an appearance of slight plasmolysis. Later in the summer, the fronds all appeared quite normal, and rhizome analysis showed no variation from the controls. The creeping soft grass on the plots, however, was severely scorched.

(d) Monuron. As the fronds on these plots came through the soil, they showed signs of slight scorching; but by the end of July, these symptoms had been overcome, and no further effects were visible. The rhizomes were unaffected when analysed in September.

Since monuron is regarded as a persistent herbicide, the results of one year's treatment cannot necessarily be regarded as conclusive. It seems just possible that the monuron was inactivated owing to the thick top organic layer (17) which is present on the soil of Drumclog Moor.

## General conclusions

Two seasons' testing of the effects of chemical herbicides on bracken suggests:

(1) that young, actively growing plants of bracken are readily affected by translocated chemical substances, and that these can produce marked systemic effects on the underground stem when applied to the fronds. Among the characteristic effects produced, dormancy of the apex of the branches of the rhizome is frequent; but the effects are seldom lethal.

(2) that in mature plants of field bracken there is no evidence of any translocation of compounds beyond the organ to which the herbicide is applied.

(3) that ammonium sulphamate and amino-triazole readily kill the fronds of mature field bracken, but no effect has been observed on the underground stem. Such a contact frond removal is similar to defoliation by cutting or thorough crushing.

(4) that springtime soil applications of ammonium sulphamate act directly as contact agents on young developing fronds; but there is no evidence in one season that such treatment is directly effective on the rhizome. Effects may be cumulative; but even so, there is little to suggest that they will be drastic.

Thus, it must be said once again that the deep-seated underground stem of mature bracken in the field, with its large storage reserves, is an extremely well-protected organ, and one whose point of vulnerability is difficult to find. As our appreciation of the form and behaviour of the plant increases, so does our realisation of its impregnability. That any effective attack must be made on the underground stem is a point which cannot be too strongly emphasised; but at the moment we have no evidence that, with the compounds tested, chemical treatment can be any more effective in checking the plant than the more usual methods of cutting or thorough crushing. It may be that the chemical herbicides in such general use against angiospermic plants are not useful agents of attack on such a well protected organ as the underground stem of the bracken fern. If so, it becomes essential that we should look for further information on the functioning of the rhizome, on the mode of starch metabolism and on the paths and centres of break-down of substances which can move into and through such a storage organ as the bracken rhizome.

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DISCUSSION ON THE PREVIOUS TWO PAPERS

Mr. R. J. Chancellor

If you kill out the bracken what comes in afterwards? That seems to be one of the basic problems, in the bracken areas of Wales for example.

Mr. J. R. Forrest

In plots cut three years ago there was nothing below the bracken at all and now creeping soft grass and bent, and in some cases native grasses are coming in and establishing themselves. These plots were not treated at all apart from the cutting treatment.

Mr. R. W. Shorrock

Have Miss Conway and Mr. Forrest tried the combination of mechanical bruising of the bracken with chemical treatment? I know that would not help in places where you could not use a machine but it might quicken up the process on land where you can. Secondly, there have been reports in the press of what appear to be very promising results from chemicals supplied by American Chemical Paint. I wonder if they could tell us anything about that?

Mr. J. R. Forrest

We haven't tried combinations of cutting and chemical control. As regards the second question I was as much in the dark as many other people. All I know is that one of the chemicals used was amino-triazole. I don't know about the other two.

Dr. E. Åberg

Have you used dalapon? In Sweden we have found that dalapon is effective against even *Equisetum arvense* when applied at 25 lb/ac. Possibly it could also be useful against bracken.

Mr. J. R. Forrest

We have not tried dalapon but I hope to be getting some to try next year.

Mr. L. Jones

I would suggest that the resistance of bracken may be due to antiseptic substances in the fronds. This part of the plant seldom shows signs of disease. Perhaps chemical research could give us leads to control.

Dr. E. Conway

I would like to support those remarks. I think chemical investigations are much needed, and I would welcome far more biochemical research on the bracken plant.

It was Copisarow who suggested in 1945 (1) that there were antiseptic substance in bracken fronds. We have always had that suspicion, but so far no one has been able to isolate an actual substance. But even if there are special

(1) Copisarow, M. (1945) .. Gardners' Chronicle, Feb. 10th 1945.

glucosides or other such substances in the fronds, I do not think that the fronds are the real target for attack. There have been, and I am sure will continue to be, numbers of reports in the press of what are spoken of as "promising substances", but the effects so produced are on the fronds, and we maintain that it is the underground stem which must be more directly attacked. We would much welcome more analyses (particularly chemical) of the state of the underground stem. Mr. Forrest did not tell you of the innumerable samples which have been taken by digging up rhizomes; and anyone who has tried this will know what it means to dig up a square yard of bracken! We have made a large number of such analyses after using chemical substances; and although we can find effects on the fronds, we cannot find those effects on the rhizomes. For instance, as Mr. Forrest said, after two years of putting ammonium sulphamate on to marked plots the rhizome showed no perceptible difference from untreated controls, even though the fronds were rapidly killed each year.

# THE CHEMICAL CONTROL OF GRASSES IN LUCERNE

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and

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## Summary

Three experiments are described. The first was designed to compare five chemicals for control of seedling grasses in a newly sown ley of lucerne and meadow fescue: CDEA, CDEC and propham were applied before seedlings emerged, and dalapon and 2,2,3-trichloropropionate six weeks after the lucerne appeared. In the second experiment dalapon was applied in June to an established crop of lucerne infested with perennial weed-grasses; and in the third, dalapon was applied in November, early February and late March to similar grasses on land which had remained uncultivated for three years. For seedling grass control propham was applied at 2, 4 and 6 lb and other chemicals at 3, 6 and 12 lb/ac. In the second and third experiments dalapon was applied at 7.5, 15 and 30 lb/ac.

### Seedling grasses in seedling lucerne

1. Initially, all chemicals except 2,2,3-trichloropropionate gave some control of *Poa* seedlings. CDEA had little effect on meadow fescue. While propham was less toxic to the sown grass than CDEC, its effect on later germination of *Poa spp.* was greater: it is concluded that propham becomes active more slowly than CDEC.

2. Dalapon was the most toxic chemical to all seedling grasses. It alone gave complete control of sown grass (at 6 lb/ac) and its effect on *Poa spp.*, like that of propham, was sustained into the first harvest year.

3. None of the pre-emergence sprays affected growth of lucerne, while dalapon and 2,2,3-trichloropropionate caused considerable damage. However, lucerne made a reasonable recovery in the first harvest year after treatment with dalapon at 6 lb/ac.

### Perennial weed-grasses in established lucerne

1. *Agrostis gigantea* and *Poa trivialis* were effectively suppressed by dalapon at 7.5 lb/ac. Eleven months after spraying, when perennial grasses contributed 19% of yield in control plots, they contributed less than 2% on plots treated with 7.5 lb/ac, and less than 0.5% at 15 and 30 lb/ac.

2. In spite of some immediate damage caused by spraying lucerne when it was 12 in. high, yield of lucerne in the following year was not significantly reduced by dalapon applied at 15 lb/ac.

Perennial weed-grasses: winter treatment

1. Agrostis gigantea and Poa trivialis were severely checked by dalapon at all rates and at all dates, but in the absence of a crop (or of further treatment, e.g. cultivation) the Agrostis made some recovery on all plots. In August, its recovery was almost complete in plots sprayed in November with dalapon at 7.5 lb/ac, but the grass was very weak after treatment with 15 lb in February or 7.5 lb in March.

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## Introduction

Since the beginning of large scale chemical weed control, research on compounds having toxicity to grass weeds has always lagged behind the development of broad leaved plant killers. Until recently no really promising general grass killer has been available to research workers, but in the last few years a number of new compounds have been discovered which show promise in this direction. One chemical in particular, called dalapon, has been reported from America as being a powerful grass killer and possibly useful for selective weed control in lucerne. Other compounds, the chloro-acetamides, have so far had little research work carried out on them, while the phenyl carbamates have been available to research workers for some years and are known to have herbicidal properties towards young seedling grasses.

In view of the general need for efficient and economic grass week killers in arable and ley farming, the ARC Unit of Experimental Agronomy and The Grassland Research Institute agreed to carry out a co-operative investigation of the most promising compounds, paying particular attention to dalapon because of the encouraging reports from America.

The first stages in the investigation, the results of which are reported here, were to compare a number of chemicals in controlling seedling grasses in seedling lucerne, and to study the effectiveness of dalapon in controlling grass weeds in established lucerne.

### Experiment 1

This experiment was sited in a field which had been in annual crops for many years. The soil was a flinty loam overlying chalk. A mixture of 16 lb lucerne and 5 lb meadow fescue per acre was drilled on 19 April 1955. Five chemicals were compared, all at three rates, for control of seedling grasses, including the sown grass. Treatments were arranged in three randomised blocks, with three control plots per block.

Chemicals

Abbreviation

CDEA - Chloro-N,N-diethyl acetamide as an emulsifiable concentrate diluted in water.

CDEC - 2-chloroallyl diethyldithio carbamate as an emulsifiable concentrate diluted in water.

Propham - Isopropyl-n-phenyl carbamate as a solution in diesel oil.

Dalapon - 2,2-dichloropropionic acid as the sodium salt in water.

2,2,3-trichloropropionic acid: the technical sodium salt as a solution in water.

All treatments were applied by "Oxford" Precision Sprayer at 40 gal/ac.

Treatments

Pre-emergence spraying on 29 April 1955 with:
CDEA at 3, 6 and 12 lb/ac
CDEC at 3, 6 and 12 lb/ac
Propham at 2, 4 and 6 lb/ac

Post-emergence spraying on 16 June 1955 with:
Dalapon at 3, 6 and 12 lb/ac
2,2,3-trichloropropionate at 3, 6 and 12 lb/ac

Assessments

Frequency of meadow fescue and _Poa_ spp. following pre-emergence treatments was recorded on 17 June, and following post-emergence treatments on 20 October (forty 6 in. quadrats per plot). Further estimates were made on 28 March 1956 (forty 3 in. quadrats per plot). Seedling counts of lucerne in 1955 were followed by counts of shoot numbers in April 1956. These data are all given in Table 1.

The crop was grazed in August 1955 and cut on 21 June 1956. Yields were recorded in 1956, and samples separated into constituent species. An analysis of the crop is given in Table 2.

Results

Dalapon virtually eliminated meadow fescue at the 6 lb rate, and reduced its contribution by about 80% at the 3 lb rate. CDEC also reduced the establishment of meadow fescue at all rates, but not so markedly as dalapon. Slight reductions followed treatment with propham at 4 and 6 lb, and with CDEA at 12 lb. 2,2,3-Trichloropropionate had no effect on meadow fescue.

All chemicals except 2,2,3-trichloropropionate gave partial control of _Poa_ seedlings, dalapon again being the most effective. While the trend of the results suggested that the effect increased with dose, the increase was not proportional. There was nothing approaching complete control of _Poa_ species. However, dalapon, and to a smaller extent propham, reduced the vigour of _Poa_ throughout the seeding year. Recovery of _Poa_ species early in the first harvest year was poor in plots sprayed with dalapon at 6 and 12 lb/ac, despite the fact that lucerne was less dense in these plots than in any other. The effect on _Poa_ of propham at the higher rates was also sustained, but this was probably because the lucerne remained vigorous and unaffected by this chemical.

Pre-emergence treatments did not cause any visible damage to lucerne plants. In contrast, post-emergence spraying with dalapon at 12 lb/ac caused severe scorching of lucerne; at 6 lb scorching was less severe, and at 3 lb it was slight. 2,2,3-Trichloropropionate had no visible effect at 3 lb and at 12 lb it was equivalent to dalapon at 6 lb/ac. The effect of post-emergence sprays on lucerne became more pronounced as the season advanced; by late

September the plants were stunted, and there was distortion and withering of the shoot tips, which was very severe at the 12 lb rate of dalapon. Later still, while lucerne in other plots bore green shoots, it appeared to be dead in the 12 lb dalapon plots. However, a large proportion of the plants slowly recovered in 1956.

A count of lucerne shoots on 6 April 1956 (Table 1) showed that only dalapon at 6 and 12 lb and 2,2,3-trichloropropionate at 12 lb had reduced numbers. From an analysis of the crop cut on 21 June 1956 (Table 2) it was evident that dalapon had caused a serious reduction in yield of lucerne at the 12 lb rate, but there was a very small reduction at the 6 lb rate and no reduction at the 3 lb rate. There was, however, a reduction in yield of lucerne at all rates of 2,2,3-trichloropropionate. Since there was no longer any sign of stunting in lucerne on the 2,2,3-trichloropropionate plots, its recovery from the earlier damage was probably hindered by the high proportion of meadow fescue and other grasses on these plots compared with dalapon plots.

The presence of couch-grass (Agropyron repens) in patches of the experimental area enabled a crude visual comparison to be made of the effectiveness of the chemicals in controlling it. After treatment with 6 or 12 lb dalapon there were virtually no green shoots left on couch-grass by the end of September 1955. 3 lb of dalapon caused some reduction, and 12 lb of 2,2,3-trichloropropionate had a similar effect. There was recovery of couch-grass in 1956, but it was weak on plots treated with dalapon at 12 lb/ac. Pre-emergence treatments had no effect on couch-grass.

## Experiment 2

A crop of lucerne in its second harvest year was chosen for this experiment because, sown alone on old arable land in drills 2 ft apart, it had become badly infested with Agrostis gigantea and Poa trivialis. It afforded an opportunity to study the effects of dalapon on both the lucerne and the perennial weed-grasses. The soil was a clay loam with flints. A. gigantea (A. nigra, or red-top) is a rhizomatous species. It is a common and often pernicious weed of arable land especially in the South and East of England. It is often known in the vernacular as couch-grass, by confusion with Agropyron repens.

### Treatments

The crop was mown in late May and plots 28 ft x 9 ft sprayed on 20 June 1955 with dalapon at 7.5, 15 and 30 lb/ac in 48 gal water. Three randomised blocks, including control plots, were established.

### Assessments

As an adjunct to visual observations, counts of shoots, or groups of shoots, of Agrostis were recorded in sprayed plots. Later on, frequency of Agrostis was estimated. The crop was mown on 22 July and grazed in September 1955, and mown twice in 1956. Yields of mown crop were recorded and samples separated into botanical components. Analyses are given in Table 3 and 4.

Results

The lucerne was about 12 in. high when sprayed on 20 June 1955. The foliage was rapidly scorched by dalapon at all rates. With progressive desiccation the crop turned brown and there was considerable loss of leaf. The grass species present between the lucerne drills (mainly *Agrostis gigantea* with some *Poa trivialis* and *Bromus mollis*) were similarly affected by the spray. The crop was cut, and samples analysed, on 22 July 1955 (Table 3). The loss of fresh weight in lucerne, largely due to desiccation, was related to the dose-rate of dalapon. All levels of dalapon reduced the amount of fresh grass by over 94%. Recovery of lucerne after the July cut appeared to be quite normal in all plots. The area was grazed early in September, and again the rate of recovery in lucerne was similar in all plots. In early November the area between the drills in all sprayed plots was almost completely bare, in striking contrast to control plots. A count of small islands of *Agrostis gigantea* (some consisting only of one or two shoots) surviving on 27 November gave 35 per plot at 7.5 lb, 17 at 15 lb, and 12 at the 30 lb rate. At this time control plots carried a very dense and uniform stand of *Agrostis* and *Poa trivialis*.

On 6 April 1956 there was a continuous cover of *Agrostis* with a little *Poa trivialis* on control plots. On the treated plots *Agrostis* was present in occasional, small groups. A frequency estimation (forty 12 in. quadrats per plot) gave 32% *Agrostis* present in plots treated with dalapon at 7.5 lb/ac, and 16% at the two higher rates. At this time bare ground in treated plots was rapidly being colonised by seedling grasses, mainly *Poa annua*: by 6 April there was a 40% ground cover between drills.

Recovery of lucerne in the spring of 1956 was apparently normal except in plots treated with dalapon at 15 and 30 lb/ac, where it was slightly less dense and did not grow as tall as in other plots. This observation was confirmed when the crop cut on 31 May was analysed (Table 4). While the yield of lucerne following dalapon at 7.5 lb was consistently higher than the yield in control plots (where lucerne had still to compete with dense grass), it was equal to control following the 15 lb treatment, and slightly below control following the 30 lb treatment. A similar trend was found in the aftermath, which was cut on 25 July 1956 (Table 4).

From the crop cut in May it was evident that there had been a very effective control of *Agrostis gigantea* at all levels of dalapon. The amount present was only 8% of that in control plots at the 7.5 lb rate and a mere trace at 15 and 30 lb. *Agrostis* recovered very slightly between the first and second cut in 1956, but in July, more than a year after spraying with 15 or 30 lb of dalapon, it had still made less than 5% of the growth of *Agrostis* measured in control plots: following the 7.5 lb treatment it had reached about 20%. Over the season as a whole *Agrostis gigantea* and *Poa trivialis* contributed about a quarter of the total yield in unsprayed plots, while the *Poa annua* and other weeds which took their place in treated plots contributed less than one tenth of the total yield in those plots.

Experiment 3

An area of old arable land which had been allowed to tumble down to native grasses in 1952 was used in the winter of 1955-6 to compare the effect of dalapon at different dates and rates on these grasses. The major species were again *Agrostis gigantea* and *Poa trivialis*.

Treatments

Dalapon was sprayed at 7.5, 15 and 30 lb in water at 100 gal/ac, on 18 November 1955, 7 February 1956 and 27 March 1956. There were three randomised blocks, each containing two control plots.

Results

When the first plots were sprayed in November 1955 there was a dense cover made up almost entirely of Agrostis gigantea and Poa trivialis in the proportions 3 to 1. Three weeks later the herbage on sprayed plots was yellow. It gradually turned brown, although fresh shoots continued to appear from some time. Later in the winter these green shoots also withered, and the mat of dead herbage collapsed and slowly rotted. The plots sprayed early in February and those sprayed late in March also reacted slowly, but two months after spraying there was little trace of live grass at any level. In May, all sprayed plots were characterised by an abundance of broad-leaved weeds.

Some recovery of Agrostis gigantea occurred in all sprayed plots in 1956, starting in June in the November-sprayed plots and later in plots sprayed in February or March. An assessment was made on 20 August (Table 5). Agrostis was only slightly less vigorous after November spraying at 7.5 or 15 lb/ac than in controls: at 30 lb it was weaker, though well distributed. In plots sprayed in February or March, Agrostis was much less dense. However, scattered small shoots had begun to reappear even in plots treated in March with dalapon at 30 lb/ac. In contrast to control plots, sprayed plots carried very little Poa trivialis.

## Discussion

In the first experiment all chemicals applied before seedling emergence gave an initial, partial control of Poa. Of these chemicals, propham alone effected later recovery of the Poa population. CDEC gave the greater reduction of meadow fescue for a given dose. Since most of the plants of meadow fescue germinated soon after sowing, and since Poa seedlings appeared throughout the year, it may be inferred CDEC and propham were roughly equal in toxicity, but that CDEC acted and disappeared more rapidly than propham. CDEA, which was toxic to meadow fescue at the 12 lb rate only, also failed to check later germination of Poa, and in respect of persistency it was probably similar to CDEC. In no plots was the population of Poa sufficient to have much effect on the development of lucerne. However, a serious infestation of susceptible weed grasses could usefully be checked by any of the three chemicals at say 3 to 6 lb/ac without damage, and probably with benefit, to a newly sown lucerne crop. Because of its persistence, propham would probably be the most suitable of the three.

2,2,3-Trichloropropionate appeared to be ineffective against seedling grasses, and caused some damage to the crop when applied after the lucerne seedlings had emerged. Dalapon, also applied after emergence, gave the nearest approach to complete and prolonged control of seedling grasses: at 6 lb/ac it caused no permanent damage to the crop, and at a rate of application of this order it, too, would be useful in cases of serious infestation. Its effect on meadow fescue and Agropyron, and, in the other experiments, on Agrostis gigantea and Poa trivialis, suggests that it would have a greater range of usefulness than propham.

It was apparent from the second experiment that dalapon would effectively control Agrostis gigantea in an established lucerne crop, at rates between 7.5 and 15 lb/ac. Although this treatment was followed by a reduction in yield of lucerne in 1956, this reduction is not thought to be any greater than the effect of a cut taken at the time of spraying. The interval between first and second cuts in 1955 was about 8 weeks. Defoliation caused by spraying had virtually the same effect as an extra cut interposed between them. There is evidence (1) that when lucerne is cut at intervals of 4 weeks early in the year, the consequent reduction in vigour does not become apparent until the crop has over-wintered. It is possible that, had the crop been sprayed immediately after being cut in May 1955, there would have been no reduction in yield of lucerne in 1956.

The alternative of spraying the grasses when the lucerne is dormant, when it is least likely to be affected by defoliation, was tested in the third experiment. The most interesting feature of both experiments was that Agrostis gigantea was much weakened by foliar application of dalapon at all rates, although it was not quite eliminated at 30 lb/ac. Together with Poa trivialis, a more common pest in lucerne crops, it was severely depressed for many months.

The results of Experiment 3 indicate that dalapon will not give permanent freedom from Agrostis in the absence of a crop. However, under a vigorous crop of lucerne in Experiment 2 the grass had made very little recovery a year after treatment.

The measured effect of dalapon on Agrostis gigantea, and the observed effect on Agropyron repens, suggest that there is a good prospect of controlling either of these two strongly rhizomatous perennial grass weeds of arable land while growing a productive crop like lucerne.

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Table 1. Experiment 1. Effect of pre-emergence and post-emergence sprays on seedling grasses and lucerne

| Assessment | Species | Control | CDEA lb/ac | | | CDEC lb/ac | | | Propham lb/ac | | | Dalapon lb/ac | | | 2,2,3-trichloropropionate lt/ac | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 3 | 6 | 12 | 3 | 6 | 12 | 2 | 4 | 6 | 3 | 6 | 12 | 3 | 6 | 12 |
| 13 June 1955 Plants per 6 in. quadrat | Lucerne | 7.9 | 7.8 | 8.3 | 7.0 | 8.7 | 8.5 | 8.9 | 9.2 | 9.9 | 10.7 | - | - | - | - | - | - |
| 17 June 1955 % frequency 6 in. quadrat | Meadow fescue | 88 | 88 | 86 | 78 | 46 | 28 | 26 | 76 | 71 | 54 | - | - | - | - | - | - |
| | Poa species | 69 | 48 | 40 | 33 | 44 | 34 | 33 | 33 | 23 | 27 | - | - | - | - | - | - |
| 20 October 1955 % frequency 6 in. quadrat | Meadow fescue | 96 | - | - | - | - | - | - | - | - | - | 43 | 12 | 5 | 97 | 91 | 86 |
| | Poa species | 58 | - | - | - | - | - | - | - | - | - | 15 | 18 | 10 | 66 | 48 | 56 |
| 28 March 1956 % frequency 6 in. quadrat | Meadow fescue | 74 | 72 | 69 | 55 | 38 | 18 | 18 | 73 | 47 | 42 | 16 | 0 | 2 | 72 | 78 | 61 |
| | Poa species | 48 | 43 | 39 | 39 | 44 | 38 | 39 | 33 | 18 | 28 | 28 | 19 | 8 | 53 | 30 | 42 |
| 6 April 1956 Shoots per 6 in. quadrat | Lucerne | 4.1 | - | - | 4.2 | - | - | 5.0 | - | - | 5.0 | 4.4 | 1.5 | 0.2 | - | - | 2.0 |

Table 2. Experiment 1. Analysis of crop cut on 21 June 1956: fresh weight, lb per sample 36 ft x 3 ft

| Chemical lb/ac | | Lucerne | Meadow fescue | Other grasses | Other species | Total |
|---|---|---|---|---|---|---|
| Control | | 20.6 | 8.3 | 6.5 | 0.6 | 36.0 |
| CDEA | 3 | 21.9 | 12.6 | 3.4 | 0.4 | 38.3 |
| | 6 | 22.6 | 12.6 | 2.7 | 0.4 | 38.3 |
| | 12 | 26.2 | 9.3 | 2.8 | 2.0 | 40.3 |
| CDEC | 3 | 25.3 | 7.0 | 3.7 | 0.7 | 36.7 |
| | 6 | 24.3 | 1.1 | 9.8 | 1.1 | 36.3 |
| | 12 | 23.8 | 0.7 | 8.3 | 0.3 | 33.1 |
| Propham | 2 | 25.0 | 4.0 | 7.0 | 0.7 | 36.7 |
| | 4 | 21.8 | 5.4 | 6.1 | 0.7 | 34.0 |
| | 6 | 29.4 | 4.3 | 4.6 | 0.4 | 38.7 |
| Dalapon | 3 | 23.3 | 1.6 | 4.9 | 2.9 | 32.7 |
| | 6 | 17.3 | tr | 3.8 | 2.6 | 23.7 |
| | 12 | 8.4 | - | 1.8 | 2.5 | 12.7 |
| 2,2,3-Trichloropropionate | 3 | 16.2 | 10.9 | 5.6 | 0.3 | 33.0 |
| | 6 | 14.6 | 14.9 | 6.3 | 1.5 | 37.3 |
| | 12 | 9.7 | 7.3 | 6.6 | 0.7 | 24.3 |

Table 3. Experiment 2. Analysis of crop cut on 22 July 1955, a month after spraying: fresh weight, lb per sample 28 ft x 3 ft

| Dalapon lb/ac | Lucerne | Green grass | Dead grass | Other species | Total |
|---|---|---|---|---|---|
| 0 | 14.1 | 3.5 | - | 1.7 | 19.3 |
| 7.5 | 7.9 | 0.2 | 0.4 | 0.6 | 9.1 |
| 15.0 | 5.2 | 0.1 | 0.4 | tr | 5.7 |
| 30.0 | 3.8 | tr | 0.4 | tr | 4.2 |

Table 4. Experiment 2. Analysis of crops cut in 1956: fresh weight, lb per sample 28 ft x 3 ft

| Date of cut | Dalapon lb/ac | Lucerne | Agrostis gigantea | Other grasses * | Other species | Total |
|---|---|---|---|---|---|---|
| 31-5-56 | 0 | 14.4 | 3.9 | 2.0 | tr | 20.3 |
| | 7.5 | 15.8 | 0.3 | 0.8 | 0.4 | 17.3 |
| | 15 | 13.0 | tr | 0.7 | 0.3 | 14.0 |
| | 30 | 11.2 | tr | 0.5 | 0.3 | 12.0 |
| 25-7-56 | 0 | 16.0 | 2.6 | 0.2 | 0.3 | 19.1 |
| | 7.5 | 18.1 | 0.5 | 1.0 | 1.0 | 20.6 |
| | 15 | 15.7 | 0.1 | 0.7 | 1.1 | 17.6 |
| | 30 | 13.6 | 0.1 | 0.9 | 0.8 | 15.4 |

* In treated plots the main grass species was Poa annua.

Table 5. Experiment 3. Percentage frequency of Agrostis gigantea in 3-inch quadrats on 20 August 1956

| Dalapon lb/ac | Date of application | | |
|---|---|---|---|
| | 18 Nov. 1955 | 7. Feb. 1956 | 27 Mar. 1956 |
| Control | | (98) | |
| 7.5 | 98 | 56 | 30 |
| 15 | 85 | 38 | 17 |
| 30 | 83 | 16 | 9 |

# CHEMICAL CONTROL OF COUCH GRASS IN FALLOWS

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## Summary

The control of couch grass foliage (Agropyron repens and Agrostis gigantea) in unploughed land, or as regrowth after ploughing, by dalapon applied in the autumn of 1955 was in excess of 90%. Dalapon proved superior to TCA (sodium), amino triazole and maleic hydrazide at comparable amounts of active chemical. Dalapon treatment produced a marked inhibition of rhizome bud development, but no actual death of couch rhizomes was observed.

Dalapon and amino triazole and mixtures of these two chemicals applied in the spring of 1956 to couch grass (Agropyron repens) regrowth after autumn ploughing, gave a control of foliage in excess of 95%. At this time of the year dalapon at 40 lb/ac killed couch rhizomes.

## Introduction

Five large scale trials laid down by Messrs. T. C. Breese and P. F. Le Brocq in the autumn of 1954 showed that TCA (sodium) (sodium trichloroacetate) applied as two doses of 20 lb/ac, each with subsequent cultivations, gave an unsatisfactory control of couch grasses (Agropyron repens, Agrostis gigantea) in autumn and winter fallows. Moveover, cultivations appeared to assist spring regrowth.

The object of the 1955/56 investigation was to compare dalapon, amino triazole and maleic hydrazide with TCA (sodium) for the control of couch grasses, (couch or twitch Agropyron repens, black bent or red top Agrostis gigantea, onion couch Arrhenatherum elatius) in autumn and winter fallows, without affecting the following spring crop.

Two chemicals newly employed for this purpose in the U.S.A. have shown considerable promise. The chemicals are dalapon which is the sodium salt of 2,2-dichloropropionic acid, and amino triazole which is 3-amino-1,2,4-triazole.

It is claimed that both dalapon and amino triazole are absorbed by both leaves and roots of grasses and translocated within the plant. TCA (sodium) on the other hand, is absorbed by the roots and rhizomes of grasses only. Neither of these two new chemicals is very persistent in the soil.

## Experimental Methods and results

### General data on trials, autumn 1955 and spring 1956

Plot size was standardised for all trials at 5 yd x 20 yd. Chemicals were applied in 65 gal/ac of water through a Land Rover-mounted sprayer fitted with a 15 ft spray boom.

### Autumn 1955 trials

Twelve trials, each of four randomised blocks and one trial, three blocks, were laid down during the autumn of 1955. The majority was on uncultivated land infested with couch grasses, the remainder was on couch grass regrowth after cultivations.

All sites remained undisturbed until the following spring as owing to the relatively small scale of these trials it proved impracticable to include post-treatment ploughing.

Treatments were:- TCA (sodium) at 20, 40 and 80 lb/ac of sodium trichloroacetate; dalapon at 10, 20 and 40 lb/ac of sodium 2,2-dichloropropionate; amino triazole at 3, 6 and 12 lb/ac active ingredient (i.e. 3-amino-1,2,4-triazole); maleic hydrazide at 4, 8 and 16 lb/ac; control, unsprayed. However, not all these chemicals were included in any one trial (see Table 1).

### Spring 1956 trials

One trial with two randomised blocks only was laid down on the 25th April, 1956, on couch grass (*Agropyron repens*) regrowth after autumn ploughing.

Treatments were:- dalapon at 20 and 40 lb/ac of sodium 2,2-dichloropropionate; amino triazole at 6 and 12 lb/ac of 3-amino-1,2,4-triazole; dalapon/amino triazole mixtures at 2.5/2.5, 5/5, 10/10 and 20/12 lb/ac; control, unsprayed.

### Methods of assessment

1. An estimation by eye of the cover of couch foliage in a yard quadrat expressed as a percentage. Ten such yard quadrats were taken per plot, five by each observer.

2. A qualitative examination of couch rhizomes, dug up and removed to the laboratory.

### Results of autumn application trials (Table 1)

#### First assessments

These were made from January 30th to March 9th, 1956, at periods after spraying ranging from ten to eighteen weeks post-treatment. The effect of any one treatment was fairly constant on the various couch grass species present, except for onion couch (one trial) which is dealt with separately. For this reason the results from treatment of *Agropyron repens* and *Agrostis gigantea* are taken together under the collective term "couch grass".

Dalapon at 10 lb/ac was more effective in controlling couch foliage than TCA (sodium) at 40 lb/ac and dalapon at 20 lb/ac was as effective as TCA (sodium) at 80 lb/ac. Dalapon here was four times as effective as TCA (sodium), in terms of active chemical. However dalapon at 40 lb/ac was slightly more effective than TCA (sodium) at 80 lb/ac; dalapon here was only twice as effective as TCA (sodium), in terms of active chemical.

The control of couch foliage by amino triazole at 12 lb/ac was slightly superior to dalapon at 10 lb/ac and as effective as dalapon at 20 lb/ac.

Amino triazole produced chlorotic shoots on Agrostis spp. and other species, and pink coloured shoots on Agropyron repens and onion couch.

The control of couch foliage by maleic hydrazide was poor at this stage of the trials.

In onion couch the control of foliage by dalapon was striking (99.5 - 100%) and TCA (sodium) was only slightly inferior (94 - 99.5%). The control of onion couch by amino triazole was only fair ranging from 20% at 3 lb to 70% at 12 lb/ac.

Unfortunately the onion couch trial was ploughed shortly after this assessment and no further data on regrowth were obtained.

Second assessments

These were made on the eight remaining unploughed trials from the 21st March to the 26th April, 1956 at periods after treatment ranging from 16 to 27 weeks.

The results showed that dalapon at 10 lb/ac was superior to all rates of TCA (sodium), amino triazole and maleic hydrazide, also that maleic hydrazide was at this stage superior to amino triazole.

Final assessments

Only two trials were left unploughed for these assessments which were made on the 7th May, 1956, 26 weeks post-treatment, and on the 5th June, 1956, 24 weeks post-treatment.

Results show a vast superiority of dalapon over TCA (sodium) and maleic hydrazide at comparable rates of active chemical. Amino triazole, however, 12 lb/ac is only slightly inferior to dalapon at 10 lb/ac.

Assessment of one trial in the following crop of barley

An assessment was made of one trial in the following crop of barley, on the 14th June, 1956, 28 weeks post-treatment. The vast superiority of dalapon at the low rate of 10 lb/ac over all rates of TCA (sodium) and amino triazole was clearly demonstrated. There appeared to be no effect of treatment on the crop.

Examination of rhizomes

Examination of rhimozes at the time of each assessment showed a suppression of bud development by all chemical treatments, especially at their high rates of application.

The inhibition of bud development was particularly striking as a result of dalapon treatment, but no actual death of rhizomes was observed in these autumn trials.

Results of spring application trial

First assessment

Results from the first assessments of this trial, nine weeks after treatment showed that a good control of couch foliage (*Agropyron repens*) was obtained by all treatments.

As in the autumn application trials it was noted that amino triazole treatment produced weak pink shoots of *Agropyron repens*.

Second assessment (final)

The second and final assessment made fourteen weeks post-treatment showed an increase in growth on the untreated plots giving 100% cover. There was an increase in the percentage control of couch foliage by all treatments except dalapon 10 lb + amino triazole 10 lb which remained constant at 97%.

Examination of rhizomes (*Agropyron repens*)

As in the autumn application trials examination of rhizomes showed an inhibition of bud development particularly marked where dalapon was included in the treatment.

Actual death of rhizomes was observed as a result of dalapon treatment at 40 lb/ac.

## Discussion and conclusions

Results showed that an excellent control of the aerial growth of couch grasses and suppression of development of rhizome buds was obtained by an autumn application of dalapon to the foliage. It is claimed that the control is increased by ploughing about one month after treatment, but it was found impracticable to include this treatment in these trials.

In practice dalapon would be applied in the autumn to infestations of couch grasses in unploughed stubble, as soon as possible after harvesting. Autumn ploughing would be delayed for about one month after treatment to allow time for absorption.

Dalapon, therefore, would be easier to apply than TCA (sodium) which is normally applied to exposed couch rhizomes on ploughed land, and as two applications plus cultivations.

Table 1

Autumn 1955 trials on couch grasses

| Site | Assessment | Dates of assessment in 1956 | Weeks post-treatment | Percentage control of couch foliage | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | TCA (sodium) | | | Dalapon | | | Amino triazole | | | Maleic hydrazide | | |
| | | | | 20 | 40 | 80 | 10 | 20 | 40 | 3 | 6 | 12 | 4 | 8 | 16 |
| No cultivations before assessment | First | 30 Jan. to 9 March | 10 - 18 | 69 | 79 | 87 | 83 | 87 | 90 | 72 | 81 | 87 | 32 (3 trials) | 38 (3 trials) | 37 (2 trials) |
| | | | | (7 trials) | | | (13 trials) | | | (7 trials) | | | | | |
| | Second | 21 March to 26 April | 16 - 27 | 52 | 67 | 83 | 93 | 96 | 97 | 49 | 59 | 78 | 71 (3 trials) | 88 (3 trials) | 89 (2 trials) |
| | | | | (4 trials) | | | (8 trials) | | | (4 trials) | | | | | |
| | Third A | 7 May | 26 | 35 | 58 | 81 | 88 | 94 | 94 | 24 | 65 | 86 | - | - | - |
| | Third B | 5 June | 24 | - | - | - | 94 | 94 | 97 | - | - | - | 15 | 59 | 66 |
| Cultivations before assessment | Second C | 14 June | 28 | 46 | 61 | 70 | 82 | 87 | 91 | 58 | 60 | 66 | - | - | - |
| No cultivations before assessment | (one trial on onion couch) | 1 March | 18 | 94 | 94 | 99.5 | 99.5 | 100 | 100 | 20 | 60 | 70 | - | - | - |

TCA (sodium) expressed as lb/ac of sodium trichloroacetate.
Dalapon expressed as lb/ac of sodium 2,2-dichloropropionate.
Amino triazole expressed as lb/ac of 3-amino-1,2,4-triazole.

Note: A = one trial on Agropyron repens     B = one trial on Agrostis gigantea

C = one trial on Agrostis gigantea - assessment following crop of spring barley.

(47011)

Table 2

Spring 1956 trial on couch grass (Agropyron repens)

(laid down 25th April)

| Assessment | Date of Assessment 1956 | Weeks Post-Treatment | Percentage control of couch foliage | | | | | | | | Percentage cover of couch foliage on control plots |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Dalapon | | Amino triazole | | Dalapon + amino triazole mixture | | | | |
| | | | 20 | 40 | 6 | 12 | 2.5 + 2.5 | 5+5 | 10+10 | 20+12 | |
| First | 27th June | 9 | 90 | 94 | 88 | 93 | 81 | 89 | 97 | 97 | 75 |
| Second | 3rd August | 14 | 96 | 98 | 90 | 97 | 87 | 90 | 97 | 98 | 100 |

Dalapon expressed as lb/ac of sodium 2,2-dichloropropionate.
Amino triazole expressed as lb/ac of 3-amino-1,2,4-triazole.

# VALUE OF DALAPON

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## Summary

Dalapon under New Zealand conditions has proved an efficient selective grass killer. Its efficiency is often enhanced by the addition of amino-triazole. It has given poor results when compared with TCA as a pre-emergence chemical and has a shorter residual life in the soil. To date it has given the most effective control of fibrous rooted and stoloniferous rooted grasses and sedges in New Zealand. Dalapon shows particular value as an aid to oversowing and cultivation in low fertility pastures.

A selective grass killer is probably more important initially in New Zealand economy than the equivalent selective broad leaved preparations MCPA and 2,4-D. Dalapon, in the work carried out to date promises to be such a preparation. I propose to deal with the main grass weed control problems in New Zealand and to evaluate the use of dalapon for the problems discussed.

## Crops

Lucerne - Nearly one hundred thousand acres of lucerne were grown for hay and silage last year. More lucerne would be grown if one of the main problems in its maintenance, grass weeds, could be readily controlled. No lucerne is grown in the north of the North Island where summer droughts are frequent, due largely to the presence of paspalum, *Paspalum dilatatum*. Under irrigation in the drier parts of the South Island browntop, *Agrostis tenuis*, and other rhizomatous grasses decrease the value of the stand within 3 or 4 years after sowing. Dalapon applied just before the onset of spring growth has given excellent control of browntop and annual grasses, such as *Poa annua*. Provided the application is made so that one to two days fine weather follows, the lucerne suffers little. Often a rate of 5 lb/ac * is sufficient in young stands and a rate of 5 to 10 lb/ac for older stands. Least damage occurs if the lucerne is completely defoliated before the application of dalapon is made, so that if the grass weeds are not growing before the lucerne breaks dormancy in the spring, a light grazing to defoliate the lucerne before the dalapon is applied is worth while. Application to growing lucerne has caused significant depression even at 5 lb/ac. Damage also occurs if rain washes the dalapon into the root zones of the growing lucerne. Trials have shown, that used in the above manner dalapon has out-yielded cultivation treatments and has many advantages over TCA, the only other satisfactory alternative for grass weed control in this crop.

Orchards - Little work has been done in New Zealand but results to date indicate that provided the dalapon is applied so that several days fine weather follows the application, excellent grass control can be obtained in orchards, base of hedges etc., without damage to the associated plants of value.

## Pastures

Barley grass. *Hordeum murinum*, - This species is damaging to stock, unpalatable, and is increasing rapidly with the buildup of fertility, both on the high productive flats and on the hill country. It is common both to sheep and dairy pastures. Dalapon at 1 to 2 lb/acre kills seedling plants. If the application is followed by several days fine weather oversowing and top dressing can be made at the time of application to arrest further establishment. The above rate has little detrimental effect on established clovers. Rye grasses are slightly checked, and cocksfoot suffers little. Less damage to the ryegrass and cocksfoot occurs if the area is grazed before application. Dalapon is likely to replace TCA for the control of barley grass.

Nassella tussock, *Nassella trichotoma*. - This unpalatable species occupies more than one hundred thousand acres and occurs over two million acres of country. A further area exceeding two hundred thousand acres would probably be infested if no control measures were adopted. Parliament granted one hundred thousand pounds for its control in the financial year 1956-57. This figure is an increase over previous years and is aimed at controlling nucleus areas of this weed.

TCA at rates not under 100 lb/ac * has given complete kills of mature nassella tussock during the hot months of January and February. Dalapon at rates of 20 to 30 lb/ac has given equal control over a much wider period, October to March. The value of dalapon plus 3-amino 1, 2, 4-triazole is still to be determined.

Tall fescue, *Festuca arundinacea* - This species is of low palatability and is troublesome in areas that cannot be cultivated. Mature plants are very resistant to TCA. Rates of 300 lb/ac have been non-effective. Dalapon, particularly in conjunction with amino-triazole, in the ratio of 2 to 1 has proved very effective. A rate of 10 lb dalapon plus 5 lb/ac amino-triazole has given complete kills of mature plants. This rate is non-selective to clovers and other grasses such as rye-grasses and cocksfoot. Rates exceeding 20 lb/ac are required if dalapon is used alone.

Kikuyu, *Pennisetum clandestinum* - This species is widespread in the north of the North Island. It can invade high producing pastures but is particularly troublesome in orchards and waste areas. TCA in conjunction with cultivation has been satisfactory but rates as low as 10 lb dalapon plus 2.5 lb/ac amino-triazole have given excellent control. Dalapon at 20 lb has given satisfactory results.

Sedges, *Carex species* - Five species of native sedges are able to compete with high producing pastures in New Zealand. One species is troublesome in tiled drains in Southland. The areas are naturally wet and when tile drained sedge roots soon fill the tiled drains. These species are not successfully controlled with TCA but can be killed successfully with dalapon 20 lb plus amino-triazole 5 lb/ac. Dalapon at 40 lb/ac has given the same results.

## Turf

Paspalum and fog, *Holcus lanatus* often infest low fertility browntop, chewings fescue, *Festuca rubra var, fallax*, turf. Both species are readily killed with spot applications of dalapon. Amino-triazole improves the efficiency of dalapon for the control of paspalum.

## Aquatic weeds

Reed sweet grass, *Glyceria maxima*, floating sweet grass, *G. fluitans* occur in hundreds of miles of drains that are never free of water. The annual cost of clearing these drains mechanically is high. Both *Glyceria* species can be killed with TCA, monuron etc., but dalapon is the only chemical to date that has controlled these species when growing in water. The smaller growing species, floating sweet grass, has been killed at 10 to 15 lb/ac and the larger growing species, reed sweet grass at rates of 20 to 30 lb/ac. It is not clear to date if the inclusion of amino-triazole is beneficial.

Waste areas

The cheapest method of obtaining weed free areas appears to be to control the existing vegetation with specifics and then apply soil sterilants. To use soil sterilants for killing existing vegetation initially is costly and not satisfactory, e.g. both paspalum and cocksfoot require rates of 60 to 80 lb/ac of monuron for control. The same species can be killed with 10 lb dalapon plus 5 lb/ac amino-triazole. As grasses are the dominant species in waste areas there appears to be a big field for the use of dalapon.

Railway tracks - The continued use of sodium chlorate over the past decade on railway lines in New Zealand has led to a dominance of grass weeds. Dalapon plus amino-triazole appear worth while alternatives in many areas.

Specialised uses

Pasture renovation - There are over thirteen million acres of browntop country in New Zealand and much of this area is too steep to be cultivated. Many of these areas have little clover or if clover is present it is of low purity. Good strains of clovers and higher producing strains of grasses are difficult to introduce. The present practice is to attempt oversowing after hard grazing but the results are often unsatisfactory and the poor strains of clovers if present respond to the heavy topdressing applied. Dalapon at rates of 2.5 to 5 lb/ac has given sufficient control of the browntop to allow clovers, and even high fertility grasses, to be introduced. As all these operations can be done aerially and the rate of clover seeding reduced considerably, this method appears to have great promise. The best results have been obtained where the dalapon has been applied about two weeks before oversowing and topdressing. If fine weather follows the dalapon application oversowing and topdressing can be carried out immediately after the application.

As an aid to cultivation - In many hill country areas the necessary cultivation to prepare a seed bed in browntop areas is costly but trials have shown that if the browntop is killed about 2 months prior to cultivation then an equivalant seed bed can be produced with several cuts of the discs instead of 6 to 8 cuts. Even harrowing may suffice. In dry areas the browntop turf rots so slowly that a seed bed often takes 12 months to prepare. Dalapon has again hastened this process.

As an aid to crop establishment - Initial trials have shown that brassicas can be drilled into high producing areas with the aid of dalapon. Statistical data is not available but it is indicated that crops drilled in this method may out-yield crops sown in the normal way. Weed infestation is not serious and this would allow crops to be grown in areas where crop failure in the past was due to weed infestation.

Factors affecting efficiency

Stage of growth - Sufficient work has been done to show that the best results are obtained when dalapon is applied to fresh growth. Ryegrass in early spring has been killed with rates as low as 5 lb/ac. In summer plants have persisted at rates of 15 to 20 lb/ac.

Type of growth - Dalapon has given more effective control of fibrous rooted and stoloniferous grasses than rhizomatous species. TCA when used under correct moisture conditions in conjunction with cultivation has given more effective control of rhizomatous grasses than dalapon.

Physical selectivity - For weed control in lucerne, orchards and over-sowing in pastures, dalapon only shows sufficient selectivity to warrant use if applied when a period of several days fine weather follows.

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* Rates given as the sodium salt equivalent for TCA and dalapon.

## DISCUSSION ON THE PREVIOUS THREE PAPERS

### Dr. E. K. Woodford (Introduction to discussion)

We have three papers for consideration in this session. The first (B.10) by Le Brocq and Beech is concerned with the control of couch grass (*Agropyron repens* and *Agrostis gigantea*) by the application of herbicides during the autumn and winter after the crop has been harvested. These workers tried dalapon, TCA, amino-triazole and maleic hydrazide and found dalapon by far the most promising.

The second paper (B.11) by Green, Evans and Elliott is a joint contribution from the Grassland Research Station and the A.R.C. Unit of Experimental Agronomy. It is concerned with the control of grass weeds in seedling and established lucerne and again emphasizes the great value of dalapon.

Mr. Matthews' paper (B.13) is entitled "The Value of Dalapon". It surveys the many ways in which this promising selective grass killer is being tested and used in New Zealand. Many of you will remember Mr. Matthew's presence at our first Conference in 1953. This year he has sent us his report from New Zealand.

As time is short, I will confine my remarks to dalapon. This extremely promising herbicide is being used extensively in North America, tested widely in many parts of the world and will, we hope, soon be available for the farmer in this country. It seems fairly certain that dalapon has an important part to play in British agriculture and that it should be tested on a much larger scale in 1957.

The three papers before us indicate the most important situations in which dalapon can be used, but a great deal more work is required before we will be in a position to make definite recommendations to the farmer.

Dalapon will probably be found most useful in our farming system for the destruction of perennial grasses during autumn and winter when the land is lying fallow. Le Brocq and Beech showed that 10 lb/ac of dalapon when applied in the autumn resulted in an 80-90 per cent control of couch grass foliage. Doses of up to 40 lb/ac are, however, recorded as not killing the rhizomes. The final observations were made in most of the experiments before May and one wonders if the rhizomes did not die subsequently. Data from the other two papers and from other literature suggest that 40 lb/ac does under many conditions kill both *Agropyron repens* and *Agrostis gigantea*. In established lucerne Green, Evans and Elliott obtained almost a complete kill of *Agrostis gigantea* with 7.5 lb/ac of dalapon.

Are these differences in observed effect due to the differences in susceptibility of the grass at different times of the year as is suggested by Matthews, or to crop competition, or to other causes? It would be interesting to hear more about this from the writers of the research reports.

We know that dalapon disappears from the soil faster than TCA, but if we are to recommend that it should be applied during the winter we must find out a lot more about its persistence in different soils, in different seasons and the relative susceptibility of a range of crop plants.

It seems a pity that in only one of the 13 experiments laid down by Le Brocq and Beech did they record the subsequent effect of the treatment on the crop. Our own experiments have shown that 20 lb/ac of dalapon produces visible reduction in the growth of barley, red clover, kale and peas planted 6 weeks after the dalapon was applied to the soil and that the same dose can kill wheat and barley planted a month after treatment. It would appear, therefore, that a dalapon treatment, if it is to be safe, will have to be applied in the autumn or early winter.

Another important use for dalapon is as a selective post-emergence spray for lucerne. The one experiment reported by Green, Evans and Elliott gave a very good control of couch but the depressing effect of 7.5 lb/ac of dalapon on the lucerne was quite pronounced. It would appear that for safety not more than 5-10 lb/ac should be used. Are such doses high enough to be effective against the perennial grasses that are likely to become troublesome in lucerne? Do we agree with Matthews that the grasses are more susceptible if treated in the spring and that selective action of the herbicide is assisted if the lucerne is cut or grazed prior to spraying?

Several other very important uses for this chemical are suggested by Matthews.

Water weeds are a problem in many countries. Our experiments on emerged aquatics, although limited, confirm Matthews' general findings and we feel that much more work is required in this very promising field.

Pasture renovation too is a problem in both our countries. Details of management vary, but a chemical that would facilitate the "over sowing" of hill pastures might be very useful. Dalapon may also be able to assist in the development of a chemical-cultural treatment for the preparation of seedbeds on difficult to plough hill pastures and unworkable watermeadows. The combined use of herbicides and cultivation for the preparation of seedbeds for watermeadows, where cultivation methods alone have failed, is a promising development which we would like to hear more about.

Mr. P. F. Le Brocq

I would like to expand Dr. Woodford's statement by mentioning that we did one trial in the spring this year when we did actually get death of rhizomes with dalapon at 40 lb. In the autumn application trials of which we did 13, we could not find any actual death of the rhizomes although we obtained a good suppression of the aerial growth. We did look at one of the autumn application trials in June in the following crop of barley and there was still a good control of the aerial growth of couch (about 90%). We did not assess for death of rhizomes on this occasion.

Mr. J. G. Elliott

We did two further experiments this year on the control of grasses in lucerne by spraying in the early spring when the lucerne had little top foliage. 5 lb/ac dalapon gave a nearly complete grass control, and at that rate we measured an approximate 20% increase in yield of pure lucerne. At 10 lb/ac we killed all the grasses but also checked the lucerne.

Mr. L. Jones

Coming from the hills of Wales I see great openings for the use of dalapon in the field of pasture renovation. However, unploughable land also has a high percentage cover of dicotyledonous weeds. Is there any evidence as to the efficiency of mixtures of dalapon and MCPA or 2,4-D?

Mr. J. G. Elliott

I have no actual experience of this but at a guess I would say that it would not be a very good idea to apply them together because dalapon gives some scorch of top growth and this would tend to reduce the translocation of the growth regulator. On the question of pasture renovation, we have started an experiment in a river meadow which involved spraying in June with 2,4-D for broad-leaved weed control and followed up with dalapon in late September: the idea being that we hope to have nearly bare ground next spring which we will then surface cultivate and re-seed. This experiment is only in its initial stages at the moment.

Dr. R. K. Pfeiffer

Regarding the question of pasture renovation and dalapon, we have carried out an experiment this year in Devon on a pasture heavily infested with Holcus lanatus (Yorkshire fog) and containing clover. This experiment was carried out with the logarithmic sprayer and we found a considerable dosage range where Yorkshire fog was killed, clover hardly touched and certain grass species also survived. With regard to the question of interaction between 2,4-D and dalapon I understood from Dr. Warren Shaw in Beltsville that a marked antagonism had been proved in the United States.

Mr. P. Gregory

I should like to add to what Dr. Pfeiffer has just said on this particular experiment which we sprayed with a logarithmic sprayer using dalapon. There was a very high proportion of dicotyledonous weeds. These were not of course treated in any other way but had this been possible there was a very good chance that at a certain dosage range we should have been left with nothing but white clover which might have been quite useful. At a slightly lower dosage ryegrass and other useful grasses come in.

Dr. W. Madel

We have tried dalapon for the control of couch (Agropyron repens) around fruit trees since 1954 and got a very good control using between 10 and 30 kg/hectare without damage to apple trees with one exception. In this case the rootstock was Malling IX which roots much nearer to the surface. These were damaged to a small extent with 30 kg/hectare.

Cherry trees (Variety "Schattenmorelle") were damaged to a certain extent with 20 - 30 kg/hectare.

Dr. Van der Zweep

I am interested in the possible influence of TCA and dalapon upon the food value of the lucerne harvested. My colleague Dr. Bakker has carried out experiments in Holland which indicated that the food content of the product is not influenced, but I wonder if you have any information as to this?

Dr. W. S. Rogers

We have also tried dalapon for couch grass around fruit trees. My colleague Dr. Greenham has applied 5 lb and 20 lb/ac on a small scale and finds good control with 20 lb but little with 5 lb. 20 lb/ac did not damage plum trees but in one case small apple trees were damaged.

May I mention that the roots of Malling IX are in fact deeper than most other root stocks but it is of course a dwarf rootstock and perhaps that may account for its damage in the experiments in Germany.

# THE SUSCEPTIBILITY OF RUSH SPECIES TO THE GROWTH REGULATOR HERBICIDES 2,4-D and MCPA

Joint N.A.A.S. and A.R.C. experiments
1953 - 55

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## Summary

1. The results are reported of five experiments on the common rush *Juncus effusus*, of four experiments on the hard rush *J. inflexus* and of two experiments on the heath rush *J. squarrosus*.

2. In an experiment on established common rush to test a range of formulations of MCPA and 2,4-D; when applied at ¾ lb per acre, MCPA (sodium), MCPA (amine), 2,4-D (amine) and 2,4-D (ester) were similar in toxicity and produced 73-81% reduction in shoot numbers a year after spraying. In an experiment to test the effects of 1 lb per acre 2,4-D (amine) when applied at different dates and in combination with different cutting treatments, the chemical applied on the 30th June, 1953 and combined with cutting a month later, produced a 93% reduction in shoot numbers one year after spraying: which result was superior to applications a month earlier or later. It was also superior to the chemical application alone or when combined with cutting immediately before spraying.

3. In three experiments on seedling common rush, 1 lb per acre of either MCPA (sodium) or 2,4-D (amine) produced a mean 97% reduction in shoot numbers one year after spraying.

4. The results of the four experiments on established hard rush were variable. In two experiments MCPA (amine) and MCPA (ester) at 2 lb per acre with a wetting agent produced a 87-95% reduction in shoot numbers one year after spraying; but in another experiment 4 lb per acre was required to give the same effect.

5. Unsatisfactory results were obtained in two experiments on the heath rush. In one because no kill of rush was obtained by doses of up to 3 lb per acre with wetting agent of 2,4-D (amine) and MCPA (sodium), and in the other because a partial kill of rush left the ground unproductive one year after spraying.

## Introduction

In the summer of 1952, the Agricultural Research Council Unit of Experimental Agronomy in co-operation with the National Agricultural Advisory Service, started an investigation of the susceptibility of agriculturally important rush species to the growth regulator herbicides. Preliminary results were reported to the 1953 conference (1). This report summarises the work that continued between 1953 and 1955 during which time experiments were carried out on established and seedling common rush *J. effusus*, established hard rush *J. inflexus* and established heath rush *J. squarrosus*.

The organisation of the co-operative programme has been described in detail elsewhere (2). Briefly, the A.R.C. Unit were responsible for planning, spraying and summarising the results of the experiment, while the N.A.A.S. were responsible for finding the sites and carrying out the field work. Space does not permit detailed descriptions of designs and methods of assessment. In general all the experiments were of randomised block design and normally contained three replicates. Although pre-treatment quadrat assessment was not normally carried out, the plots were laid out so as to obtain a uniform stand in each block on visual assessment. Post treatment assessment, usually a year after spraying, was where possible by quadrat counts of green shoots on each plot (usually one or two hundredths acre in size). With established common and hard rush which may grow to a height of three feet or more, the whole area was mown off during the winter following spraying to permit shoot counts on the regrowth the following summer.

It is necessary that a report on the experimental application of herbicides should contain an assurance that the chemicals were accurately and uniformly applied: although special equipment and great care were used, the unevenness of the ground upon which rushes grow makes it inevitable that a part of the variability of the results is due to uneven application.

Details of the experiments may be seen in Table No. V.

Chemicals used in spraying

MCPA sodium - 2-methyl-4-chlorophenoxyacetic acid as the sodium salt in a water solution.

MCPA amine - The triethanolamine salt of 2-methyl-4-chlorophenoxyacetic acid as a solution in water.

MCPA ester - 1953 experiments were sprayed with a water/oil emulsion made up from 10% w/v a.e. stock containing the n-butyl ester of 2-methyl-4-chlorophenoxyacetic acid, Empelam A and Carnea oil.

- 1954 experiments were sprayed with a water/oil emulsion made up from 25% w/v a.e. stock containing the n-butyl ester of 2-methyl-4-chlorophenoxyacetic acid, lissapol NX and Carnea oil.

2,4-D amine - The triethanolamine salt of 2,4-dichlorophenoxyacetic acid as a solution in water.

2,4-D ester - 1953 experiments were sprayed with a water/oil emulsion made up from 10% w/v a.e. stock containing the n-butyl ester of 2,4-D, Empelam A and Careea oil.

- 1954 experiments were sprayed with a water/oil emulsion made up from 30% w/v a.e. stock containing the n-butyl ester of 2,4-D, lissapol NX and Carnea oil.

In experiment GR/25/53 Teepol at 0.7% of spray solution was used as a wetting agent. In the other experiments Teepol at 0.5% was used.

## Results

### Established Common Rush *J. effusus*

Information is available from two experiments that were sprayed in 1953; in one in Bleasdale (Lancs.) a range of formulations of 2,4-D and MCPA were compared low volume at low doses. In the other at Llancn (Cardigans.) the effects of 1 lb per acre 2,4-D (amine) were compared when combined with different times of cutting and applied in different summer months.

In the Bleasdale experiment sodium, amine and ester formulations of MCPA and amine and ester formulations of 2,4-D at ¼, ½ and ¾ lb per acre were applied on 12th June 1953 to a uniform stand of common rush that had been cut in 1952 and was coming into flower at the time of spraying. After winter cutting quadrat counts were made on shoot regrowth in the summer of 1954 and the results may be seen in Table No. I. All ½ and ¾ lb per acre treatments caused significant ($P = 0.05$) reduction in shoot numbers compared with control. Considered together, 2,4-D (amine) and 2,4-D (ester) treatments caused significantly ($P = 0.05$) greater shoot reduction than did MCPA (amine) and MCPA (ester), but there was no significant difference between the effects of 2,4-D (amine) and MCPA (sodium). A year after spraying, the numbers of shoots on the plots sprayed with ¾ lb per acre MCPA (sodium) and MCPA (amine) and ¾ lb per acre 2,4-D (amine) and 2,4-D (ester) were very similar and all within the range of 73-81% reduction on control.

TABLE No. I

The Effect of Treatment on Numbers of Rush Shoots One Year After Spraying
Experiment No. 277/53 Bleasdale *Juncus effusus*

Means of fifty 12" quadrats per plot.

| | lb/acre ¼ | ½ | ¾ | |
|---|---|---|---|---|
| MCPA sodium | 1178 | 516 | 279 | S.E. % mean = 24.9% |
| MCPA amine | 1031 | 602 | 352 | S.D. between two treatments = 520 |
| MCPA ester | 1160 | 738 | 728 | ($P = 0.05$) |
| 2,4-D amine | 605 | 515 | 383 | |
| 2,4-D ester | 767 | 464 | 307 | |
| | Control mean = 1421 | | | |

Experiment No. GR/5/53 Llanon *Juncus effusus*

Mean of thirty 12" quadrats per plot.

| | 1 lb/acre 2,4-D (amine) applied in 1953 on:- 29th May | 30th June | 29th July | |
|---|---|---|---|---|
| Cut on day of spraying | 6250 | 1500 | 2370 | S.E. % mean = 21.2% |
| Cut one month after spraying | 670 | 470 | 1700 | S.D. between 2 treatments = 1877 (P = 0.05) |
| Not cut | 1690 | 1970 | 3340 | |
| | Control mean = 6776 (uncut and unsprayed) | | | |

In the results of experiment GR/5/53 at Llanon (see Table No. I) two effects may clearly be seen. At all three times of application, spraying combined with cutting one month afterwards produced a greater reduction in shoot numbers than did spraying alone or combined with simultaneous cutting. The effect of cutting treatment was statistically significant ($P = 0.01$); cutting a month after spraying being superior to the two alternatives. In consideration of the effect of date of spraying, the treatments on 30th June produced significantly ($P = 0.05$) greater reductions in shoot numbers than did similar applications on 29th May or 29th July. In this experiment, the most effective treatment, which resulted in a 93% reduction in shoot numbers, was 1 lb per acre, 2,4-D (amine) applied on 30th June 1953 and followed by cutting one month later. This result is in agreement with earlier experimental work and recommendations for the control of common rush.

Seedling Common Rush *J. effusus*

Results are available from three experiments that were laid down in 1954 on seedling common rush at Wolsingham (Co. Durham), at Blacko (Lancs.) and at Haltwhistle (Northumberland). The three experiments were placed on fields that had been reseeded in 1953 and were grazed in 1954. In them 2,4-D (amine) and MCPA (sodium) were compared low volume at ¼, ½ and 1 lb per acre on young rush plants not more than one year old.

The assessment of the treatments was by quadrat counts of shoots on each plot in the summer of 1955 and the summarised results may be seen in Table No. II. In all three experiments 1 lb per acre of either chemical produced a 95-100% reduction on the control shoot numbers one year after spraying. The lower application rates were more variable in effect and generally did not produce a complete control, although ½ lb per acre MCPA (sodium) at Haltwhistle caused a 92.4% reduction in shoot numbers. In the comparison of both chemical means, MCPA (sodium) was significantly ($P = 0.05$) more toxic than 2,4-D (amine) in the Haltwhistle experiment, but the two were not significantly different at Wolsingham and Blacko.

TABLE No. II

Seedling Common Rush J. effusus

The Effect of Treatment on Shoot Numbers One Year after Treatment. (Means for each treatment). Haltwhistle 30 - 6" quadrats per plot; Wolsingham 30 - 6" quadrats per plot; Blacko 10 - 12" quadrats per plot.

| Experiment | Control | 2,4-D (amine) lb/acre $\frac{1}{4}$ | $\frac{1}{2}$ | 1 | MCPA (sodium) lb/acre $\frac{1}{4}$ | $\frac{1}{2}$ | 1 | S.E. % of mean | S.D. between 2 treatments P = 0.05 |
|---|---|---|---|---|---|---|---|---|---|
| Haltwhistle | 343 | 255 | 66 | 6 | 30 | 26 | 0 | 26.8 | 108 |
| Per cent of control | | 74.3 | 19.2 | 1.7 | 8.7 | 7.6 | 0 | | |
| Wolsingham | 437 | 264 | 180 | 9 | 261 | 102 | 7 | 18.2 | 116 |
| Per cent of control | | 60.4 | 41.2 | 2.0 | 59.7 | 23.3 | 1.6 | | |
| Blacko | 492 | 279 | 150 | 22 | 403 | 147 | 21 | 18.8 | 155 |
| Per cent of control | | 56.7 | 30.6 | 4.5 | 82.0 | 30.0 | 4.3 | | |
| Mean for three experiments | 424 | 266 | 132 | 12 | 231 | 92 | 14 | | |
| Per cent of control | | 63 | 31.3 | 2.8 | 54.3 | 21.7 | 3.3 | | |

The Hard Rush J. inflexus

Four experiments were laid down on the hard rush; two in 1953 (at Ampney Mill and Fordingbridge) and two in 1954 (at Breamore and South Cerney). The treatments and results may be seen in Table No. III.

The two 1953 experiments were observational and included a range of formulations of 2,4-D and MCPA. While the results were inconclusive, they produced two indications worth further study: these were that the addition of a wetting agent appeared to increase the chemical toxicity to the rush, and that MCPA amine and ester were possibly more toxic than the other formulations that were applied. These two possibilities were tested in the 1954 experiments.

At Breamore and South Cerney, which were fully replicated experiments, 2,4-D (amine), MCPA (amine) and MCPA (ester) were applied at 1, 2 and 4 lb per acre in 12 gallons per acre with a wetting agent. At Breamore, shoot counts one year after spraying showed that the reduction in shoot numbers produced by the 2 lb per acre rates were 2,4-D (amine) - 78%, MCPA (amine) - 87% and MCPA (ester) - 91%. The equivalent figures for the South Cerney experiment were 2,4-D (amine) - 27%, MCPA (amine) - 44% and MCPA (ester) - 41%. As might be expected, the 1 and 4 lb per acre applications produced respectively smaller and greater reductions. MCPA (amine) and MCPA (ester) in both experiments produced significantly (P = 0.05) greater reduction in shoot numbers than did 2,4-D (amine).

## TABLE No. III

### The Hard Rush J. inflexus

The Effect of Treatment on Numbers of Rush Shoots One Year After Spraying.

GR/25/53 Ampney Mill - unreplicated (observation plots).
Total shoot counts in 20 - 18" quadrats per plot on 6th June 1954.

| | MCPA | | | | | | 2,4-D | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sodium | | Amine | | Ester | | Amine | | Ester | |
| lb/acre | 2 | 4 | 2 | 4 | 1½ | 3 | 2 | 4 | 1½ | 3 |
| With wetter | 168 | 22 | 42 | 24 | 130 | 15 | 164 | 94 | 154 | 2 |
| No wetter | 116 | 61 | 125 | 66 | 69 | 8 | 216 | 108 | 142 | 11 |
| | Control mean = 732 | | | | | | | | | |

GR/24/53 Fordingbridge - two replicates (observation plots)
Means for each treatment of total shoots in 30 - 12" quadrats
per plot on 28th June, 1954

| | 2,4-D amine | | | 2,4-D ester | | | S.E. % mean | SD between treatments |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 4 | ¾ | 1½ | 3 | | |
| With wetter | 333 | 787 | 301 | 748 | 687 | 368 | 46.6 | Treatments |
| No wetter | 817 | 749 | 531 | 1355 | 1059 | 565 | | |
| | Control mean = | | | 1067 (not included in analysis) | | | | Non-sig. |

GR/47/54 Breamore - Three replicates
Means of total shoots in 20 - 12" quadrats per plot on 13th May, 1955.

| | 2,4-D amine | | | MCPA amine | | | MCPA ester | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 4 | 1 | 2 | 4 | 1 | 2 | 4 |
| | 538 | 145 | 104 | 275 | 86 | 50 | 223 | 60 | 26 |
| % of control | 82.0 | 22.1 | 15.8 | 41.9 | 13.1 | 7.6 | 34.0 | 9.1 | 4.0 |
| Control mean = 656 | | | | | | | | | |
| S.E. % mean = 21.6% | | | | | | | | | |

P = 0.05: Significant difference between two treatments = 165.7
" " " treatment and control = 143.5

GR/48/54 South Cerney - Three replicates
Means of total shoots in 20 - 12" quadrats per plot on 3rd May, 1955.

| | 2,4-D amine | | | MCPA amine | | | MCPA ester | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 4 | 1 | 2 | 4 | 1 | 2 | 4 |
| | 654 | 504 | 179 | 618 | 388 | 77 | 684 | 352 | 86 |
| % of control | 94.6 | 72.9 | 25.9 | 89.4 | 56.1 | 11.1 | 99.0 | 50.9 | 12.4 |
| Control mean = 691 | | | | | | | | | |
| S.E. % mean = 20.7% | | | | | | | | | |
| P = 0.05 - Significant difference between two treatments = 274.2<br>" " " treatment and control = 237.8 | | | | | | | | | |

The Heath Rush J. squarrosus

In carrying out two experiments on the heath rush it was appreciated that there would be little agricultural demand for a chemical control of this species, partly because of the difficult nature of the land upon which it grows and because the species is recognised as providing useful grazing for sheep. As the experimental organisation was available in 1953 it was considered worthwhile trying to obtain limited information.

Two experiments were laid down in the summer of 1953 in Widdale (Yorks) and at St. John's Chapel (Co. Durham). In them, 2,4-D (amine) and MCPA (sodium) were compared at 1 and 3 lb per acre alone and with a wetting agent on dense uniform stands of heath rush. Both experiments were sprayed low volume by a land rover sprayer in satisfactory weather conditions. The assessment of the results of spraying was made in the summer of 1954.

In the St. John's Chapel experiment quadrat counts of ground cover of heath rush were made on each plot in the summer of 1954, and the results may be seen in Table No. IV. MCPA (sodium) treatments caused a significantly (P = 0.01) greater reduction in rush cover than did 2,4-D (amine) treatments. The 3 lb per acre treatments caused significantly (P = 0.01) greater reduction in ground cover than did 1 lb per acre treatments. The presence or absence of wetting agent had no significant effect at the P = 0.05 level. The most effective treatment was 3 lb per acre MCPA (sodium) with wetting agent, which resulted in a ground cover of 4.5% live heath rush as compared with 57% cover on the control plots.

None of the treatments in the Widdale experiment produced any visible effect on the heath rush. A year after spraying, quadrat counts of ground cover of rush were attempted and abandoned when it was found that the treated plots did not differ from the control plots. The two experiments were sprayed by the same machine and the sprays were made up from the same chemical stocks; the difference in the reaction of the rush at the two sites is inexplicable. Although the results of the St. John's Chapel experiment indicate a partial control of the species, in practice the killing of the heath rush resulted in a brown useless area of ground which had not been colonised by other species a year after spraying.

TABLE No. IV

The Heath Rush J. squarrosus

Experiment No. GR/13/53 St. John's Chapel

One year after spraying. Percentage ground cover of rush assessed by awarding marks out of ten in 20 quadrats per plot.
Means for each treatment

| | | No Wetter | | | | With Wetter | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Control | MCPA Sodium 1 lb/acre | 3 | 2,4-D amine 1 lb/acre | 3 | MCPA sodium 1 lb/acre | 3 | 2,4-D amine 1 lb/acre | 3 |
| % Ground cover | 57 | 32 | 19.5 | 58.5 | 37 | 38.5 | 4.5 | 47 | 32 |
| Arc sin trans-formed | 54.2 | 33.6 | 25.4 | 49.8 | 36.9 | 37.5 | 12.2 | 43.0 | 34.3 |

S. E. % of mean = 16.3% ) transformed figures
S.D. between treatments = 18.4 ) only.

DISCUSSION

The results on the common rush J. effusus in the Llanon experiment have provided confirmation of existing recommendations as to the effects of cutting and time of application; while new information concerning the effects of different formulations is available from the Bleasdale experiment. Both experiments will add to research experience on the common rush. The control of seedling common rush by light doses of both MCPA (sodium) and 2,4-D (amine) in the year after sowing may prove useful in the reseeding of rush infested pastures. Abundant information is available as to the quantities of buried viable rush seed in the soil of many wet pastures and to the dangers of seedling rush invasion during the year of reseeding. The conclusion from the three experiments is that a single application of either chemical a year after re-seeding would substantially delay rush reinvasion on such pastures.

In the experiments on hard rush J. inflexus, there was some variation in chemical toxicity from one experiment to another. While no definite explanation can be given for the greater toxicity of the chemicals at Ampney Mill and Breamore as compared with Fordingbridge and South Cerney, it is possible that the frequency of cutting before and after spraying may have influenced the results. Further work on combinations of spraying and cutting might well be worthwhile.

The results of the two experiments on heath rush J. squarrosus lead to the conclusion that the species is unlikely to be susceptible to sufficiently light doses of MCPA (sodium) or 2,4-D (amine) to make chemical control an economic possibility. The quality of the land upon which the species grows would probably prohibit the necessary expenditure on spraying unless accompanied by other improvements such as drainage and liming.

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## References

1. Elliott, J. G. (1953) The Use of Growth Regulator Herbicides for the Control of Rushes. Proc. Brit. Weed Control Conf. 1953, pp. 184-190.

2. Fryer, J. D. (1953) The Effect of 2,4-D amine on Clean Cereal Crops. Proc. Brit. Weed Control Conf. 1953, pp. 37-43.

TABLE V. Details of Experiments

| Expt.No. | County | Location | N.A.A.S. Officer in charge | Species | Chemicals | Volume Rate gall/acre | Date Sprayed | Type of Land |
|---|---|---|---|---|---|---|---|---|
| GR/5/53 | Carmarthen | Llanon | A. J. Davies | Est. J.effusus | 2,4-D/dates of cutting | Low volume | 29/5, 30/6, 29/7/53 | Poor permanent pasture |
| 277/53 | Lancashire | Bleasdale | A. Clegg | Est. J.effusus | 2,4-D/MCPA formulations | 7 | 12/6/53 | Wet permanent pasture |
| GR/26/54 | Northumberland | Haltwhistle | H. Meads | Seedling J. effusus | 2,4-D/MCPA | 12 | 7/7/54 | Upland pasture reseeded 1953 |
| GR/27/54 | Durham | Wolsingham | J.A. Newrick | Seedling J. effusus | 2,4-D/MCPA | 12 | 14/7/54 | Upland pasture reseeded 1953 |
| GR/29/54 | Lancashire | Blacko | R. Helme | Seedling J. effusus | 2,4-D/MCPA | 12 | 8/7/54 | Upland pasture reseeded 1953 |
| GR/6/53 | Yorks. N.R. | Widdale | C.H. Sawden | J. squarrosus | 2,4-D amine MCPA sodium | 7 | 8/6/53 | Rough hill grazing |
| GR/13/53 | Durham | St. John's Chapel | J.A. Newrick | J. squarrosus | 2,4-D amine MCPA sodium | 7 | 10/6/53 | Rough hill grazing |
| GR/24/53 | Hampshire | Fordingbridge | S.P.W. Eldridge | J. inflexus | 2,4-D amine and ester | 7 | 27/7/53 | Low-lying wet pasture |
| GR/25/53 | Gloucester | Ampney Mill | T.F. Blood | J. inflexus | 2,4-D/MCPA formulations | 12 | 7/8/53 | Water meadow |
| GR/47/54 | Hampshire | Breamore | S.P.W. Eldridge | J. inflexus | 2,4-D/MCPA | 12 | 19/6/54 | Water meadow |
| GR/48/54 | Gloucester | South Cerney | T.F. Blood | J. inflexus | 2,4-D/MCPA | 12 | 9/7/54 | Wet permanent pasture |