Assessment was by regular observations and final score on a whole plot basis on June 16th 1959. The table below summarises the degree of kill of grass species on that date, each figure being the mean of scores for 3 plots.

Treatment	per cent kill Hill Sward	per cent kill Lowland Sward
7½ lb dalapon May	5) mean	1) mean
15 lb " "	10) 7½	3) 2
7½ lb " July	53) mean	3) mean
15 lb " "	87) 70	53) 28
7½ lb " September	63) mean	17) mean
15 lb " "	93) 78	42) 29

Conclusions

There were no appreciable differences between times of application in the degree to which the top growth of grass was killed initially. 15 lb. dalapon gave a complete kill of top growth and 7½ lb about 80 per cent kill.

There were big differences between dates of spraying in the speed of re-growth after the initial kill of top growth. Recovery was rapid after late spring application and was practically complete after about six weeks on the lowland sward. Recovery was much slower after the summer application and slower still after the autumn application. Late spring was therefore less satisfactory for spraying as a pre-treatment for re-seeding because of the short period during which new seeds could establish before competition from the old sward began. This period would, however, be lengthened in proportion to the severity of any surface cultivations that followed.

The lowland sward reacted to the treatment much more rapidly than the hill sward but also recovered more quickly.

2,4-D-ester mixed with the dalapon was ineffective in controlling broad-leaved weeds at all times of application. These weeds spread rapidly after the kill of grass on the lowland sward and would have constituted a serious problem on a farm scale, since further spraying with MCPA also failed to control them.

2. Study of Mixtures of dalapon and other herbicides

The trials already referred to had indicated that mixtures of dalapon and 2,4-D-ester were ineffective in controlling broadleaved weeds of known suscepti-bility and also that their rapid spread after spraying such a mixture would constitute a serious practical problem in re-seeding. In order to determine whether this finding also applied to other herbicides similar to 2,4-D-ester, observation plots were laid down in duplicate on 29th August 1958 comparing standard rates of the following chemicals each sprayed without dalapon and with dalapon at 20 lb/ac on a grass sward with a heavy infestation of creeping buttercup (Ranunculus repens):-

MCPA-sodium 2 lb/ac
MCPA-amine 2 lb/ac

2,4-D-amine	2 lb/ac
MCPB-sodium	2 lb/ac
2,4-D-ester	1½ lb/ac

The plots were observed at intervals with a final eye assessment on a whole plot basis a year after spraying.

Conclusions

All chemicals without dalapon controlled buttercup satisfactorily. None did so when mixed with dalapon and many other weeds, including arable weeds, appeared in the plots.

3. Study of re-seeding without cultivations

The earlier trials had revealed the difficulties and limitations of surface cultivations after dalapon application in areas where suitable implements are often not available. Two large plot trials were therefore laid down in the spring of 1959 to investigate the feasibility of establishing grass and clover seeds without previous cultivations. Two half-acre plots were sprayed with dalapon at 5 lb and 10 lb/ac at 20 gal volume rate in March 1959 on each of two contrasting sites, a fairly good hill sward at 1,300 feet and a lowland sward at about 350 feet. Six weeks were allowed for decomposition of dalapon and a seeds mixture and complete fertiliser broadcast. The fields were then stocked and it was expected that the combined effect of rainfall and stock trampling would enable the seeds to establish. In fact the sowing was followed by an unprecedented drought with the result that establishment was generally poor, though good in small areas where soil moisture and stock treading were adequate.

Assessment was by regular observations and a final inspection on a whole plot basis.

Conclusions

10 lb dalapon was satisfactory but there was considerable regrowth of the old sward on the 5 lb. plots. In the absence of cultivations to bury them the new seeds largely failed to establish because of the long drought that followed. Broadleaved weeds spread rapidly on both sites after dalapon application, were not controlled by subsequent spraying of MCPA and presented a serious problem in re-seeding.

4. Study of dalapon plus amino triazole and subsequent cultivations

In the autumn of 1959 a trial was laid down to test the inclusion of amino-triazole to control broadleaved weeds in a hill sward and also to assess further the value of cultivations in establishing a new ley after killing the existing sward. Two one-acre plots were sprayed in October 1959 whth 8 lb dalapon plus 4 lb activated amino-triazole per acre and with half these amounts. By early spring there appeared to be a good kill of all species except for some broadleaved weeds. The sprayed plots were crossed at right angles by two strips, one of which received surface cultivations with spike and pitch-pole harrows while the other was left untouched. On 24th March a seeds mixture and complete fertiliser was sown over the whole of the sprayed plots, and the cultivated plot harrowed again. The cultivations completely failed to penetrate the tough, undergrazed mat of vegetation in spite of burning-over beforehand and the seeds on both strips remained above the soil surface and dependent on the normal heavy rainfall for germination and establishment. In fact there was practically no rainfall from sowing until early July, by which time the old sward, including broadleaved weeds, had regenerated completely and there was practically no establishment of sown grasses.

Assessment of this trial was by regular observations on a whole plot basis.

Conclusions

Both mixtures used gave a satisfactory kill of top-growth. Amino triazole did not satisfactorily control broadleaved weeds. Neither spike nor pitch-pole harrows gave satisfactory surface cultivation. The seeds failed completely over the whole area owing to prolonged drought.

DISCUSSION

The problem

The aim of this series of trials has been in the main to develop a technique which could be used to improve grassland in the marginal and hill lands of the East Midland Region, which lie wholly in Derbyshire. In this, as in similar areas elsewhere, the farms are mostly small, with limited capital, labour and machinery. It was hoped that re-seeding after dalapon application would prove to be within the capacity of such farms and at least as satisfactory and consistent as conventional methods. It was not visualised as an alternative to ploughing where that was practicable, but as a possible means of quickly improving the many thousands of acres of such land which for one reason or another were not suitable or likely to be ploughed.

The type of sward in the area is very variable, even at comparable altitudes reflecting the geology, climate and, in particular, the past management of the land. Some of the improved fields are basically similar to lowland swards with an open type of sward amenable to surface cultivations and establishment of new seeds. At the other extreme are swards with an acid mat forming a tough carpet several inches thick while in between there is a whole range of swards of varying degrees of difficulty.

The more dense and matted the sward the more important are the implements available for surface cultivation. Unfortunately the typical farm of the area is not likely to have implements strong enough to make much impression on a tough sward. Only the pitch-pole harrow and more especially the rotavator are suitable and these are rare in hill and marginal areas. Capital is also very limited on such farms and the land is inherently of low productivity, so that the cost per acre of improvement methods must be kept down. Such methods must also be reliable, for the farmer has too low a margin to risk complete failures owing to weather or other unknown factors. Neither must an acceptable technique demand the same skill and technical knowledge that might reasonably be expected of a farmer on better land experienced in cultivations and establishment of leys.

The problems to be solved is therefore a difficult one: how far it has been solved must now be discussed.

Sward killing

Though individual plants may be completely killed by dalapon and similar chemicals, the normal sward is a mixed community and cannot be killed in the absolute sense by normal rates of any of the known grass killers. The effect of dalapon on a grass sward is to kill all vegetation above ground and inhibit vegetative re-growth for a period of weeks or months. Successful re-seeding depends on making use of this period to establish new seeds sufficiently strongly for them to be able to suppress this re-growth. When cultivations follow dalapon the effect is two-fold; firstly, if severe enough they add to the killing effect (especially rotavation which attacks the root system directly) and secondly they help to create suitable conditions for establishing seeds. By and large it may be said that the degree of kill of top growth of grass obtained by 10-20 lb/ac of dalapon is satisfactory, though it would often be desirable for re-growth to be suppressed for a longer period.

Broadleaded weeds

Most swards contain a proportion of broad-leaved weeds and the effect of applying a grass-killer is to allow them to spread rapidly so that in the absence of severe cultivation they may dominate the sward. The experiments reported have failed to discover a satisfactory way of preventing this by including another herbicide with dalapon. It would seem that the degree of control of susceptible perennial broadleaved species usually achieved is dependent on the competitive power of the grass sward completing the job started when a severe check is given by a chemical such as MCPA. In the absence of grass competition most perennial species recover more quickly from MCPA and similar chemicals than does the grass from dalapon. Amino-triazole in one experiment sprayed in autumn seemed little more effective.

The most hopeful method in sight so far seems to be to spray with MCPA or 2,4-D in the spring or summer before the application of dalapon and allow a few months to elapse for grass competition to do its work.

Time of application

Within wide limits it seems that the time to apply dalapon can be chosen to suit local conditions and subsequent re-seeding. On balance autumn spraying seemed most suitable as it allowed cultivations and re-seeding to be carried out while the land still had its winter moisture, but the experience of long spring and early summer droughts in the last two years suggests that late summer sowings may possibly be less risky.

Cultivations and re-seeding

This seems to be the crux of the problem as applied to marginal and hill land. Even if the sward can be effectively killed can the land be satisfactorily re-seeded within the limitations described?

On the basis of the experiments without cultivations, it seems unlikely that broadcast seeds can be reliably established over a wide range of dense swards by relying on stock trampling and rainfall alone. With an open type sward and a well distributed high rainfall the position might be different. The method would also stand a greater chance if seeds could be cut into the true soil by a suitable disc drill, but in marginal areas these implements are not common and the discs would certainly not cut into the tougher type of sward even when killed by dalapon.

If cultivations are necessary which implements are likely to be effective? On open type swards discs or spike harrows may be able to work up sufficient tilth, but on dense swards something stronger is needed. The pitch-pole harrow seems to be satisfactory on moderately dense swards, but on tough swards even this is ineffective and only the rotavator is likely to do the job. In marginal areas, however, rotavators are rare and difficult even to hire, and pitch-pole harrows are uncommon. It is difficult to resist the conclusion that on this type of land a technique relying on such implements is unlikely to become widely practised.

Economic and general

If surface cultivation is to be carried out by a rotavator, probably hired, there is little difference in cost between this and ploughing. The cost of the chemical is high at present and there is no grant to offset it as with ploughing. The technique is therefore more expensive than ploughing and re-seeding and is unlikely to be economic on the poorer type of land under consideration.

It has been suggested that such a technique would be valuable where land cannot be ploughed, but during this work it has become apparent that a lot of such land in hill areas cannot be safely sprayed and surface cultivated either. There is some land which cannot be ploughed but where this technique could be used; it does not, however, constitute a big proportion of the improvable land in Derbyshire, nor probably of other similar hill areas.

For both technical and economic reasons, therefore, it seems that the technique of pasture renovation with herbicides is likely to find less application in hill and marginal areas than at one time seemed probable. This view is based largely on difficulties inherent in the farming system and type of land and is therefore not likely to be greatly modified by improvements in chemicals or reduced costs. There may be particular farms in such areas where it could be of value, but a more promising field for exploitation would seem to be land of inherently greater productivity and less physical difficulty such as the many thousands of acres of wet land and flood land in the river valleys of this country, often infested by the easily-killed species Deschampsia caespitosa (Tussock grass) and Juncus spp. (Rushes).

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HILL PASTURE IMPROVEMENT WITH DALAPON

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Summary: An account is given of six trials carried out in the S.E. of Scotland on bent-fescue, Nardus and Molinia dominant swards. The susceptibility of individual species, the effect of dose time of spraying, time of sowing, and the benefit of cultivation and burning on the establishment of the sown sward is reported.

INTRODUCTION

This paper reports on six trials in which were studied the herbicidal effects of dalapon on hill pasture species, on its value as a pretreatment to oversowing, and on its residual effect on the germination of sown species.

The work was carried out in S.E. Scotland where conditions, both of rainfall and pasture type, differ from those found in the West of Scotland (Gardner 1959). The lower rainfall and dense turf found on Molinia and Nardus swards in this area make the successful establishment of surface sown seeds more difficult than where the rainfall is higher and the mineral soil is not covered by a 2 - 4 in. mat.

METHODS, MATERIALS AND RESULTS

Six trials were carried out, five at Sourhope, the Organisation's farm in the Cheviots, and one at Blyth, Lauder, belonging to Mr. J. Logan MacDougal. In trials 1 and 2, it was intended to assess the residual toxicity of dalapon on germinating seeds, in trials 3 and 4 the susceptibility of different species to various rates and dates of dalapon spraying was studied, while in trials 5 and 6 various procedures were tried using farm implements and working on a field scale to test their value in establishing a sown sward after dalapon pretreatment. The details of trials 1 - 4 are given in Table I.

Trials 1 and 2. Residual Toxicity

As can be seen in Table I, two designs were used to study residual toxicity. In trial 1, all the treatments were sprayed on one date and sowing took place at intervals afterwards. In trial 2, the spraying took place on different dates and all the plots sown on one date.

The summer of 1959 was extremely dry and hot and germination took place on none of the plots. No information could, therefore, be collected on the residual effects of dalapon. The plots were subsequently manured and resown in the spring of 1960, trial 2 being burnt before being resown. A good establishment was got on trial 2 and a fair one on trial I. Both trials were given 2 cwt. "Nitro-chalk"/ ac after the sown species had germinated.

While these two trials were a complete failure for the purpose for which they were designed, the incidental information they yielded, on susceptibility of species and success in the establishment of sown species, will be discussed later in the paper. Certainly the experience of 1959 in these trials underlines the difficulties encountered in establishment.

Trials 3 and 4. Susceptibility of Species

The data arising from trials 3 and 4 are shown in Tables II and III respectively. This data was collected about 12 months after spraying and this delay was deliberate. In reseeding a sward pretreated with dalapon, the important feature is not the apparent suppression of the species in the second or third month after spraying but the genuine reduction in ground cover from the level initially afforded by the natural species. If they survive, they survive as competitors with the sown species and over which they have a competitive advantage.

The observations on the susceptibility of the various species given below arise from the statistical examination of the data in Tables II and III where this procedure is applicable or from visual estimates among all the trials.

A. tenuis is more susceptible to a May than to an August spraying ($P < 0.01$; trial 3 data for July recording, Table II). There is a significant dates x rates interaction ($P < 0.05$). It appears that a considerable reduction can be achieved by a 5 lb dose in May.

F. ovina is more susceptible to an August than to a May spraying ($P < 0.01$; trial 3 data for July recording Table II). This was also apparent in trials 4 and 5. The rates x dates interaction was not significant. For a considerable reduction a 10 lb dose in August appears to be the lowest suitable rate.

In trial 4 the first spraying date at the lowest rate was too early to affect Molinia but it at later dates, and Nardus at all dates were suppressed by the lowest dose (5 lb /ac). This was also observed in trials 1 and 2.

The 1 lb amino triazole addition to the 5 lb dalapon dose appeared to be no advantage.

Species which appear to be highly resistant to at least a 10 lb rate are Holcus lanatus, Holcus mollis, Anthoxanthum odoratum and Deschampsia flexuosa among the hill grasses while Carex spp., Galium hercynicum, Potentilla erecta and Vaccinium myrtillus are also resistant. Agrostis canina appears to be as susceptible as A. tenuis.

Trials 5 and 6. Reseeding

Trial 5 This trial was on a larger scale than the other four and covered 2 acres sited on a peat podsol at 1700 ft. The main grasses were N. stricta, A. canina, A. tenuis and Festuca ovina. These were more or less co-dominant. Other grass species were F. rubra, D. flexuosa, A. ordoratum, Molinia caerulea and Poa pratensis. Dicotyledonous plants were sparse.

In the spring of 1959, the trial with the exception of the control plots received 2 tons Carbonate of lime and 7 cwt of basic slag/ac and in the spring of 1960 it received an additional dressing of 1½ cwt/ac triple superphosphate.

Treatments

1. Sprayed at 10 lb /ac on 26th May 1959. Burnt on 8th July 1959 and sown with grass and clover seeds mixture on 14th July 1959.

2. Sprayed at 10 lb/ac on 26th May 1959. Sown with grass and clover seeds mixture on 14th July 1959.

3. Sprayed at 10 lb/ac on 14th July 1959. Burnt on April 17th 1960 and sown on April 20th 1960.

4. Sprayed at 5 lb/ac on 26th May 1959. Sown with clover seed on 14th July 1959.

5. No treatment except manures.

6. Control.

Plots containing treatments 1, 2 and 4 were split, one half being harrowed with a heavy Wilder pitch-pole on 13th July 1959.

Treatment 4 was sown with 4 lb Wild White Clover/ac.

Germination in the autumn of 1959 was very poor with the result that all the plots sown in the autumn had later to be resown in April 1960.

The whole area was grazed by cattle and sheep for short periods during the summer of 1960.

Observations at the end of August 1960 were that harrowing had been effective on most plots in getting rid of F. ovina, in breaking the surface mat and giving a better take of grass and clover seeds that burning had had little effect on the establishment of a sown sward even where combined with harrowing and that the 5 lb/ac dose with or without harrowing was completely ineffective in the establishment of clover.

Trial 6 This trial was sited at Blythe, Lauder, at 1,000 ft on a podsolic brown earth and the area employed extended to 2 ac.

Predominantly a bent-fesque sward, it contained a large proportion of P. pratensis, H. lanatus, and A. odoratum. The presence of these resistant species is perhaps one of the reasons for the failures encountered in this trial. The area had been manured in 1957 with 4 ton/ac magnesium limestone and was given a further 1 ton of carbonate and 10 cwt of 19 per cent P205 basic slag in the spring of 1959.

The 8 treatments were:

Dalapon		Cultivation (by Wilder pitch-pole)		Oversowing Mixture (sown July 1959)
20) 10) lb/ac in May	x	Harrowed Not Harrowed	x	1) Grass and clover as in trials 1 and 2. 2) 2 lb/S184/Wild White Clover.

There was an almost complete failure in germination following the July 1959 sowing. A resowing in late April 1960 was again a failure.

The cause of these failures is difficult to assess, but the dry weather following sowing, the species composition of the original sward and the failure of the harrow to deal with the dense deep incompletely killed turf at the site were all contributory.

DISCUSSION

Doses After improvement, hill swards are liable to revert. This reversion will be the more rapid, the greater the proportion of original vegetation not killed by ploughing or in this case by the dalapon pretreatment. If the take of sown species is good and their subsequent growth luxuriant, they may effectively compete with the hill species. This has not been the case in the trials now reported and, although a large proportion of some swards are now composed of sown species, the remaining hill species, mainly by selective grazing are likely to spread at the expense of those sown.

Except in an almost pure *Nardus* or *Molinia* sward where 5 lb/dalapon/ac might suffice, serious competition can be expected from resistant hill species at all doses up to and including 20 lb dalapon/ac, and the inclusion of a herbicide to deal with the dicotyledonous weeds would be necessary when they were present to any extent.

Harrowing We have not yet found a satisfactory technique for treating the turf, killed or weakened by the dalapon, to improve the establishment of the sown species. There is no doubt that the pitch-pole harrowing greatly increased the effectiveness of the spray by tearing up plants of resistant species, principally *F. ovina*, temporarily weakened by the spray and also improved the establishment of the sown species. However, it was not effective at all sites and the more effective it was, the greater the problem of dealing with the trash which, in our work, was left in rows by tripping the pitch-pole harrow.

Dates of spraying Due to the susceptibility of *Nardus* at all dates of spraying and to *A. tenuis* and *F. ovina* being susceptible at different periods of the summer no differences were apparent in reducing the vegetative ground cover among different spray dates. For purposes of oversowing, however, autumn spraying followed by spring sowing would be preferable in the S.E. of Scotland and as autumn sowing might be followed by a severe kill of the sown species (especially clover) over winter.

Burning Burning appeared to confer no advantage in establishing the sown species. It was found impossible to burn a sward in July which had been sprayed in May but one sprayed in August burnt readily the following spring. Even in the driest weather, it is impossible to reduce the tussocks by burning although the dead grass lying above them can be burnt.

Our work has led us to think that it is yet too early to come to a firm conclusion on the advantage of dalapon as an aid to oversowing. We have had both successes and failures with sufficient of the former to make continuation of the work worthwhile.

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TABLE I
(see pages 162-3)

TABLE II
EFFECT OF DALAPON ON THE PERCENTAGE GROUND COVER AFFORDED BY DIFFERENT SPECIES SPRAYED ON 26/5/59 AND 4/8/59 AND RECORDED ON 2/5/60 AND 7/7/60. PERCENTAGE GROUND COVER ASSESSED USING 10 POINT QUADRAT.

Trial 3

Species	Recorded 1960	Dose lb dalapon/ac								
		2½ Sprayed		5 Sprayed		10 Sprayed		20 Sprayed		Control
		May	Aug	May	Aug.	May	Aug	May	Aug	
Bare ground	May July	13 8	31 12	47 29	59 13	59 35	74 41	80 52	87 47	10 6
A. tenuis	May July	25 20	26 25	8 18	18 43	1 8	12 39	0 8	1 27	45 42
F. ovina	May July	35 37	14 32	25 29	3 20	14 28	1 7	8 17	2 5	22 32
P. pratensis	May July	10 15	8 10	4 7	7 4	2 4	2 3	0 6	0 4	7 7
Other species	May July	17 20	21 21	16 17	13 20	24 25	11 10	12 17	10 17	16 13

TABLE I.

Trial No.	Soil	Pasture type	Date of spray	Treatments dalapon lb/ac
1	Peaty podsol	*Molinia* + *Agrostis spp.* and *F. ovina*	27.5.59	5, 10 and 20
2	Peat	*Molinia* tussock	24.6.59 1.7.59 8.7.59 15.7.59	5 and 10
3	Podsolic brown earth	*A. tenuis* + *F. ovina* *P. pratensis* and others.	26.5.59 4.8.59	2.5, 5, 10 and 20
4	Peaty gley	*Molinia*, *Nardus* and *F. ovina*	27.5.59 2.7.59 4.8.59	5, 10, 15 and 20 lb dalapon. 5 lb dalapon + 1 lb amino triazole

DETAILS OF TRIALS 1 - 4

Object of trial	Seeds mixture per acre	Manurial rates	Remarks
Residual effect on germination of sown species and susceptibility of natural species.	)2 lb S184 W.W.C.)3 lb S59 R. fescue)3 lb S50 Timothy)3 lb S48 Timothy)5 lb S23 P.R.G. 5 lb D. Cocksfoot 1 lb R.S.M.G. $\frac{1}{4}$ lb Yarrow	)2 tons $CaCO_3$)per acre.)5 cwt. triple)superphosphate)per acre.)2 cwt. N. chalk)per acre.)	)Because of bad)germination in)spring 1959)residual)effects could)not be)determined and the two trials were manured and resown in spring 1960.
)))))Susceptibility of)grass species.))))			

TABLE III. EFFECT OF DALAPON ON THE PERCENTAGE GROUND COVER AFFORDED BY DIFFERENT SPECIES

Trial 4

Recorded 20/7/60. Sprayed 27/5/59, 2/7/59 and 4/8/59

Spraying treatments	Control	5 lb/ac			5 lb + 1 lb/ac amino triazole			10 lb/ac			15 lb/ac			20 lb/ac		
Spraying dates		May	July	Aug	May	July	Aug	May	July	Aug	May	July	Aug	May	July	Aug
Bare ground	1	14	29	31	20	28	40	24	29	53	46	39	54	30	48	59
F. ovina	18	20	13	23	16	15	11	14	12	7	11	6	3	5	-	-
M. caerulea	19	17	3	1	17	3	-	3	-	2	3	3	2	2	1	-
H. lanatus	3	-	5	1	3	11	8	3	-	-	6	3	10	3	4	8
D. caespitosa	2	1	-	-	1	2	-	-	2	-	-	2	-	-	-	-
N. stricta	22	-	-	-	1	3	2	-	3	-	3	-	-	-	-	-
A. odoratum	2	1	2	-	1	2	-	2	-	-	2	2	5	6	-	6
A. canina	11	-	2	4	-	2	-	-	2	-	-	-	-	2	-	2
A. tenuis	4	-	2	-	-	3	2	-	-	-	-	-	2	-	-	2
Carex spp.	8	16	28	21	17	8	21	20	19	3	8	25	13	39	20	11
G. hercynicum	3	10	3	7	10	15	3	2	9	3	9	-	3	5	7	2
P. erecta	4	9	5	7	3	6	3	11	9	8	8	3	3	5	13	-
Other species	3	12	8	5	11	2	10	21	15	14	14	17	5	3	7	10

IMPROVEMENT STUDIES ON FESTUCA/NARDUS AND CALLUNA/MOLINIA AREAS

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Summary. Following applications of lime and fertilisers, sown grasses established quite readily without surface cultivation on a Callunetum (Calluna vulgaris) community grazed by cattle. Satisfactory swards were produced within two years. Similar treatments on a Nardetum community grazed by sheep gave a poor grass establishment with a low white clover content after four years. On a similar site, grazed by cattle and sheep, there was much better "take" of white clover and this had developed quite strongly by the second year. Where dalapon was used as pre-treatment on Nardetum, a fairly good establishment of sown grass and white clover was obtained within twelve months of treatment, but the Festuca sp. present were only retarded by the herbicide, and became the dominant grasses in the sward.

INTRODUCTION

It is well to remember that the present sub-climax vegetation of hill grazings is the product of climatic, edaphic and biotic factors which have been at work over a long period. In order to effect any change in the vegetation and maintain it, it is necessary to modify the soil environment and to effect some changes in the grazing management. Investigations by Milton (1947) and Gardner et al (1954) have indicated how this can be achieved without the use of the plough provided certain mineral deficiencies are corrected and also that the grazing animal plays a major role in the improvement programme. These techniques have not been widely adopted, mainly because of the slow rate at which improvement takes place as compared with the spectacular changes brought about by ploughing and reseeding. In spite of the excellent results obtained, the plough has brought certain problems in its trail in some upland areas. Crompton (1953) has drawn attention to the possible deleterious effects of ploughing, particularly on some poorly drained soils where invasion by Juncus sp. in reseeded swards is a common occurrence; he commends surface treatment as a means of achieving more lasting improvement. During recent years, this approach has been given further impetus following the introduction of the grass killing herbicides, Work by Gardner (1959) has illustrated how these chemicals can assist the establishment of sown grass and clover by killing out or retarding the growth of competitive natural species. In this paper, it is intended to review some of the studies carried out during the past five years by the N.A.S. in Wales. This will be done with reference to four hill sites, three of which were on Nardetum communities and one a Callunetum community.

METHODS AND MATERIALS

Site 1. Nardetum on open hill, grazed by sheep

This was situated in the Plynlymen area at an altitude of 1,100 ft; the soil was a shallow peat overlying Ordovician shale. The most abundant plants in this association were fine leaved Festuca sp., Agrostis tenuis, Nardus stricta and Molinia caerulea.

In November 1954 different phosphate treatments were applied in duplicate on ⅛th acre plots, with and without lime. The phosphate treatments consisted of basic slag, ground mineral phosphate and superphosphate, each at 200 lb P_2O_5 / ac, the lime treatment was 3 ton/ac of magnesium limestone. In May 1955, one duplicate of each treatment was oversown with seed cleanings at the rate of 50 lb/ac. These cleanings contained approximately 50 per cent Lolium perenne (Perennial ryegrass, S.23), 40 per cent Dactylis glomerata (Cocksfoot, S.143) and 10 per cent Trifolium repens (Kent wild white clover), the per cent germination ranging from 42-60.

Site 2. Nardetum on open hill, grazed by sheep and cattle

This area was at an altitude of 1,000 ft near Bala, Merioneth. The soil was a medium loam with a thin layer of peat, overlying shale. The natural herbage was similar to that at Site 1, except that it had been closer grazed, The phosphate treatments at this site were as in Site 1 but equivalent to 100 lb P_2O_5/ac, and the lime was in the form of ground limestone at 2 ton/ac.

Site 3. Callunetum, grazed by dairy cattle

This was sited on a heather moor in N. West Carmarthenshire at an altitude of 900 ft. The most abundant plants in the association were Calluna vulgaris, Molinia caerulea, Deschampsia flexuosa. The soil was mainly peat, which was rather shallow in parts.

The trial area was dressed with 4 ton/ac of ground limestone and basic slag at 120 lb P_2O_5 /ac in the winter of 1955, and in spring 1956 at time of reseeding, muriate of potash and nitrogenous fertiliser were applied each at 2 cwt/ac.

The mixtures sown were:-

		lb/ac	
A.	Lolium perenne (Perennial ryegrass S.23)	20	+ 2 lb Alsike (Trifolium hydridium)
B.	Phleum pratense (Timothy S.48)	10	
C.	Dactylis glomerata (Cocksfoot S.143)	15	+ 1 lb White Clover (Trifolium repens)
D.	Control - no seeds	-	

No surface cultivation was employed.

Site 4. Nardetum on enclosed hill, grazed by sheep

This site was on an exposed hill in N.W. Denbighshire at an altitude of 1,300 ft. The soil was thin peat overlying gley soil. The natural herbage was composed of Nardus stricta, Festuca sp., Agrostis sp., Agrostis tenuis and Juncus squarosus. There was alsoa proportion of Galium saxatile, Potentilla erecta and Polytrichum. This herbage contained rather more Nardus than the sites referred to earlier. The trial area was dressed with 2 ton/ac of ground limestone and 6 cwt/ac of a 6 : 15 : 15 complete fertiliser. The full range of treatments can be listed as follows:-

A. 6 lb/ac dalapon - fertiliser 7 days before spraying and seeds 24 hr after spraying

TABLE I. PER CENT FREQUENCY OF SPECIES (POINT QUADRAT METHOD)

Species present	Mixtures sown A S.23	B S.48	C S.143	D No seeds
Sown grass species	42	29	40	-
Unsown grass species	17	19	20	36
T. repens	31	41	30	10
Calluna vulgaris	7	6	7	34
Carex, *Scirpus*, *Juncus*	-	-	-	12
Bare ground	3	5	2	8

The sown grasses and clovers produced a satisfactory cover on most of these plots. Intensive grazing by cattle helped to reduce the *Calluna vulgaris* and unsown grasses to a small proportion on the seeded plots. These stood out in sharp contrast with the controls which received no seeds. Very little change had taken place on the latter though they had also received lime and fertiliser treatments.

Preliminary Studies with Herbicides on Nardetum (Site 4)

Nardus stricta and *Juncus squarosus* were markedly affected by dalapon at both 6 and 12 lb /ac. *Festuca* sp. were retarded in growth, but subsequently recovered and from assessments made in August this year, this species had become dominant on the sprayed area. *Galium saxatile* and *Potentilla erecta*, unaffected by dalapon, had also increased on some of the sprayed plots. The figures given in Table II illustrate the differences in botanical composition between the sprayed and unsprayed areas.

TABLE II. PER CENT GROUND COVER 8.8.60 (6 in. x 6 in. QUADRAT METHOD)

Species	Treatments A	B	X	Y	Z
Lolium italicum (Italian ryegrass)	Tr.	Tr.	-	-	-
Lolium perenne (Perennial ryegrass)	24	13½	14	20	Tr.
Phleum pratense (Timothy)	5½	1	1	2	-
Trifolium repens (White clover)	4½	2	6	14	½
Nardus stricta (Moor grass)	½	8	1½	½	32
Festuca sp. (Fescues)	35	44	45	39	31½
Agrostis sp. (Bents)	2	2	1	2½	4
Galium & *Potentilla* (Weeds)	12½	9½	5	5½	4½
Juncus squarosus (Heath rush)	-	-	-	-	27
Bare ground	16	20	26½	16½	½

A reasonable "take" of sown species was obtained on all the sprayed plots which contrasted sharply with the unsprayed area where hardly any change in botanical composition took place.

DISCUSSION

Surface improvement studies have been described with reference to four hill sites in Wales where the management had been that normally prevailing on each particular farm. It is obvious that the pace of improvement using these methods is determined by (a) the native plant communities, (b) the livestock policy in the area, (c) the grazing management. The grazing animal is the most important element in this whole process.

It has been shown that at Site 1, where sheep were the only graziers, the botanical composition remained relatively stable, although it was obvious that more palatable herbage had been produced. Of the sown species only T. repens had established in any quantity at Sites 1 and 2 and was satisfactory at the latter site where cattle and sheep were grazing. Unfortunately, it has not been possible in these studies to evaluate the nutritional improvement due to lime and fertilisers, but work by Davies et al (1959) has shown that herbage from treated hill swards when cut and fed to hill ewes, produced higher live weight gain than botanically similar herbage from untreated swards. This suggests that the ultimate value of improvement in hill swards may not of necessity lie entirely with a movement in the plant community toward one dominated by lowland species.

These studies have shown that particularly under conditions of open hill grazing where the fine leaved Festuca sp. are present in quantity, they are strong competitors with any introduced species. A greater measure of controlled grazing by fencing, raises possibilities of solution.

Where the plant community is of an open type such as the Callunetum at Site 3, there seems to be no difficulty in establishing a satisfactory sward from sown grasses and clover, even without surface cultivations.

The introduction of dalapon at Site 4 has aided establishment of sown grasses in the absence of any cultivation. The Nardus stricta and Juncus squarosus were affected by the chemical, offering bare ground, though the spread of the fine leaved Fescue was encouraged by this. It now remains to be seen whether or not good grazing management can foster the white clover and cause it to spread into the bare ground vacated by the Nardus stricta and Juncus squarosus and help in the control of Festuca sp.

In conclusion, it should be emphasised that in any approach to the improvement of hill grazings, the ultimate aim should be clearly understood before schemes are drawn up. Some of the methods by which different hill swards may be improved have been discussed, but the extent to which these should be adopted will depend on the cost in relation to the future use of the area concerned.

The writer wishes to acknowledge his colleagues in the N.A.A.S. for all advice and assistance in this work and particularly to Mr. I. E. Edwards for information supplied. He also wishes to express gratitude for all facilities provided by farmers on their land.

THE USE OF DALAPON FOR GRASSLAND IMPROVEMENT IN THE SOUTH WEST OF SCOTLAND

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Summary. The use of dalapon as a means of reducing interplant competition in the improvement of hill land by the over-sowing technique is discussed. The limitations and problems involved with this technique and hill land improvement in general are outlined. A method of improving permanent pasture by using dalapon to kill selectively undesirable plants is reported.

INTRODUCTION

Dalapon with its grass killing properties has given grassland improvers a new weapon with which to attack the problem of renovating or replacing unproductive grassland. In trials, attempts were made to fit the use of this substance into existing techniques of grassland improvement.

Trials with dalapon have been on areas where, for one reason or another, it has been considered impossible or undesirable to plough; from a farmer's point of view this is the only outlet for this chemical in view of the present subsidies on ploughing and the certainty with which a seed bed can be obtained by ploughing.

The objects of this paper are (a) to summarise results to date, (b) to indicate some of the general problems involved and (c) to assess the potential use for the chemical technique under the conditions of the south west of Scotland.

RESEEDING UPLAND GRAZINGS

The oversowing technique

The essence of a good improvement technique is that it be simple, certain in its effect and economic. The oversowing method whereby the lime, fertilizer and seed are merely broadcast on the undisturbed soil surface may meet these requirements and can be very successful provided there is ample surface moisture and the existing herbage does not compete too severely with the sown seed.

Such conditions exist on wet peat carrying a sward of short heather, sedges, rushes, moss and some grass. Here seeds can penetrate easily to the soil and the natural herbage which does not grow vigorously acts as a nurse crop to the young seedlings rather than a competitor. The replacement of the original herbage by better grasses and clover can be achieved within 2 years of sowing without any surface cultivations other than that supplied by the hooves of the grazing animals, (Gardner et al, 1954).

When this technique is applied to a dense grassy sward difficulties are encountered by competition from the existing species, so that if the sown seeds ever reach the soil they are rapidly crowded out by the existing grasses. It is at this point that the use of dalapon is justified in removing or reducing interplant competition. Where such competition does not exist, there is no need for prior chemical treatment.

The initial trial work has already been reported, (Gardner, 1959) and since then, the technique used in those small plot experiments has been repeated on a larger scale on different areas. The sites chosen have been dominantly flying bent (Molinia caerulea) and moor mat grass (Nardus stricta) with smaller amounts of tufted hair grass (Deschampsia caespitosa), sheeps fescue (Festuca ovina) and bent (Agrostis spp.). These trials have confirmed the original findings that, despite heavy applications of lime and fertilizer, the oversowing technique will fail on grassy swards unless the competition is removed by chemical or mechanical methods.

Doses of dalapon

The amounts of dalapon used have been restricted to what might be considered economic levels since, despite all that may be discovered regarding the tolerance of one species or another, cost will determine the rate at which hill farmers will apply it. It is fortunate that our poorer hill grasses, which are in most need of replacement, are susceptible to low doses of the chemical. A Nardus/Molinia sward can be adequately dealt with by 4 lb dalapon/ac applied in the autumn. Bent/fescue swards which can be considered good hill grazing are not so susceptible and, depending on the amount of fescue present, would require considerably higher rates (8 - 10 lb) in order to ensure a sufficiently long dormancy and a take of sown seed. At the present cost of the chemical this may well put them outside the economic limit.

Timing

The timing of spraying and seeding are obviously important as the optimum time for both must be considered. The best kill of Nardus and Molinia has been obtained when sprayed in automn allowing the sowing of grass seed to be made, in perfect safety, early the following spring. In the conditions of south west Scotland late February or early March is not too soon for oversowing as this ensures the seeds receiving adequate rainfall during their establishment period and being well grown to face the following winter.

DIFFICULTIES OF IMPROVING UPLAND GRAZINGS

Low fertility

It is important to remember that spraying with dalapon is only one stop towards more productive hill grazings and that it does not, in itself, bring about improvement. If the fertility of the soil is not raised a return to the original position is inevitable.

In hill land reclamation the first essential is lime, usually 2 - 3 ton/ac to bring the pH of the top soil up from 3 - 3.5 to 5.5 - 6.0. Secondly, phosphate is almost always deficient and basic slag (upwards of 1 ton/ac) is usually necessary. Copeman et al (1960) show similar conditions to exist in the north of Scotland.

The results in table I which are typical of oversowing highlight this fertility problem. This area was sprayed with 3.75 lb dalapon/ac in April 1959 and the seeds and fertilizer sown a month later. No cultivations were given and the area was grazed throughout the winter 1959-60.

Better establishment has resulted where the higher rate of slag was applied. As the summer of 1959 was exceptionally dry and the area subjected to hard grazing these results can be considered quite satisfactory. It is of interest to note that under these conditions the slower establishing species timothy (Phleum pratense), meadow fescue (Festuca pratensis) and cocksfoot (Dactylis glomerata) have not fared as well as the ryegrass (Lolium perenne).

TABLE I. PERCENTAGE GROUND COVERED BY SOWN SPECIES
14 months after sowing

Seed mixture lb/ac	Fertilizer treatment: 2 tons ground limestone		
	1 ton slag	½ ton slag	means
12 lb S.24 perennial ryegrass			
8 lb S.23 " "	28.0	12.0	20.0
2 lb S.184 wild white clover	19.5	8.0	13.8
20 lb S.143 cocksfoot	14.5	8.5	11.5
2 lb New Zealand white clover	18.0	17.5	17.8
10 lb Danish meadow fescue	5.0	3.5	4.2
8 lb S.48 Timothy	2.0	1.0	1.5
2 lb New Zealand white clover	9.0	15.0	12.0
Means: Sown grass	16.5	8.3	
Means: Clover	15.5	13.5	

Grazing control

If full use is to be obtained from reseeded hill land then fencing is essential otherwise reseeded areas, which naturally draw stock to them, are so severely punished that reversion takes place. Fencing is also necessary to permit rest periods in preparation for out of season grazing.

When the cost of grass and clover seed (and possibly drainage) are added to these items of fertilizer and fencing it can be appreciated why expensive chemical sprays are unlikely to be accepted by hill farmers especially when mechanical forms of cultivation are subsidised.

Acid mat

The areas tackled by the chemically-assisted oversowing technique were chosen to avoid heavy acid mat formations. Cultivation difficulties reported by other workers (Elliott, 1958; Hunter 1960; Ormrod, 1958) which result from the thick mat of dead material left by spraying have not been encountered.

If such areas are to be tackled then reduction of the mat should commence several years in advance by the use of lime and phosphate. Once this first phase has been passed reseeding after ploughing, cultivating or spraying will be more easily and safely achieved. Crompton (1960) has underlined the need to encourage the decomposition of a mat so providing more suitable conditions for plant growth.

Aerial techniques

In New Zealand the use of the aeroplane to distribute light dressings of phosphate has brought land, previously considered un-improvable, into economic production but it is doubtful if this approach will be successful under west of Scotland conditions for the following reasons.

To be economic aerial spraying or top-dressing requires that large blocks of land be tackled and as far as spraying is concerned this presupposes large areas of species susceptible to dalapon. Areas are difficult if not impossible to find under our conditions where heather, moss, bracken, Molinia and Nardus communities can occur within a few acres of the same hill. Aerial spraying of this land would be wasteful as much of the spray would fall on resistant or valuable species.

Another factor militating against the improvement of large tracts of country is the necessity to stock the improved areas adequately, not only to cash in on the improvement, but also to promote a strong clover growth by judicious hard grasing. The capital outlay required to meet these needs might well prove prohibitive.

The large quantity of lime required on most U.K. hill land would also render the aeroplane uneconomic even if the requirement could be halved by the use of pelleted seed.

It therefore seems unrealistic to envisage large scale improvement schemes being undertaken by aeroplane in western Scotland at present.

IMPROVEMENT BY SELECTIVE CONTROL

There are thousands of acres of permanent pasture which carry a herbage composed mainly of bent, red fescue (Festuca rubra), crested dogstail (Cynosurus cristatus), sweet vernal (Anthoxanthum odoratum), meadow grasses (Poa spp.), Yorkshire fog (Holcus lanatus), perennial ryegrass and wild white clover and are often rush (Juncus spp.) infested. Ploughing such land without drainage often results in an even worse rush infestation and farmers prefer to improve it by applications of lime and slag which promote clover growth and encourage the better grasses.

A field of this type was sprayed with MCPA in the autumn of 1958 to eliminate the rushes, then 2 ton of ground limestone and 1 ton slag were applied. In April 1959 an acre of this field was sprayed with 3.75 lb dalapon. This gave a very temporary set-back to the grasses which had apparently recovered completely by the end of June. Due to this very poor 'kill' and the subsequent dry weather grass seed sown in May did not establish. This left two comparisons 1) sward limed and slagged and 2) sward limed, slagged and sprayed with dalapon.

The sprayed area rapidly took on a green fresh appearance which was apparently associated with a luxuriant clover goowth. A botanical analysis was carried out in May 1960 when the sprayed area could still be readily picked out from the rest of the field. From table II can be seen the botanical changes that have taken place as a result of dalapon spraying.

TABLE II. PERCENTAGE GROUND COVER 1 YEAR AFTER SPRAYING

Treatment	Perennial ryegrass	Wild white clover	Agrostis spp.	Other grasses	Dicotyledonous weeds
3.75 lb dalapon	28	20	6	28	17
No dalapon	10	16	40	22	12

The *Agrostis* has been greatly reduced and its place largely taken by perennial ryegrass. It is possible that the unsprayed area will eventually reach the same botanical composition as the sprayed area due to the raising of the fertility. Further interest in this field will be centred on seeing if and when this takes place.

CONCLUSIONS

Where the establishment of sown seed is impeded by competition from existing grasses the use of dalapon to reduce or remove this competition will greatly help the establishment and spread of the better species. Although the technique is sound on technical grounds the economics are open to question and may limit the use of the chemical to swards that are readily killed by low rates of application.

Grassland improvement by selectively killing less desirable types with small doses of grass-killing chemical combined with accepted practices of good husbandry shows promise. When more information becomes available on the relative tolerance of different species it may be possible to eliminate unwanted grasses without retarding the growth of the sward as a whole.

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Discussion on preceeding four papers

Mr. H. M. Lawson I would like to ask the authors of the various papers to what extent slug damage to seedlings was responsible for poor establishment of new swards in their trials, and whether much of the failure attributed to poor seedbed conditions might be due to slug damage.

Mr. J. F. Ormrod We have not had any evidence of slug damage.

Professor W. Ellison Part of our work this year has been sod-seeding kale into pasture after dalapon spraying. Unfortunately the kale seedlings suffered severely from slug damage, to such an extent that the crop was virtually a failure.

Dr. M. Neenan Four years ago we tried at 25 centres applications of 2,4-D and superphosphate to pasture. The quality of the hay was decidedly improved. On another pasture dominated by *Agrostis gigantia*, we sprayed dalapon and followed with clover oversown at weekly intervals but the clover did not succeed owing to the slow kill produced by dalapon. A previous trial was more successful but the clover suffered competition from broad-leaved weeds.

Mr. J. G. Elliott After much experimental work on sward renovation, the situation is being clarified. All our grass killing has been based on one chemical-dalapon. Dalapon is extremely toxic to *Deschampsia caespitosa*, *Molinia caerulea* and *Nardus stricta*; but *Agrostis* spp. and *Festuca* spp. are more resistant. Against dalapon are its slow action and persistence in the soil. We want chemicals with grass killing powers that are quick acting with no persistence in the soil.

Mr. G. D. Holmes In our experiments, slow-acting herbicides, when applied to heavy swards, have resulted in a dry surface mulch of persistent dead remains, which are not ideal for reseeding. Recent trials with diquat at 2 lb/ac alone and in combination with dalapon on *Molinia*, *Nardus* and *Agrostis* swards have shown greatly accelerated break down and disappearance of the dead grass.

Mr. G. A. Toulson I cannot agree with the chemical destruction of *Molinia*. This moorland grass gives a useful contribution to grazing. Lime and heavy stocking cause *Molinia* to give place to more useful species, and then seed cleanings can be introduced with surface cultivations.

Dr. S. H. Crowdy Following Mr. Holmes comment, we have a second dipyridyl which is very much more effective against grasses than is diquat. (Editor - see "The Control of Perennial Grasses with Dipyridyl Herbicides Alone and in Mixtures" by R. S. L. Jeater and H. C. McIlvenny, Session 6).

SESSION 4

Chairman: Professor W. Ellison

BRACKEN

ECONOMIC ASPECTS OF BRACKEN (PTERIDIUM AQUILINUM) IN UPLAND FARMING

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Summary: Some of the economic aspects of bracken are discussed, though no precise measure of its importance can be obtained. The origin and extent of the problem, together with costs of eradication are outlined. The effects of bracken infestation are discussed and it is pointed out that both the distribution pattern on the farm and botanical considerations affect the suitability for improvement. It is emphasised that eradication should be regarded as the first step in a programme of improvement involving measures to establish and maintain a useful pasture in its place. In many cases the elimination of bracken might bring about an increase in the productivity of the hill, but to ensure a permanent improvement positive measures to maintain fertility are essential. A proper balance must be achieved between immediate economic advantages and the long term demands of sound land use.

INTRODUCTION

A precise assessment of the significance of bracken in upland farming is not possible. Where open hill pasture is concerned, the environment of production consists of many interacting factors both difficult to measure and incapable of decisive management control. Thus, the various components of production cannot be assigned realistic economic values. In examining the economic aspects it is important to distinguish between short-term and long-term considerations. The farmer is primarily concerned with the first, as he must operate within the immediate economic framework. The second involves ecological implications which may have important repercussions on future production from the uplands. This should concern the state and should have due consideration in framing land use and agricultural policy.

The bracken problem does not differ essentially from that of controlling the other plant communities composing upland pasture. The special interest in bracken arises from its occupation of some of the better soils, capacity for rapid spread with consequent depletion of the sward, and its tendency to poison cattle. In many respects the problem of bracken differs from that of other communities only in degree and our present inability to control it is one example among many of the inadequate control we have at present on ecological trends in upland pasture and therefore on the quality and productivity of its herbage.

ECOLOGICAL STATUS OF BRACKEN

The existence of bracken in this country can be traced back to early times (Godwin), 1956) but the present problem, induced by changes in land use, is of comparatively recent origin. Historically, it is a woodland plant but on removal of the tree canopy, and being unpalatable to stock, an extensive grazing environment provides little hindrance to vigorous growth and spread. The former climax woodland vegetation of Britain rose to an elevation of 1000 - 2000 ft. Destruction of the tree cover has taken place over an extended period in Wales and in the Southern Uplands of Scotland which have a long history of grazing use, while in the Scottish Highlands deforestation is a much more recent event. The coming of extensive sheep farming to the uplands 150 - 200 years ago is generally regarded as the begining of the present problem, while changes in grazing use within this period, including the disappearance of wether flocks and herds of ponies, and reduction of cattle have enhanced the opportunities for spread. Attention has been drawn on many occasions to the spread of bracken since the beginning of the century (Stapledon, 1944: Report, 1944) and many such soils today provide abundant evidence of the former dominance of other plants. During the depression, extensive areas of permanent pasture became infested and destruction of much of this by ploughing up during and after the war may have offset to some extent encroachment on the hill. Indeed, a recent enquiry in Wales (Report, 1958) found no evidence of spread on a significant scale, and in parts some contraction was said to have occurred. Nevertheless, there is evidence of continued encroachment on the hill itself, often associated with heather burning, but the magnitude is impossible to judge.

ACREAGE AND DISTRIBUTION

Available figures for bracken infestation are only rough approximations and it is unfortunate that the figures for England and Wales on the one hand and Scotland on the other are not strictly comparable owing to the different methods of estimation. The most recent estimate for Scotland (Hendry, 1958) is 442,000 acres of rough grazings affected and over 8,500 acres of permanent grass. About 20 years ago in surveying the grasslands of England and Wales (Davies, 1941), the aggregate acreage of dense bracken was estimated at 406,000 together with a further 45,000 acres of mixed fern and gorse, while in an earlier survey in Wales (Davies, 1936) the figure of 152,000 acres of dense bracken was arrived at. In 1956, the Welsh bracken acreage was estimated at 144,000 (exclusive of common land) of which 25,000 acres were accessible and could be ploughed.

In the Scottish counties of Selkirk, Argyll and Kirkcudbright, one quarter to two thirds of the farms are affected, but in the north and east the infestation rate is only one in twenty farms. Three quarters of all bracken in Scotland is found in these counties, together with Inverness, Perth, Roxburgh, Wigtown and Dumfries. Taking Scotland as a whole, on those farms which report a bracken problem, one acre in every twelve is affected.

If the upper limit of bracken is taken as 1,500 ft, on the basis of figures for percentage land below this level in Wales (Ashby and Evans, 1944) and Scotland (Halstead, 1959), the percentage infestation of the total permanent grass and rough grazings is 4.7 per cent for both countries. In view of the considerable area of peat in Scotland, however, within the bracken altitudinal zone, the intensity of infestation would seem to be greater than in Wales.

Unfortunately, it is not possible to calculate a similar figure for England. Considering that bracken occupies the better soils and that on many soils, including wet peat, it will not grow at all, the overall infestation is by no means light.

FORMS OF INFESTATION AND SOIL POTENTIAL

Bracken is generally considered indicative of productive soil for cultivated grass, crops and trees. Indeed, the annual dry matter production of bracken is itself high. For example, 2 ton/ac is not exceptional for moderately dense bracken, while a denser stand may produce 4 ton or more/ac. Under crops and grass during the war a considerable area of the more accessible bracken land demonstrated the inherent potential for crop growth. Boyd and Ellison (1954) give estimated values for mean starch equivalent production per acre from reseeded bracken land compared with other similarly treated hill communities as follows:-

Mean S.E. in cwt/ac/annum	
Bracken	17.4
Nardus/fescue	14.2
Molinia	10.6

In one case at 1,000 ft an area of bracken gave a yield of 30 cwt/ac S.E. in the first year after improvement, the estimated production before treatment being 3 cwt/ac S.E. In comparison, the estimated net yield of starch equivalent in the U.K. (excluding rough grazings) is about 15 cwt/ac (Baker and Ferguson, 1954). Although not considering bracken land in particular, it is interesting that the great potential value of certain hill soils has also been demonstrated recently by Crompton (1958).

Though examples of cultivable bracken land provide a useful measure of potential, the real problem of bracken is its infestation of extensive grazing land which must continue to be used for this purpose, and where the economic limit of exploitation is well below its potential under cultivation.

In relation to topography and location of inbye land, three distribution types of bracken infestation can be recognised as follows:-

1. Restriction to the lower slopes forming a belt between the arable and the open hill.

2. Presence of a similar altitudinal belt on more broken terrain, dissected by deep valleys. Much of the area in this case is not easily accessible and also remote from the inbye land.

3. Occurence of more discreet areas widely scattered over the hill.

Botanical differences in the ground vegetation are also associated with these distribution patterns according to soil, accumulation of litter and density of the upper canopy. The herbage varies from bent/fescue pasture unaffected by the associated bracken to scattered plants or none at all. Both the distribution and botanical nature of the communities must obviously be borne in mind when considering improvement programmes.

The first distribution category is the type most frequently the subject of past reclamation projects involving ploughing, fencing and incorporation into the arable or acreage of permanent pasture. Bracken in such circumstances need not raise any special problem. Fencing and the more intensive use, while continued, will effectively prevent re-establishment. The cost of such treatment has been studied in many situations (e.g. Grant, 1955) and prediction of the economics of the operation does not raise special difficulties.

The second and third distribution patterns present a problem of extensive pasture management, not properly understood, and represent the crux of the bracken problem.

SOME EFFECTS OF BRACKEN

The problems associated with bracken infestation are well known and include not only impairment of growth of the underlying sward, but complete destruction where the density is great enough, sometimes leading to a reduction of stock in severely infested areas. Less dense stands may provide useful grazing in spring and autumn (Hunter, 1954), but if Holcus mollis is abundant, the sward is of little value in winter. Interference with herding may also be a problem and occasional fatalities to cattle by poisoning occur. Light infestation, however, may not be without its benefits owing to the tendency for earlier growth of pasture in such areas and in periods of drought a moderate canopy may provide some insulation from the worst effects on herbage growth. Despite such advantages, if the stand is dense enough to exclude stock in summer, grazing from good land is denied at a time when nutritious pasture would be beneficial to growing lambs.

Although the influence of bracken on the soil profile is obscure, and no experimental evidence has been adduced to show the effects of bracken invasion of soil with marked podsolic features, it has been suggested that benefical changes in profile characteristics may develop. The presence of bracken has also had a protective effect from long continued extractive sheep grazing to which other hill communities have been exposed. On the other hand, where cutting for litter is practised the loss is much heavier than under sheep grazing. It has been suggested (Campbell, 1959) that the eradication of the Scottish acreage might permit an increase of 100,000 breeding ewes, but without the simultaneous application of real management of hill pastures (Nicholson, 1959), including fertiliser application, it is doubtful whether a future decline in productibity could be avoided.

COST OF ERADICATION AND EXTENT OF WORK

Various schemes of grant aided bracken clearance have been in operation since 1936, including assistance as part of comprehensive improvements under the Hill Farming and Livestock Rearing Acts. Apart from comprehensive assistance, the current scheme introduced in 1941, offers a 50 per cent grant in aid of bracken control.

The gross costs of double cutting bracken in 1952 on West of Scotland farms were found by McCreath and Martin (1954) to vary from 13s 0d to 21s 8d for farmer's own tractor work and from 20s 0d to 35s 0d by contract. Duthie (1954) studied the comparative operating costs of four different machines under experimental conditions in south east Scotland in the same year. He showed the range of costs to vary from about 7s 6d per acre for the Holt breaker to 20s10d for the Ferguson mower. A rough approximation of the "average" cost in Scotland can be calculated from the figures for annual grant paid (D.O.A.S., 1960) and on this basis the cost in 1952 was 22s 4d per acre for double cutting. These figures also indicate the upward trend of cost between 1948 and 1959 (see graph), the most recent estimate being 31s 6d per acre. At this rate the total gross cost for completing an approved scheme over three years would be about 95s 0d per acre.

Accurate figures for the acreage of bracken land which has received the full three year treatment, since the inception of assisted bracken eradication, are not readily available. The following estimates, however, are calculated from information supplied by the Department of Agriculture for Scotland and the Ministry of Agriculture, Fisheries and Food.

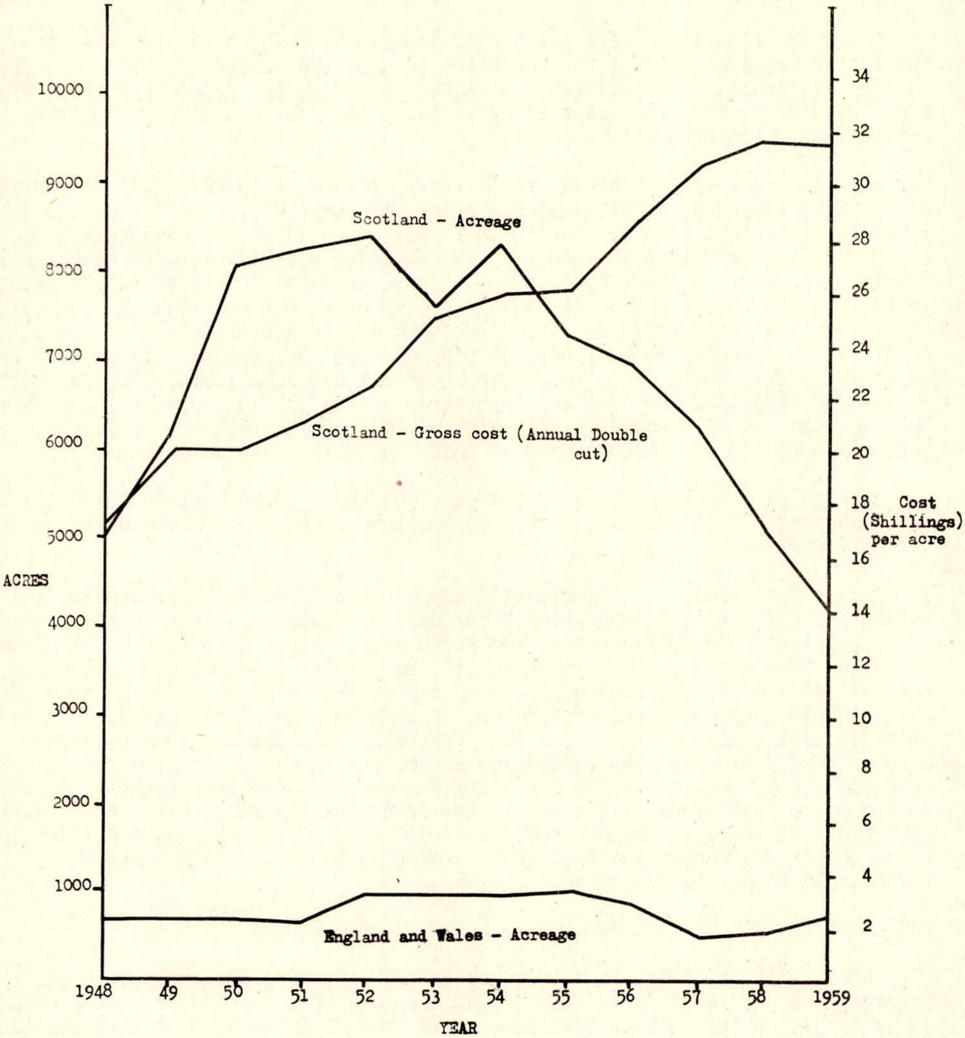
The acreage, completing the first year's treatment (double cut) in Scotland since 1948, excluding comprehensive schemes, is about 82,000 acres (D.O.A.S. 1960). The acreage treated from 1936 until that year amounted to approximately 45,500 acres, while in addition the annual area cut under the Hill Farming and Livestock Rearing Acts has been over 2,000 acres. Thus, assuming the first year's treatment is followed up in all cases, the total acreage which has received the complete three year treatment would be about one third of the current bracken figure, but since 1954 the annual rate of cutting has declined (see graph). In England and Wales (M.A.F.F., 1960) the eradication programme has been less intensive, only about 9,500 received the complete treatment (making the same assumption as above) between 1948 and 1959 and a further 4,900 acres between 1941 and 1947. In addition there is the acreage treated under the comprehensive schemes.

The total annual grants paid between 1948 and 1959 in England and Wales have varied between £1,345 and £2,383 and in Scotland between £10,266 and £19,226 in the same period.

It is impossible to estimate with any accuracy what economic benefit the farmer and the nation have derived from the expenditure of these considerable sums of both private and public money. McCreath and Martin (1954) have examined the situation in a sample survey in Perthshire and provided encouraging evidence. In the case of some farms, control measures avoided the necessity of reducing the ewe stock and in many cases the performance of both ewes and lambs was much improved, while in some instances the stock was profitably increased. In a few cases, bracken eradication was not considered economic. On the basis of a specific case, McCreath (1958) worked out the necessary increase in both lamb numbers and prices to cover the cost of eradication. In the drier Roxburghshire hills the benefits appeared less decisive though eradication did tend to improve the fertility of the ewes, and it was recognised that bracken control on a long term basis was undoubtedly sound practice (Corner, 1956).

TREATMENT AND USE OF BRACKEN LAND

Unfortunately, there is no measure of the extent of the various types of bracken land mentioned above. As far as the more open communities are concerned it is very doubtful whether clearance would provide an economic return and as Corner (1956) points out complete eradication may not be sought. With increasing frond density, however, the prospects of profitable improvement are enhanced. Where there is little or no herbage beneath the canopy, additional treatment to produce a worthwhile sward is needed. Where such areas are on the open hill there is no reason to expect that treatment will ensure permanent clearance so long as the grazing regime remains unaltered. For this reason, the treatment of bracken with an effective spray is not necessarily a "once only" job.



BRACKEN CUTTING Estimated Approximate Annual Acreage Receiving Double Cut in First Year of Treatment and Gross Cost for 1948-1959 (Excluding work under Hill Farming and Livestock Rearing Schemes

A proportion of the bracken land in the first category above could be improved for out of season grass, by ploughing or by the slower management techniques including fencing. In view of the present high cost of hogg-wintering (Grant 1960) its use for that purpose would be of considerable benefit on many farms.

As regards bracken distributed more widely on the hill, the value of eradication is a rather open question. An increase in production of sheep and cattle from the uplands at lower cost is an aim to be pursued, but the large scale clearance of this land for further exploitation, without the integration of improved areas into a sound system of hill pasture husbandry, could lead to unfortunate ecological effects.

CONCLUSIONS

Although the acreage of bracken infestation throughout Britain is extensive, the area on the hill itself which could be profitably destroyed may be more limited than would at first appear to be the case. There is no doubt that routine bracken control is an essential element in maintaining production on hill grazings, but large scale clearance is unrealistic without measures to improve the husbandry techniques which are the fundamental cause of its existence. Theoretically, extensive eradication would be the means of temporarily increasing production from hill grazings, but immediate economic advantages should not make more difficult the long-term requirement which is the adoption of pasture management techniques capable of progressively improving the status of rough grazings under pastoral use.

ACKNOWLEDGEMENTS

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CONSIDERATIONS IN JUDGING CONTROL METHODS OF PTERIDIUM AQUILINUM

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Although the usual methods of judging control methods of Pteridium aquilinum, the common bracken fern, are by frond counts from unit areas, it is now widely recognised that the expanded fronds of Pteridium aquilinum are only seasonal and temporary organs, and that effective attack must be directed towards the massive underground stem. This paper is an attempt to present some considerations that must be borne in mind in evaluating methods of control, and a primary consideration is the form of this underground stem, the plant's central organ. It is this organ from which the fronds arise, and it is the agent responsible for invasion as well as for the plant's ability to pass the winter in a healthy state ready to begin further growth and expansion the following year.

The tangled mass of rhizome which is found when bracken land is dug is really a large number of branches, each with a marked growing-point at the tip and each capable of forming a new and separate centre of growth and development. These branches can be divided into three categories: (1) thick ones that run deeply into the soil and are the main agents responsible for the outward expansion of the the colony. Normally, they carry few fronds or frond-buds; but if any factor causes them to grow up towards the surface of the soil, they initiate frond-buds that later come above the soil as expanded fronds; (2) thinner, smaller branches running near the soil surface: these are the main frond-bearing branches; and (3) intermediate branches linking (1) and (2) and capable of developing into either as environmental factors act on them. Branches (2), with their frond-bearing function, are those of immediate interest, though branches of type (1) are those which give the plant its considerable resistance to extermination.

In the West of Scotland, fronds expand on branches (2) during May from frond-buds already initiated in the previous year. The branch axes elongate from late May or early June onwards, and new frond-buds become visible (one or two on each apex) late in July. Growth of the stem axis appears to slow down (though not necessarily to stop) during the early part of the autumn, while development of the frond-buds continues markedly as long as the soil temperature and drainage remain at a high enough level. Closer examination of branches of type (2) at the end of a season show that they may be divided into two categories:
(A) certain of the branches are those carrying expanded fronds with one or more frond-buds on the same axis and nearer to its apex. Usually each axis bears only one expanded fonnd each season, though if that frond dies or is removed, the adjacent frond-buds are stimulated and expand to replace the earlier frond.
(B) Intermingled with branches A, other similar axes can be found that carry frond-buds but no expanded fronds. Such frond-buds appear capable of remaining below ground in a healthy state for undetermined lengths of time, only developing into expanded fronds in response to some environmental or other factor. It is clear, then, that the number of expanded fronds on a unit area gives no adequate picture of the reserve of front-buds below ground; and in almost all areas, this large reserve of frond-buds is a constant feature.

During the past few years, the development of the rhizome in the field has been examined in a number of areas in the West of Scotland and the North of England, by digging out unit areas of 1 sq yd and analysing branches A and B.

Some examples of the extent of the variability in the number of stem axes and frond-buds present is shown in Table I. From this, the chief points for comment are (1) the variations are great enough from plot to plot in any area to call for individual explanation of drainage, soil type and fertility as well as litter-cover and other factors of micro-environments. For instance, site C of the Dumfriesshire areas was found to be near a winter water course: the water-logged state of the soil through the cold season had slowed down and curtailed development, so that the analysis of the underground organs showed much reduced development of stem tips and frond-buds. Similarly, the Yorkshire site analysed was on land known to have been cut yearly for many years. The very high degree of frond-bud initiation is in line with results from other areas of prolonged cutting (Conway & Stephens, 1954). (2) From all the sites analysed, the number of healthy branch apices and frond-buds was high; numbers of dead branch tips or frond-buds were very small indeed. (3) The reserve of underground frond-buds was marked on all the sites and the ratio of frond-buds to expanded fronds was higher than normal replacement would suggest. Such high ratios suggest either that a considerable number of frond-buds die before expansion or that many can remain in a quiescent and dormant state for undetermined periods, expanding only on receiving some form of stimulation. (4) The majority of frond-buds are carried by branches that do not show an expanded frond of the current year, branches of type B. It is clear that these branches cannot be directly affected by methods of control that act only on the expanded fronds.

The point of primary consideration to the agriculturalist, and the acid test of any form of attack on Pteridium aquilinum, is the degree to which healthy fronds are found on treated areas in the years after treatment. And so, in considering the value of any form of treatment, it is clear that we must know, not only the way in which the treatment affects the underground frond-buds and the stem apices that continue to form frond-buds, but also something of the extent of the reserve of frond-buds. Table 2 shows an analysis of the state of branches A and B dug out from experimental areas treated both by cutting away the fronds and by chemical spraying with a translocated growth-regulating compound, 4-chlorophenoxyacetic acid. This table shows that (a) cutting has no lethal effects on the growing points of the underground stem though it may slow up the rate of development. This point can be seen in the slightly fewer frond-buds visible on the branch tips of both A and B types. (b) Spraying of a translocated herbicide has marked lethal effects on the stem apices and on the frond-buds which they carry. In this way further development of the axes concerned is stopped. (c) The rate of damage caused in the apical tissues of axes adjacent to a current year frond - i.e. to the point of application of the chemical - is high; but damage caused to branches of type B is markedly less. Experimental work has shown that translocated compounds such as 4-CPA are carried with ease to the apex of an axis on which a treated frond is borne; but that there is much less translocation in a basal direction or to the tip of an axis without a point of direct application. (Conway & Forrest, in the press).

It thus becomes clear that evaluation of treatment made by counting fronds on a unit area in the following years reflects the number of frond-buds that escaped the effects of treatment and are later able to expand. This number is further conditioned by the extent of the rhizome development in the treated area before treatment was applied; for example, the areas shown in table I by Dunbartonshire C or the Yorkshire area, with their high ratio of frond-buds on branches of type B, are likely to show extensive regrowth in the first year or two after any form of treatment. The very great advance shown by foliar spraying with certain of the translocated herbicides is that the branches affected are killed and are unable to develop further. In the case of defoliation treatments, the growing points are not killed: though their rate of development may be reduced they remain as growth-centres, and sooner or later fully formed fronds will again expand from the apices of all the branches.

In judging methods of controlling bracken, then, it is important that two primary considerations shall be (a) appreciation of the development of the underground stem in the area to be treated, and (b) recognition of the damage caused by treatment and the degree to which it is lethal. Only if these points are known and understood can the worth of any form of control really be judged.

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TABLE I. FROND & FROND-BUD POPULATIONS OF 1 SQ YD IN SEPTEMBER

	Argyll		Dunbartonshire			Dumfriesshire				Yorkshire
	(i)	(ii)	(i)	(ii)	(iii)	(i)	(ii)	(iii)	(iv)	(i)
No. of expanded fronds	28	14	30	40	22	27	34	18	25	40
No. of living stem apices	88	75	246	198	174	138	204	66	118	282
No. of living frond-buds	60	51	164	110	156	106	124	30	68	132
Ratio: expanded fronds to frond-buds	1:2.1	1:3.6	1:5.5	1:2.7	1:7.1	1:3.9	1:3.6	1:1.7	1:3.6	1:3.3
Ratio: frond-buds on branches A to frond-buds on branches B.	1:2.7	1:4.7	1:4.4	1:1.9	1:5.0	1:3.2	1:2.0	1:1.0	1:4.0	1:8.2

TABLE. II. THE EFFECTS ON STEM APICES & FROND-BUDS OF MECHANICAL & CHEMICAL TREATMENT

	Mean figures from sites analysed in September:							
Treatment (data from not less than 5 sites in each case)	Branches type A				Branches type B			
	Rhizome-tips/20		Associated frond-buds		Rhizome-tips/10		Associated frond-buds	
	Healthy	Dead or dying	Healthy	Dead or Dying	Healthy	Dead or Dying	Healthy	Dead or dying
Untreated	20	-	17	-	10	-	9	-
Twice Cut (End of June and early August)	20	-	16	-	10	-	8	-
Foliar spray in early July with 4-CPA (Butoxyethanol ester):-								
10 lbs. a.e. " "	3	17	2	8	4	6	3	3

SOME ASPECTS OF THE CHEMICAL CONTROL OF BRACKEN

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A. H. Marks & Co. Ltd.

Summary: Trials have been continuing since 1955 in Scotland and 1958 in England on the control of bracken by chemicals. Hormone-type herbicides have been found to be most effective, in particular, emulsifiable ester formulations of 4-chlorophenoxy-acetic acid. The extensive rhizome system of bracken with its large number of frond buds invariably possesses an unfavourable ratio of growing fronds to potential frond buds. To give control of a high order a chemical must be capable of being easily translocated at lethal dosage over relatively long distances within the rhizome. The amount of chemical translocated is, within limits, dependent on the quantity penetrating the frond cuticle and this in turn is probably dependent on the stage of maturity of the bracken. These and other factors limit the degree of control obtained with chemicals. To date a reduction in the bracken density of 70-80% appears to be possible under normal climatic conditions. Reductions of a higher order have been obtained and investigations are in hand to evaluate the conditions under which these higher reductions take place.

INTRODUCTION

In 1955 Coulson (1956) acting on a suggestion by Amchem Products Inc. laid down a set of bracken trials at Moffat, Scotland, involving a range of herbicides. A visual inspection of the plots in 1956 indicated that 4-chlorophenoxyacetic acid (4-CPA) was markedly toxic to bracken. An extensive study of the effect of herbicides on bracken, in particular 4-CPA, was initiated in 1957 and this work is still actively proceeding. This paper is an interim progress report of these investigations.

As details of Coulson's now famous plots have not previously been published, a brief summary of the work is given. Plots of 1/40th acre were sprayed with a watering can at 100 gals total volume per acre using the following herbicides ;

Plot	
1	6 lb MCPA/ac as emulsifiable butyl glycol ester.
2	12 lb MCPA/ac as emulsifiable butyl glycol ester.
3	9 lb 4-CPA/ac as emulsifiable butyl glycol ester.
4	18 lb 4-CPA/ac emulsifiable butyl glycol ester.
5	1¼ lb 3-amino 1,2,4-triazole/ac + 1¼ lb sodium sesqui-carbonate/ac.
6	2½ lb 3-amino 1,2,4-triazole/ac + 2½ lb sodium sesqui-carbonate/ac.
7	As Plot 1 + Plot 5.
8	As Plot 3 + Plot 5.

Frond counts were not recorded in 1956 but visual examination indicated a reasonable reduction in plots 1, 2, 7, and 8 and an excellent reduction in plots 3 and 4. The plots were inspected in August 1960 when four still showed good control. The reduction in frond density for these plots based on randomised frond counts is given in Table I.

TABLE I. REDUCTION IN FROND DENSITY IN AUGUST 1960 FOR COULSON 1955 PLOTS

Plot	Percentage Reduction
2	65
3	82
4	93
8	89

METHODS AND MATERIALS

To obtain a representative selection of bracken growing under a variety of different climatic and soil conditions, five sites have been used in Scotland since 1957, namely Langholm, Dumfrieshire; Moffat, Dumfrieshire; Callander, Perthshire; Kilmelfort, Argyllshire and Tobermory, Isle of Mull. In England, Ramsgill, Yorkshire, has been used since 1959. Single plot experiments were made at each site on 1/40th acre plots and in the main experiments were repeated on each site. Whilst it is appreciated that replication would have been ideal, the size of the programmes and our limited resources did not make this feasible. In 1957 and 1959 plots 10 x 12 yd were used and in 1958 4 x 30 yd. The latter size has now been discarded as encroachment of fronds from the perimeter makes accurate assessment difficult, if not impossible, in future years.

Although some screening trials have been made, the main experiments have involved low volatile 4-CPA ester formulations containing 5 lb 4-CPA/gal. All formulations were applied with the Oxford Precision Sprayer as aqueous emulsions at total volume rates of 20 - 100 gal/ac.

The reduction in frond density has been assessed in years subsequent to treatment by six randomised one square yard frond counts in the plot and six in the adjacent untreated bracken. This method of assessment gives fairly consistent results in uniform bracken but can give a false picture where growth is patchy and interspersed with dense clumps. Where an obvious reduction in density has been obtained, the growth the following year normally shows typical growth regulator effects and is less vigorous than adjacent untreated bracken. Although the reduction in vigour has not been recorded as a routine, it has been observed that the greater the density reduction, the less vigorous is the regeneration.

The emergence of fronds from rhizomes at different depths takes place over an extended period and treatment with hormone herbicides often further delays emergence of fronds the following year. In order to obtain a true assessment it has been found necessary to delay counting until late August or early September. Table II illustrates the difference in reductions obtained at Ramsgill when counts were taken in late June and early September 1960.

TABLE II. PERCENTAGE FROND REDUCTIONS FOR 1959 RAMSGILL PLOTS AT DIFFERENT ASSESSING DATES

Spraying date 1959	5 lb 4-CPA/ac		7½ lb 4-CPA/ac	
	June 1960	Sept 1960	June 1960	Sept 1960
29th July	73	55	76	59
13th August	51	17	70	38
19th August	57	30	49	38
7th September	32	55	9	42
7th September	23	38	38	52

This delay in obtaining a true assessment of the previous year's treatment results in a two year interval between the treatment and any subsequent treatment based on the initial results.

RESULTS AND DISCUSSION

The complex nature of the bracken rhizome with its large reserve of potential frond and apical buds presents a formidable herbicide problem particularly when coupled with the many other variables well known in the weed control field, viz. stage of growth, climate, soil type, aspect, drainage, etc. The Conway method of rhizome analysis (Conway, E. 1958) has been applied to all the material excavated from one square yard plots of untreated bracken at various sites, and some of the results are summarised in Table III. At dosage levels of 5 - 10 lb 4-CPA/ac rhizome analysis has shown that a high percentage of the frond buds associated with the current fronds are destroyed. This is not the case, however, with frond buds attached to older rhizomes where translocation of the herbicide over relatively long distances is required. The destruction of these frond buds is usually of the order of 50-90 per cent, i.e. a number of healthy frond buds always remain underground after treatment and can approximately equal the number of fronds above ground at the time of treatment (Table IV). Such healthy frond buds are responsible for regeneration and some will appear as fronds the year after treatment, or in future years. Several years' work has confirmed the indication obtained by digging analysis, i.e. it is not possible to obtain consistently complete or near complete eradication of the rhizome with the materials tested. Of the latter 4-CPA esters have been found to be most effective. Occasionally conditions combine to give a reduction in excess of 90 per cent, but on average reductions are below this figure.