TABLE III. TYPICAL 1 SQ YD RHIZOME ANALYSIS FOR 1958 SCOTTISH SITES

	Langholm	Callander	Moffat	Kilmelfort	Tobermory
No. of fronds/sq yd	21	25	27	28	45
Rhizome at base of current year frond.					
Stem apices	16	26	30	30	38
Frond buds	16	22	26	20	34
Older parts of rhizome.					
Stem apices	94	126	114	56	154
Frond buds	60	80	84	42	112
Ratio current fronds : Older rhizome frond buds	1 : 2.9	1 : 3.2	1 : 3.1	1 : 1.5	1 : 2.5

TABLE IV. ANALYSIS OF FROND BUDS ATTACHED TO CURRENT FROND AND OLDER RHIZOMES

Average results obtained over five sites in 1958 Scottish Trials for late June and July Treatment.

Treatment	Percentage of Frond Buds healthy or only slightly affected			
lb 4-CPA/ac	Attached to current frond.		Attached to older rhizome	
	June	July	June	July
5/Formulation A	10	0	50	30
5/ " B	15	0	40	20
5/ " C	10	5	40	30
5/ " D	0	0	40	20
7½ " A	5	0	50	20
7½/ " C	5	10	40	40
7½/ " D	5	0	50	20
10/ " A	0	0	40	10
10/ " C	0	0	30	20
10/ " D	0	0	-	10

To date only a limited number of the variables associated with 4-CPA ester formulations have been examined and these are summarised as follows:-

(a) Rate of Application

In 1957 trials were made involving dosage rates of 5, 7½, 10, 15 and 20 lb 4-CPA/ac as low volatile ester formulations. Although higher dosage levels gave better control, the increase was not pro rata and for economic consideration future work was restricted to 5, 7½ and 10 lb 4-CPA/ac. (Table V).

TABLE V. COMPARISON OF FROND REDUCTIONS AT DIFFERENT DOSAGE AND VOLUME RATES

Treatment	Percentage Reduction in Frond Density	
lb 4-CPA/gal H_2O/ac	August 1958	August 1960
Moffat 23rd July 1957		
7½/20	85	85
7½/50	85	77
7½/100	71	54
10/20	92	72
10/50	98	81
10/100	69	56
20/20	98	82
20/50	95	81
20/100	97	83
Tobermory 21st June 1957		
5/20	41	74
5/50	56	64
5/100	52	72
6.25/20	59	69
6.25/50	44	59
6.25/100	59	66

(b) Total Volume of Application

As shown in Table V trials were made in 1957 at different total spray volumes per acre. There did not appear to be any significant difference in the level of reduction obtained at 20 and 50 gal/ac. In some cases a lower reduction was obtained at 100 gal/ac due presumably to a greater loss by run-off from the fronds. Tractor application at rates from 5 to 30 gal/ac have confirmed that in this range spray volume is not critical. Since 1958 the total volume rate has been standardised at 20 gal/ac.

(c) Respraying in the year of application

A series of trials were made at Tobermory and Callander in 1957 involving two and three treatments of the same plot during the same season employing small dosage rates. The reduction obtained was usually lower than with the same total amount of 4-CPA applied in one application (Table VI).

TABLE VI. EFFECT OF MORE THAN ONE APPLICATION OF 4-CPA IN ONE SEASON 1957

Treatment		Percentage Reduction in Frond Density
lb 4-CPA/ac	Date(s)	August 1958
Tobermory		
5 x 1 treatment	28/6	70
5 x 1 "	28/6	67
6.25 x 1 "	28/6	67
2.5 x 2 "	14/6, 28/6	44
2.5 x 2 "	14/6, 5/7	52
3.75 x 2 "	7/6, 21/6	41
3.75 x 2 "	14/6, 28/6	45
3.75 x 2 "	14/6, 5/7	48
3.75 x 2 "	21/6, 12/7	79
2.5 x 3 "	7/6, 21/6, 19/7	67
5 x 2 "	28/6, 19/7	
Callander		
2.5 x 1 treatment	1/7	43
5 x 1 "	30/7	71
10 x 1 "	2/7	97
2.5 x 2 "	10/6, 25/6	55
3.75 x 2 "	3/6, 17/6	-70 (increase)
3.75 x 2 "	10/6, 1/7	44
3.75 x 2 "	26/6, 9/7	50
5 x 2 "	17/6, 17/7	64

(d) Time of Application

The stage of development of the bracken frond at the time of spraying is a most critical factor. The 1957 trials were made between June and July, and there did not appear to be any obvious differences in the results obtained over that period. In 1958 trials were made on two dates at each site, using different plots on each occasion. The first spraying was in the period 23rd June - 5th July and the second 21st July - 1st August. Intense scorch of the plots sprayed in the first period was observed by the second spraying date, whereas the scorch produced by the second spraying was not nearly so pronounced even a month later. At the early spraying the fronds were some 50-70 per cent unfurled and the immature fronds were extensively damaged by the heavy dose of 4-CPA. At the later spraying a high proportion of the fronds were fully unfurled and scorch was less extensive, presumably due to the development of a thicker cuticle. The effect of spraying at different stages of development was shown by rhizome analysis in the treated areas the following September (Table IV) and by the frond density reduction figures the following year (Table VII).

TABLE VII. EFFECT OF TIME OF APPLICATION ON FROND DENSITY REDUCTION.

(a) Application dates 1958

	Late June - Early July.	Late July - Early August
Langholm	4th July	1st August
Callander	1st July	27th July
Kilmelfort	23rd June	21st July
Tobermory	27th June	23rd July
Moffat	3rd July	31st July

(b) Results giving percentage reduction in frond density, September 1959: Formulation A

	5 lb 4-CPA/ac		7½ lb 4-CPA/ac		10 lb 4-CPA/ac	
	June	July	June	July	June	July
Langholm	22	50	39	62	60	69
Callander	45	87	46	78	46	82
Kilmelfort	27	62	31	68	40	61
Tobermory	58	76	78	88	83	96
Moffat	68	75	83	78	90	86
Average	44	70	56	75	64	79

A preliminary count of the 1958 trials was made in early July 1959 and in view of the results obtained the 1959 trials were retimed in an endeavour to cover the stage of maximum susceptibility. As the bracken was rather late in developing a small number of plots were treated in mid July, the majority being sprayed either early or late August. The mid July application (Table VIII) gave reductions comparable with the late July 1958 application. On average the order of reductions was mid July > early August > late August. On the west coast of Scotland the bracken in 1959 reached maturity earlier than normal and started to die back before the end-of-August application (see Kilmelfort and Tobermory). At Tobermory autumnal tints were observed even at the early August spraying and at the second spraying 90 per cent of the fronds were dead. In the above 1959 Scottish Trial the reductions in frond density were greater than those obtained at Ramsgill (Table II) and workers in other parts of the country also obtained lower average reductions with the same dose of comparable 4-CPA ester formulations.

There is little doubt that the abnormally hot, dry summer of 1959 had an important effect on the bracken cuticle as evidenced by the results obtained and the small degree of scorch observed. In many cases it is highly probable that the herbicide was not applied at the period of maximum susceptibility. The latter will vary with the season and locality. From the present state of our knowledge it would appear that maximum susceptibility is coincident with full expansion. The duration of the period of high susceptibility after the frond is fully unfurled is an unknown factor. Extensive time trials have been conducted this season in both Scotland and England in an attempt to obtain further information on this important aspect.

TABLE VIII. PERCENTAGE REDUCTION IN FROND DENSITIES FOR 1959 TRIALS.

Results based on counts made 22-26th August 1960.

(a) Application dates 1959

	July	Early August	Late August
Langholm	9th July	30th July	24th August
Callander	13th "	3rd August	27th "
Kilmelfort	15th "	4th "	29th "
Tobermory	17th "	6th "	30th "
Moffat	11th "	1st "	26th "

(b) Results.

	5 lb 4-CPA/ac			7½ lb 4-CPA/ac			10 lb 4-CPA/ac		
	July	E.Aug	L.Aug	July	E.Aug	L.Aug	July	E.Aug	L.Aug
Langholm	50	69	56	71	84	72	64	95	69
Callander	68	66	55	82	60	48	90	79	74
Kilmelfort	59	47	7	72	60	54	77	72	59
Tobermory	45	27	34	96	-11	41	75	-11	11
Moffat	84	82	72	83	91	74	79	88	72
Average	62	59	47	81	57	58	78	64	57

negative value indicates increase over control.

(c) Respraying in the following year

Half of each of the 1958 plots detailed in Table VII were resprayed at the corresponding original dosage level in either early or late August 1959. The percentage frond reduction results based on late August 1960 counts are given in Table IX.

TABLE IX. EFFECT OF RESPRAYING IN THE YEAR FOLLOWING TREATMENT

(a) Respray dates 1959

	June 1958	July 1958
Langholm	28th July	25th August
Callander	2nd August	27th "
Kilmelfort	5th "	29th "
Tobermory	6th "	30th "
Moffat	31st July	26th "

(b) Results giving percentage reduction in frond density, August 22-29, 1960.

1S = Half plot receiving one treatment
2S = " " " two treatments

(78178)

TABLE IX (continued)

	5 lb 4-CPA/ac				7½ lb 4-CPA/ac				10 lb 4-CPA/ac			
	June		July		June		July		June		July	
	1S	2S	1S	2S	1S	2S	1S	2S	1S	2S	1S	2S
Langholm	10	46	24	46	20	78	22	57	48	87	42	72
Callander	37	67	45	83	32	69	40	75	43	63	40	77
Kilmelfort	53	55	36	44	12	44	35	40	26	58	29	57
Tobermory	38	70	67	74	60	77	56	72	60	68	79	75
Moffat	74	87	65	76	64	88	59	78	91	97	82	83
Average	43	67	50	66	67	73	45	67	58	77	60	74

A further reduction in frond density is obtained by a second treatment but this does not appear to be in direct relationship to the dose applied, presumably due to the smaller number of fronds available for transporting the second treatment of herbicide. Half of each plot in the 1959 trials was resprayed in 1960 to obtain further information on this aspect.

(f) The Effect of different Formulation Types

A number of formulations involving different esters of 4-CPA in different oil-in-water emulsifier systems have been employed and there does not appear to be any significant difference in their herbicidal activity to bracken. An amine salt formulation of 4-CPA was tested in 1959 and this under dry weather conditions gave reductions of a similar order to the 4-CPA ester formulations. When applied to wet bracken or when rain following spraying, the efficiency of the amine formulation was considerably reduced. As it was not possible to always spray bracken under ideal dry weather conditions, work on amine formulations has been suspended in favour of water resistant formulations. The latter are, of course, the invert or water-in-oil formulations, developed by Amchem Products, Inc.

When an invert formulation is diluted with a hydrocarbon oil and water, a viscous water-in-oil emulsion is formed. The viscosity of the emulsion can be decreased by the addition of more oil or increased by the addition of more water. Such an emulsion produces a droplet in which the outer boundary is an oil solution of the herbicide with an inner water droplet. This emulsion is very resistant to water, adheres tenaciously to foliage, is not removed by rain and quickly wets out the cuticle.

Invert formulations of 4-CPA were tested in 1958 and were found to give higher and more consistent reductions in frond density than oil-in-water type formulations (c.f. Tables VII and X).

TABLE X. PERCENTAGE FROND REDUCTIONS USING AN INVERT TYPE FORMULATION SCOTLAND 1958

Frond counts taken September 1959

	5 lb 4-CPA/ac		7½ lb 4-CPA/ac		10 lb 4-CPA/ac	
	June	July	June	July	June	July
Langholm	66	84	79	88	65	91
Callander	84	89	84	92	86	91
Kilmelfort	47	84	40	86	44	92
Tobermory	56	76	67	92	73	95
Moffat	46	74	17	92	53	87
Average	60	81	58	90	64	91

These trials were repeated at the same sites in 1959 but reductions of a much lower order were obtained, being in some instances inferior to the normal ester formulations. (c.f. Tables VIII and XI). Invert formulations have been included in the 1960 time trial programme in an endeavour to find an explanation for the discrepancy between the two years.

TABLE XI. PERCENTAGE FROND REDUCTIONS USING AN INVERT TYPE FORMULATION SCOTLAND 1959

Frond counts taken late August 1960

	5 lb 4-CPA/ac		7½ lb 4-CPA/ac	
	Early Aug.	Late Aug.	Early Aug.	Late Aug.
Langholm	58	25	62	25
Callander	94	77	67	61
Kilmelfort	19	49	32	39
Tobermory	36	49	14	16
Moffat	71	58	74	69
Average	58	52	43	44

(g) Screening of other Chemicals

During the course of the above trials some other chemicals have been applied to bracken. No chemical more toxic to bracken than 4-CPA has been found. The following formulations have shown only a low toxicity at the levels tested.

(a) 4-CPP ester formulation at 5, 7½ and 10 lb/ac
(b) 2,4-D ester formulation at 5, 7½ and 10 lb/ac
(c) Emulsifiable DNBP formulation at 5 lb/ac
(d) Emulsifiable DNOC formulation at 5 lb/ac
(e) Emulsifiable Pentachlorophenol-3-Amino-1,2,4-triazole at 2.5 lb of each/ac.

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THE CONTROL OF BRACKEN - A PROGRESS REPORT ON HERBICIDE AND POST-SPRAYING MANAGEMENT TRIALS

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Summary. Dalapon, aminotriazole (with and without ammonium thiocyanate) and 4-CPA are compared at two sites as bracken killers, each being sprayed at two dose levels, and at two dates. These trials are identical in design to those laid down in England and Wales by the A.R.C. Unit of Experimental Agronomy at Oxford. On assessment of frond density a year after spraying it was found that (a) none of the chemicals gave a satisfactory control, (b) reduction in frond density increased with dose level and earlier spraying, (c) at site 1 (the 'later' in terms of stage of bracken growth) reductions in frond density were greater, amino triazole application giving maximum control, and (d) "activation" of amino triazole with ammonium thiocyanate decreased its effectiveness, not markedly but consistently. It would appear that the chemical did not reach, or did not enter the rhizome frond buds in sufficient quantity to have a toxic effect. The period of susceptibility of the plant may depend on such factors as stage of frond maturity and rhizome frond-bud development. The variation in results obtained between sites may be due to the influence of environment on these factors.

Results showing the influence of litter removal and fertiliser treatments on sward germination and establishment on sprayed bracken land are presented. Litter removal by fire or mechanical raking had little effect on sward establishment, removal by molasses application however, resulted in an increased yield 6 months later (Box trial). Lime and slag, but not "Nitrochalk" significantly increased sward yield.

PART I. HERBICIDE TRIALS

INTRODUCTION

Two trials of the type suggested by the International Research Group of Weed Control (1959) were laid out in 1959 in co-operation with the A.R.C. Unit of Experimental Agronomy at Oxford. The aim was to test several chemicals which had shown promise as bracken killers either in this country or in Europe.

METHODS AND MATERIALS

The trials were laid down at Dunoon, South Argyll (Site 1) and Ballachulish, North Argyll (Site 2) plot size being 6 x 4 yd, with 1 yd paths between plots. Sites had been selected for their uniformity of stand but at site 2 the bracken was generally of a shorter, more wiry nature than that of site 1. In each case the experiment was of a randomised block design having three replicates, there being one control plot per replicate.

Four chemicals tested were dalapon-sodium, amino triazole, amino triazole plus ammonium thiocyanate +, each at 10 and 20 lb/ac, and 4-CPA-nonyl ester + at 5 and 10 lb.

Using an Oxford Precision Sprayer, application of each chemical was made at the rate of 20 gal/ac with 00 ceramic jets at 30 psi. Dates of spraying were 30th July and 30th August, 1959 at site 1, and one day later in each case at site 2. The weather at time of spraying and for at least 24 hours later was warm, dry and sunny. Assessment of the trials (19th and 20th July, 1960, site 1 and 2 respectively), was carried out using a quadrat 3 x 5 yd on size, border discard being 18 in. The quadrat was divided into three sections, and all fronds within each counted. The average height of the bracken was noted in each plot as an indication of vigour.

RESULTS

The effect of spraying dalapon, amino triazole and 4-CPA at two sites with identical dosage levels and spraying dates is seen in Table I.

TABLE I. THE EFFECT OF DOSE AND SPRAYING DATE (1959) ON FROND DENSITY (1960) AT SITES 1 AND 2.

(Figures in parenthesis are percentage reductions in relation to the controls).

	Frond Number (mean of 3 replicates)							
	Site 1				Site 2			
Chemical	Dose 1	Dose 2	Spraying date 1	Spraying date 2	Dose 1	Dose 2	Spraying date 1	Spraying date 2
Untreated	435	435	435	435	389	389	389	389
Dalapon	390 (10.5)	309* (29.0)	242* (44.4)	456 (-5.0)	353 (9.6)	340 (12.7)	354 (8.9)	338 (13.1)
Amitrole	280* (35.8)	220* (49.5)	219* (50.0)	281* (35.5)	441 (-12.6)	415 (-6.6)	443 (-6.5)	443 (-14.0)
Amitrole + NH_4SCN	285* (34.5)	287* (34.1)	270* (38.0)	303* (30.5)	468 (-20.0)	428 (-9.9)	422 (-8.5)	473 (-21.7)
4-CPA	443 (11.8)	396 (9.0)	393 (9.6)	446 (-2.5)	357 (8.1)	331 (15.0)	290 (25.5)	399 (-2.5)
LSD (P=0.05) between:-								
1. Control and treatments (*)	± 129.20				N.S.			
2. Treatments	± 105.42				N.S.			

* As "Dowpon", "Weedazol" and "Weedazol T.L." respectively

+ As "Weedone Brackontrol"

At site 1, dalapon and amino triazole (both with and without ammonium thiocyanate) significantly ($P = 0.05$) reduced frond density. Generally reductions increased with dose level and with earlier spraying. Amino triazole appeared less effective when "activated" with ammonium thiocyanate.

At site 2, no spray treatment had a significant effect. Dalapon and 4-CPA tended to reduce frond density, whereas all amino triazole applications tended to increase density, especially the activated formulation, at the lower dose and later spraying date.

DISCUSSION

Previous trials with 4-CPA, and current experiments with amino triazole as reported at this conference by Erskine and Hodgson, have shown promising reductions in frond density. The results for these chemicals presented in Table I are disappointing in comparison. The following hypotheses are put forward as possible explanations.

When a translocated herbicide is applied to bracken, it is translocated from the fronds, down into the underground rhizome system where ideally it should accumulate in the meristematic regions leading to their eventual death. It would appear in this case that the chemicals did not reach, or did not enter the rhizome frond buds in sufficient quantity to have a toxic effect.

Taking firstly the hypothesis that the chemical did not reach the buds. McIntyre (1960a) using radioactive 2,4-D found that translocation was 'considerably reduced as the frond approached maturity' Apparently cuticle penetration was the limiting factor. It is possible that this finding would apply to the action of other plant growth regulators. With regard to the present trial, the growing season of 1959 was exceptionally dry. It may be that the cuticle thickened more rapidly than normal, thereby retarding even at the first spraying date, the entry of the chemical into the frond.

Another explanation, perhaps complementary to the first, may be that the chemical could not enter the rhizome frond-buds. Watt (1940) and McIntyre (1960b) have charted the activity of rhizome frond-buds throughout the growing season. The latter, for example, found in 1957 that bud formation activity (and presumably carbohydrate intake) commenced in early June, reached a maximum around mid-end July, and rapidly declined in activity during August. He suggests that soil moisture may have a marked effect on this activity curve, and that up to a point increased soil moisture will cause a later peak in activity of the bud. As the season of 1959 was exceptionally dry, it may be that the peak of maximum activity had passed even at the first spraying date, and that entry of chemical to the bud was retarded.

Both of these hypotheses would indicate that time of spraying was too late for effective movement of the chemical from the fronds into the rhizome frond-buds. The dates of spraying were based on results from trials sprayed in 1958, unfortunately the marked difference in nature of the 1958 and 1959 seasons was not taken into account. In the West of Scotland, the growing season of 1959 was some 10 - 14 days earlier, it is estimated, than average, and that of 1958 some 10 days later than average. The early summer of 1959 was characteristically dry and that of 1958 wet. Thus what was the optimum spraying period for 1958 trials may in fact have referred to a stage of frond cuticle and rhizome

bud development occurring some 3 - 4 weeks earlier in the 1959 season. This divergence would be more, or less, aggravated by such ecological factors as 'aspect' and 'altitude.' The broad difference in results between the two sites in the present trials emphasises the latter point. Although no record was taken of time of emergence, it was noted in 1959 that the bracken at Ballachulish (site 2) began to 'go back' sooner than at Dunoon (site 1). Presumably the cuticle thickened and the rhizome buds entered a state of dormancy at an earlier period also.

PART II. POST-SPRAYING MANAGEMENT

INTRODUCTION

The need for a follow-up programme has been more fully discussed elsewhere (Kirkwood and Fletcher, 1960); it is sufficient perhaps to say that the rapid establishment of a sown sward, or rapid improvement of an existing pasture would be expected to have two main consequences. First, it should allow early and increased stocking, especially with cattle. Obviously this would be advantageous from two points; first, in enabling a more rapid return of the cost of bracken spraying, and second in minimizing the regeneration of bracken from the possibly remaining 25 per cent not killed. Second, it should prevent the possible recolonisation of the treated area with weed infestations such as foxglove (Digitalis purpurea) and willow herb (Chamaenerion angustifolium).

As a preliminary approach to this problem, bracken turfs placed in boxes in a greenhouse were subjected to various litter removal and fertiliser treatments. From these experiments it was hoped to gain information on the influence of these treatments on grass-clover germination and establishment. Following this experiment a comprehensive field trial was laid down to test these treatments on a field scale and to provide information on the influence of stocking on the developing sward and bracken regeneration.

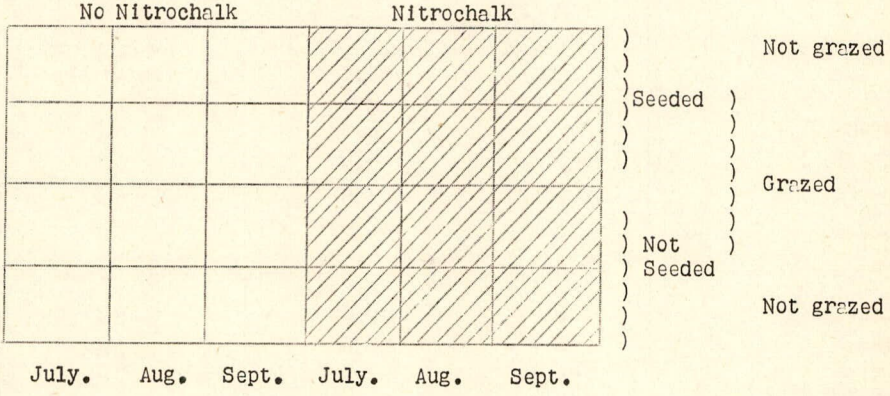
METHODS AND MATERIALS

Preliminary greenhouse trial

The treatments for litter removal were carried out on 29th January and comprised removal by fire, mechanical raking, and application of molasses (equivalent of 48 cwt/ac). Lime and fertiliser treatments were applied at the same time; hydrated lime (30 cwt/ac) and superphosphate (3 cwt/ac) being added separately and in combination. The experiment was of a randomised block design having two replicates. A uniform seeds mixture of perennial ryegrass (L. perenne) S.23 12 lb/ac, cocksfoot (D. glomerata) S.143 8 lb/ac and white clover (T. repens) Cert. Mother. N.Z. 2 lb/ac was applied to all boxes on 9th March. The watering regime was adjusted to the equivalent to 55 in. rainfall per annum, application being made twice weekly until the boxes were transferred to the field in late April. All seedlings within a 12 x 6 in. quadrat were counted on 16th and 23rd March. In late August the boxes were harvested and the dry matter yield of each grass species taken.

Field Trial

This trial, laid down at Dunoon (South Argyll) was superimposed on a bracken eradication experiment which had been laid out in 1959. The original trial comprised 6 plots (5 x 20 yd, 2 yd separation between plots) which had been sprayed with 4-CPA* in late July, August, and September at the rate of 2 gal/ac (applied as 20 gal of spray/ac).



The diagram outlines the layout of the field trial. Litter removal and fertiliser treatments were carried out on the 30th March, the methods being identical to those of the box trial except that the molasses treatment was omitted, and 20 cwt/ac of low grade basic slag was applied instead of superphosphate. These treatments made up the basic randomised block, replication being confounded with seeding, grazing and application of "Nitrochalk". The seeds mixture applied on 33rd May had a higher proportion of perennial ryegrass (16 lb/ac) than that used in the box trial. The "Nitrochalk" top dressing was applied some four weeks later.

Germination estimates were made by counting the seedlings in a 12 x 6 in quadrat. Two quadrats were counted on each plot. The harvesting procedure was identical to that outlined above, the samples being the bulked cuts of 3 (12 in. x 6 in.) quadrats per plot.

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* As "Teridox"

RESULTS AND DISCUSSION

Preliminary Greenhouse Trial

TABLE II. THE EFFECT ON GRASS/CLOVER GERMINATION AND YIELD OF (a) LITTER REMOVAL, AND (b) FERTILISER TREATMENTS

	Treatment	Germination ŧ No. of seedlings Grass	Clover	Sward yield (gm/sq ft)
A	Untreated	25.0	6.0	6.8
	Mechanical	54.0	5.5	6.5
	Fire	18.0	6.5	6.2
	Molasses	17.0	4.0	9.0
B	Untreated	28.0	9.0	6.2
	Lime	29.0	8.8	5.8
	Slag	32.0	7.9	8.2
	Lime and Slag	24.0	6.0	8.3
	L.S.D. (P=0.05)	± 10.7	± 3.1	N.S.

ŧ Figures represent seedlings present in 12 x 6 in. being the mean of four replicates.

The effect of litter removal and fertiliser treatments on grass/clover germination and yield is shown in Table II. It will be seen that removal of bracken litter, by raking, significantly (P = 0.05) increased grass/clover germination, presumably because of the improved seed bed. Subsequent establishment, however, was not affected. Although application of molasses depressed grass/clover germination, an increase in yield resulted 6 - 7 months later from this treatment. This increase though not significant was found consistently for all molasses treatments and may be worthy of comment.

A possible explanation may be that the application of such a readily available carbohydrate increased the size and activity of the soil microbial population. When this added source of energy was used up, the activated population turned to the original organic material present in the soil, and presumably bracken rhizomes and litter were decomposed with greater rapidity than normal. This explanation based on work by Broadbent and Norman (1947) and Stotzy and Mortensen (1957) is perhaps substantiated by the fact that a highly significant increase in soil carbon dioxide evolution was noted subsequent to molasses treatment (Table III).

TABLE III. THE EFFECT OF LITTER REMOVAL TREATMENTS ON SOIL RESPIRATION

Litter removal treatment	Carbon dioxide evolved ŧ	Fertiliser treatment	Carbon dioxide evolved
Untreated	3.3	Untreated	5.0
Mechanical	2.6	Lime	5.0
Fire	3.4	Slag	5.5
Molasses	11.0	Lime & slag	5.9
L.S.D. (P=0.05)	± 2.4	L.S.D. (P=0.05)	N.S.

ŧ Expressed as ml of 0.05 N HCl.

Some indication of the extent to which decomposing bracken rhizome and litter may donate minerals to the soil is given by the results noted in Table IV.

TABLE IV. ANALYSIS OF BRACKEN COLLECTED BY RANDOM SAMPLING FROM THE SAME SITE AS BOX TRIAL TURFS.

Item	Analytical results (per cent in DM)		
	Fronds	Stems	Rhizome
Per cent Nitrogen	1.39	0.45	1.61
Per cent Phosphate as P_2O_5	0.20	0.08	0.24
Per cent Potash as K_2O	0.10	0.07	1.28
Per cent Calcium as CaO	0.45	0.29	0.31

Field Trial

TABLE V. THE EFFECT OF LITTER REMOVAL AND FERTILISER TREATMENTS ON (a) GRASS/CLOVER GERMINATION (b) SWARD YIELD (RESULTS ARE EXPRESSED AS YIELD IN THE PRESENCE (+ N) OR ABSENCE (- N) OF NITROCHALK)

Treatment	Germination ≠		Yield ŧ		
	Grass	Clover	-N	+N	(-N) - (+N)
Untreated (U)	4.5	0.5	0.40	0.10	0.30
Mechanical (M)	8.0	1.3	0.80	0.20	0.60
Fire (F)	5.0	1.5	0.35	0.45	-0.10
U.L.S.	10.5	1.8	3.40	0.80	2.60
M.L.S.	12.0	2.8	2.10	0.90	1.20
F.L.S.	13.5	3.3	0.55	2.10	- 1.55
L.S.D. (P=0.05)	± 6.80	± 1.26	± 1.29	± 0.88	± 1.44

≠ Figures represent seedlings present in 2 x (12 x 6 in.) being the mean of 12 replicates.

ŧ Figures for yield represent dry matter (gm) present in 3 x (12 x 6 in.) being the mean of 3 replicates.

Table V shows that lime and slag applied in combination significantly ($P = 0.05$) increased both germination and yield. The increase in yield differed for method of litter treatment according to whether or not "Nitrochalk" was applied. There was an overall depression in sward establishment resulting from addition of the latter. It was also found that sward establishment declined in vigour with later spraying; this seems to be related to density of the frond canopy (Table VI).

TABLE VI. THE INFLUENCE OF TIME OF SPRAYING ON SWARD YIELD.

Time of Spraying	Sward Yield	Frond reduction per cent
July 1959	5.70	38.4
August 1959	4.80	4.5
September 1959	1.65	6.2

Figures for yield represent D.M. gm present in 3 x (12 x 6 in.) being the mean of 3 replicates.

The field trial was not grazed during this season as had been hoped. This was due not only to slow sward establishment but also because of the danger of plants being torn from the ground, rather than severed by grazing sheep. This latter factor may prove a difficulty in the establishment of a grazing sward, the bracken litter being of such a friable nature that young pasture plants are removed with comparative ease.

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AN INTERIM REPORT ON BRACKEN CONTROL TRIALS

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Summary: Brief details are given of experimental work carried out on the control of bracken by herbicides. The results from a trial investigating time of application suggest that the beginning of August is the optimum stage for treatment by 4-CPA formulations. In an experiment investigating dose rates, dalapon gave a maximum of 35 per cent. frond reduction at 20 lb.a.e. per acre and caused almost total kill of the underlying grass, while the nonyl ester, butyl ester and diethanolamine salt of 4-CPA gave maximum reductions of 46 per cent, 54 per cent and 74 per cent respectively in the year following treatment. Activated amitrol emerged as a very successful treatment, giving frond reductions of from 81 per cent to 95 per cent at rates from 5 lb. to 15 lb.a.e. per acre. Three field-scale trials are described in which amitrol again showed the greatest degree of bracken control, and would appear to offer considerable promise in this field.

INTRODUCTION

This report summarises the results of assessments carried out during 1960 on trials laid down in the summer of 1959 to investigate the efficiency of certain herbicides for the control of bracken.

METHOD AND MATERIALS

The herbicides under test included: 4-CPA nonyl ester ("Weedone Brackontrol"), 4-CPA butyl ester ("Teridox"), 4-CPA diethanolamine salt ("Marks' 4-CPA Amine"), dalapon (sodium salt)("Dowpon"), and amino triazole (activated)("Weedazol-tl").

All the trials referred to were located on fairly dense stands of bracken (minimum of 30 fronds/sq yd), which had a reasonably good underlying grass sward, and were selected as being practical propositions for improvement.

Section A deals with an unreplicated experiment designed to determine the optimum spraying date for 4-CPA. Plots were sprayed in a weekly series starting at the end of June 1959 and finishing at the end of September in the same year, using 7½ lb/ac a e of the nonyl ester and of the diethanolamine salt of 4-CPA, each material being applied in the equivalent of 50 gal of water/ac by means of an Oxford Precision Sprayer to a plot of 10 sq yd.

Section B describes a replicated trial in which all the herbicides listed in the first paragraph were applied at various doses of active material at as near as possible to the optimum time of application recommended by the manufacturers. The plots, each of 40 sq yd, were sprayed by means of a modified Drake & Fletcher "Mistifier" knapsack sprayer, using the equivalent of 40 gal water/ac.

Section C reports three trials in which 4-CPA nonyl ester, 4-CPA butyl ester, dalapon and amino triazole were applied at the manufacturer's recommended rates to unreplicated plots of one acre. These trials were sprayed by normal tractor mounted sprayers at an average of 30 gall water/ac.

In the tables which follow, the control of bracken has been calculated from frond counts in the early and late summer of 1960, the percentage reduction being derived from counts on the treated and an adjacent untreated (control) plots. Observations were also made on the effect of the various treatments on the underlying grass sward and, where this has been significantly affected, details are appended.

RESULTS

A. Time of application trial

(Location: Caerketton Hill, near Edinburgh, Midlothian)

TABLE I. THE RELATION OF DATE OF APPLICATION TO EFFICIENCY

Spraying date (1959)	Percentage frond reduction (as at July 1960)		Notes
	ester	amine	
June 30	39	-	Chemical scorch observed on ester treated fronds, one week after treatment
July 8	47	-	
" 15	53	-	
" 23	60	73	
" 30	74	70	
August 5	82	72	Fronds fully open
" 13	80	66	
" 19	74	56	
" 27	51	40	
September 2	66	29	
" 9	24	35	
" 16	36	34	Frost damage noted on untreated fronds
" 23	47	28	

(at July 1960, control plots averaged 45.2 fronds per sq yd)

The amine formulation was not available until the 23rd July, thus no figures exist prior to this date. The bracken was 39 in. high at the beginning of August 1959 and very little increase in height took place after that date. During the assessments in 1960 it was noticeable that all treated plots had bracken which was in general not as tall as the untreated control bracken, although there was considerable variation of height within the treated areas.

From the results of this trial it would appear that the optimum time of application under the conditions ruling in 1959 was at the beginning of August when the frond had fully unrolled, although reasonable results were obtained over a period of about four weeks. It was considered that the chemical scorch given by the ester in the early summer was seriously damaging the frond before sufficient herbicide was translocated to the rhizomes.

B. Rate of application experiment

(Location: Portmore, near Eddleston, Peeblesshire).

Dalapon and amino triazole were applied on 1st July, 1959, and the 4-CPA formulations were applied on 1st August 1959. Frond counts were made during the first week of July 1960 and again during the last week of August 1960. The figures given for the amino triazole treated plots are derived from the actual number of emergent fronds, and do not take into consideration any of these emergent fronds which show serious amino triazole chlorosis. If these chlorotic fronds were regarded as 'dead' the percentage reductions would be considerably higher than those given below.

TABLE II THE EFFECT OF DOSE RATE ON EFFICIENCY

Material	Dose rate lb/ac a e	Percentage Frond reduction		Average height (August) in.
		July	August	
Dalapon	20	10.4	34.6	17
	15	18.8	25.3	22
	10	- 6.0	25.9	26
	5	- 9.0	4.6	31
Amino triazole	15	90.9	94.8	8
	10	87.4	91.3	10
	7.5	81.3	92.3	14
	5	84.6	90.3	14
4-CPA (nonyl)	10	46.7	22.8	26
	7.5	30.3	36.4	26
4-CPA (butyl)	8	48.9	45.4	27
	6	40.6	54.5	23
4-CPA (amine)	10	61.4	68.1	22
	7.5	74.4	72.8	22

(at August 1960, control plots averaged 28.2 fronds per sq yd and a height of 35 in.)

At the end of August 1960 it was noticeable that the bracken on the dalapon treated plots was withering sooner than other bracken. At the two high rates of dalapon, almost the entire grass sward was wiped out, the remaining vegetation being predominantly dicotyledonous; at the lower rates the grass received a bad check although little was actually killed. All treated plots, irrespective of material, showed reduction in the size of the frond, pinnae and pinnules, and in general the treated areas showed a later emergence of the bracken than did the untreated areas.

The results from this trial suggest that for the type of bracken having a reasonable underlying sward, the use of dalapon, even if the control was increased, could not be tolerated on account of the serious damage to the grasses. The 4-CPA formulations were rather disappointing and only the amine formulation gave a practical reduction; it may have been that under the very dry weather conditions of this experiment the esters caused physical damage to the frond before translocation had been effected. The most outstanding feature of this experiment was the behaviour of the activated amino triazole and this chemical would appear to offer considerable promise at not too excessive a cost.

C. Field scale trials

Locations: Gilmanscleuch, Ettrick, Selkirkshire; Buckholm, near Galashiels, Roxburghshire; Carie, near Lawers, Perthshire.

Treatments: The dalapon and amino triazole were applied between the 14th and 28th July 1959, the 4-CPA formulations were applied at Carie on the 17th August, at Buckholm on the 25th August and at Gilmanscleuch on the 3rd September 1959.

Weather (during summer of 1959): At Gilmanscleuch and Buckholm the months of June, July, August and September were very much drier and warmer than the average, while at Carie the weather during the same months was much wetter and close to the normal. The nearest meterological stations to the sites are too far distant to make readings reliable.

TABLE III. BRACKEN CONTROL AT FIELD SCALE TRIALS

Material	Rate lb/ac a.e	Percentage frond reductions					
		Gilmanscleuch		Buckholm		Carie	
		July	Aug.	July	Aug.	July	Aug.
Dalapon	15	69	23	51	16	95	34
Amino triazole*	7.5	90	77	48	47	98	84
4-CPA (nonyl)	7.5	40	20	46	23	90	48
4-CPA (butyl)	6	50	51	64	46	50	41

* (see note regarding amino triazole assessments in section "B"

The amine formulation was not available until the 23rd July, thus no figures exist prior to this date. The bracken was 39 in. high at the beginning of August 1959 and very little increase in height took place after that date. During the assessments in 1960 it was noticeable that all treated plots had bracken which was in general not as tall as the untreated control bracken, although there was considerable variation of height within the treated areas.

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DALAPON, 4-CPA AND AMINO TRIAZOLE FOR THE CONTROL OF BRACKEN - AN INTERIM REPORT.

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Summary. Dalapon, 4-CPA and amino triazole have been tested for the control of bracken in 13 randomised block trials, distributed in ten counties of England and Wales. The design of the trials had been agreed upon at the 1959 meeting of the International Research Group on Weed Control held in Stuttgart. Delapon was applied at 10 and 20 lb/ac, 4-CPA at 5 and 10 lb/ac and amino triazole at 10 and 20 lb/ac "activated" with ammonium thiocyanate. Spraying was carried out on two occasions and replication was threefold. Drought conditions during most of the season may have affected the results and this should be borne in mind in the interpretation of results. Although the application of dalapon delayed frond emergence, final reductions in density were not high and varied from site to site. These results are in accord with those of earlier trials and the conclusion is reached that the sodium salt of dalapon is not promising for the control of bracken. Three ester formulations of 4-CPA were tested and differences in their effectiveness were not important. Agreement between results from site to site was poor. The maximum, as well as the average frond density was low when compared with the results of trials in previous years. Early application was effective at the lower dose but time of treatment had less influence at the 10 lb/ac dose. The "activated" amino triazole gave most promising results, control being consistantly good when applications were made in late June to early July. When treatment was delayed until late August to early September control was invariably poor and variations in the results from site to site increased. Trials are now needed to test this chemical under a wide range of climatic conditions.

INTRODUCTION

During the past seven years three chemicals have shown distinct promise for the control of bracken. Beatty (1953) first suggested 4-CPA (4-chlorophenoxyacetic acid) for the control of bracken and later Schofield (1956) reported on the effectiveness of this chemical in New Zealand.

In a series of trials Fryer et al (1959) found that applications of delapon (sodium 2,2-dichloropropionate) gave an appreciable reduction in frond density in the following year.

Although Forrest (1959) has reported that amino triazole has shown little promise as a herbicide for bracken in Scotland, Bylterud (1958) has demonstrated its effectiveness on bracken at low rates in Scandanavia.

At a meeting of the International Research Group on Weed Control in Stuttgart in 1959 it was agreed that trials of a standard design should be laid down on the Continent, in Scandanavia and in the United Kingdom to compare the effectiveness of these three chemicals for the control of bracken under a wide range of environmental conditions. This paper reports on 13 such trials laid down by the A.R.C. Unit of Experimental Agronomy in 1959.

METHODS AND MATERIALS

The trials were of a randomised block design with plots 6 x 4 yd in size, separated by 1 yd paths. The three chemicals were applied at two doses, namely dalapon at 10 and 20 lb/ac, 4-CPA nonyl ester at 5 and 10 lb/ac and amino triazole "activated" with ammonium thiocyanate in the ratio 100:95 *. All the treatments were tested at two dates of application and replication was threefold for all treatments and control plots. All applications were made at a volume rate of 20 gal/ac with an Oxford Precision Sprayer. Table I gives the location and a brief description of the sites together with the dates of spraying.

At five of the sites (Ruthin, Lydney, Barden, Eggleston and Capheaton) the following treatments were also included in the trials:- 4-CPA butyl ester+, and an ester of 4-CPA formulated as a water in oil emulsion ("Invert emulsion", supplied by Messrs. A.H. Marks & Co., Ltd). Both formulations were applied at 10 lb/ac on each occasion of spraying, except that at Ruthin the invert emulsion was not included at the earlier date of application. At Ruthin and Lydney the 4-CPA butyl ester was also applied at the later date at 5 lb/ac. At one further site (Cartmel Fell) the invert emulsion was applied at 10 lb/ac on both spraying occasions. At the Euston Park site no amino triazole treatments were included as it was not possible to find a uniform area of bracken of sufficient size to accomodate a complete trial.

Each trial was assessed twice during 1960; an initial count was made during the period June 14th-30th, soon after the fronds began to emerge, and a final assessment was carried out from August 8th to September 9th when it was considered that frond emergence was virtually complete. In the most uniform stand of bracken the distribution of fronds is somewhat uneven and so to avoid subjective bias when making the counts the assessments were made by counting all the fronds within a 5 x 3 yd quadrat placed centrally within the plot. In all the plots the height of emerged fronds during 1960 was related to the effectiveness of the treatment and at the time of the final assessment an estimate was made of the mean height of the fronds within the quadrat.

RESULTS

Dalapon. (a) June assessment. The initial counts in 1960 showed that there was a very wide variation in results from site to site as well as between treatments at individual sites (Table II). At one site an early application of 10 lb/ac gave a 91 per cent reduction in frond density but at seven other sites the decrease in density was less than 30 per cent. Similar anomolies were recorded in each of the other treatments. However these early counts did indicate that delaying the application of 10 lb/ac had increased the effectiveness o. the chemical but where the dose was increased to 20 lb/ac the effects of varying the time of application were far less marked.

(b) August - September assessment. The results of the later assessment (Aug-Sept) showed that the number of fronds had increased greatly on treated plots and that, whilst the variations from trial to trial were still great, the difference due to the various treatments was much reduced (Table II).

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* As "Dowpon" "Weedone Brackontrol" and "Weedazol TL" respectively.
\+ As "Teridox"

In general all treatments caused a reduction in the height of the bracken but in a few instances the treatments had had no visible effect on the height of stand. Grasses and associated species, where present below the bracken, were completely killed at both 10 and 20 lb/ac, irrespective of the time of application.

4-CPA nonyl ester. (a) June assessment. At the time of the first assessment it was clear that, although the effectiveness of all treatments varied greatly from site to site, both the 5 and 10 lb/ac doses had given a higher degree of control when applied at the earlier date (Table IIIa). At 5 lb/ac, although the early application was more successful at the majority of sites the maximum reduction recorded (57 per cent) was little affected by time of application. On the other hand, at the higher dose, spraying on the earlier occasion caused a reduction in density of over 70 per cent at four sites but when spraying was delayed the decrease in density was less than 41 per cent at all sites.

(b) August-September assessment. The later assessment showed that the general pattern of control remained the same but that there had been some further emergence of fronds. The maximum percentage reductions for early and late applications of 5 and 10 lb/ac had fallen from 59, 56, 84 and 41 per cent to 45, 37, 67 and 40 per cent respectively. Each of the treatments had reduced the height of the fronds to some extent but the greatest effect was noted at the higher dose when applied at the earlier date (Table III b). Grasses, where present, were seemingly unaffected by any of the treatments.

4-CPA butyl ester. A comparison was made between the nonyl ester and the butyl ester of 4-CPA at five sites and from an inspection of Tables IIIa and IIIb it can be seen that both formulations give a very similar measure of control.

4-CPA-Invert emulsion. The water in oil formulation of the nonyl ester of 4-CPA was applied at 10 lb/ac in six of the trials. It should be noted that the emulsion was sprayed at a higher viscosity than was intended by the suppliers and this may have had some effect upon the degree of control recorded in these trials. Under these conditions the reductions in frond density conformed very closely with those reported for the oil in water emulsion (Tables IIIa & b).

"Activated" amino triazole. (a) June assessment. The effects of the activated formulation of amino triazole are given in Table IV. Frond counts in June-July indicated that the 10 lb/ac application had given a high degree of control at the earlier date of spraying and that in general increasing the dose to 20 lb/ac had not effectively increased the "kill". A reduction in density of over 85 per cent was recorded at several sites for both doses and at only one site was the reduction below 60 per cent.

The effectiveness of the herbicide was considerably reduced when applications were made at the later date and the variation from site to site was appreciably greater. For example at one site the number of fronds was reduced by 84 per cent in contrast to several of the trials where there was no appreciable control.

(b) August-September assessment. On the earlier treated plots there was only a slight increase in the number of fronds during July but on the later sprayed plots the density of fronds increased and the maximum reduction in density recorded at the later assessment was 53 per cent, compared with a value of 88 per cent in June.

On treated plots those fronds that had emerged showed the characteristic chlorosis associated with amino triazole and on the plots treated in the period

June-July many of the pinnae were badly deformed. In many cases the pinnules were completely absent and usually, where present, they had failed to expand. None of the treatments appeared to have had any adverse effect upon the associated grasses and herbs.

DISCUSSION

Delapon. From a series of trials (Fryer et al 1959) it was concluded that, in many instances, although delapon gave a very high reduction in the number of fronds in the early part of the season the continued emergence of fronds during the growing season greatly reduced these early effects. He also noted a wide variation in the effectiveness of the chemical from site to site. The results of the trials reported here are fully in accord with those of Fryer et al.

As spraying techniques were standard throughout the series and weather conditions were virtually uniform during both the early and late spraying periods it seems unlikely that any of these factors could be responsible for the variable results at the 13 sites. Early in the season it appeared that where the applications had been delayed until the later period they had given a greater reduction in density. However towards the latter part of the growing season, when many fronds had emerged, this differential effect had largely disappeared, possibly due to the different time intervals between spraying and assessment. The trials have brought out the extent of the variation which may be expected from applications of dalapon under various environmental conditions but they have shed no further light on the underlying reasons for such variations.

4-CPA esters. In this particular year there were no important differences in the performance of the three ester formulations when compared at the 10lb/ac rate. The application of 10 lb/ac of 4-CPA in late August-early September gave no better control than 5 lb/ac sprayed in the period late June-early July. Thus it is apparent that the susceptibility of the plant varies greatly during the growing season but little is known of the physiological factors or morphological characters which govern its response to the chemical. More work of a fundamental physiological nature is needed to gain information on this aspect. The large variation in results from site to site may well be due to differences in the physiological activity of the rhizome systems at the various sites but with the available labour force it was not possible to engage in extensive digging operations.

The maximum reduction in density achieved in these trials is low when compared with the results of trials made in previous years (Fletcher 1959). Why the activity of the chemical should be impaired by the dry conditions of 1959 is far from clear but the trials do demonstrate that in this particular year, at 5 and 10 lb/ac, the ester formulations tested were not reliable herbicides for the control of bracken.

"Activated" amino triazole. In previous trials in this country amino triazole has not shown promise for the control of bracken but in these trials application was made only to mature bracken (Fryer 1956, Forrest 1959). In the trials reported here, the results were most encouraging where applications were made before the fronds had reached maturity. However it must be pointed out that the "activated" formulation used in the present work was unknown at the time of the earlier trials. At the present time it is not known whether the addition of the activator results in any increase in the toxity of amino

triazole to bracken. The negligible increase in control with increased dose suggests that the optimum rate for acceptable control may be lower than those tested and the wide difference in the results at the two spraying occasions indicates that the susceptibility of the plant is far from constant during the growing season. Trials are now in progress to investigate these aspects of the problem; applications of 5 and 20 lb/ac have been made at short intervals over the major part of the growing season. From the chlorotic and stunted appearance of those fronds which have emerged on treated plots it seems that the chemical is both persistant and readily translocated within the bracken rhizome system. It is possible that the treatment effects may be even more pronounced in the second year after spraying. However, it should be borne in mind that these tests were made under somewhat exceptional weather conditions and the reliability of the chemical has yet to be proved under more normal conditions.

In conclusion it may be stated that:

a) Doses of 10 and 20 lb/ac of dalapon gave variable results. Although frond emergence was delayed the continued emergence of fronds during the season resulted in an unsatisfactory level of control by the end of the season. Where grasses and other species were present they were completely suppressed. The sodium salt of dalapon does not appear particularly useful for the control of bracken.

b) The three ester formulations of 4-CPA tested showed similar activity on bracken but the results were, in general, very disappointing compared with the promising results in earlier trials. It is clear that the control of bracken with 4-CPA is liable to vary from site to site and from year to year and until further evidence is forth coming on the principal factors responsible for this variation it cannot be considered a reliable herbicide for bracken up to 10lb/ac.

c) June and July applications of activated amino triazole at 10 and 20 lb/ac gave an excellent control. Later applications gave a reduced control. Further work is in progress to assess the optimum dose for acceptable control, to determine the period of maximum susceptibility and to test the reliability of the chemical under various environmental and climatic conditions.

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TABLE I. CONDITIONS AT EACH SITE AT THE TWO SPRAYING DATES

Site	County	Approx height above sea level ft	Aspect and contour	Date of application 1959	Height of bracken ft	Weather conditions
Darley Dale	Derbyshire	1,000	Moderate S slope without shade or shelter	29.6	2½	Fine with possibility of thunder showers
				17.9	3	Overcast but dry light S wind
Edale	"	1,300	Moderately steep S slope without shade or shelter	10.7	2½	Overcast but dry. Wind-speed negligible
				17.9	3	Overcast but dry. Light E wind
Ruthin	"	400	A very slight slope, almost on the brow of a ridge. No shade or shelter	30.6	2½	Fine and dry. Light N E wind
				3.9	3	Fine and dry. Light E wind
Machynlleth	Montgomery	400	Steep S slope without shade or shelter	1.7	3	Overcast, clearing later, Light W wind
				3.9	3	Drought conditions. No wind
Pontesbury	Shropshire	1,500	Moderate E slope. Sheltered to the N and E by trees. No shade	2.7	3	Fine with light S W wind
				2.9	3½	Drought conditions. No wind
Leebotwood	"	1,200	Moderate N W slope without shade or shelter	2.7	2-2½	Warm, dry and settled. Moderate S W wind
				2.9	2½	Drought conditions. No wind.

TABLE I (Contd.)

Site	County	Approx height above sea level ft	Aspect and contour	Date of application 1959	Height of bracken ft	Weather conditions
Lydney	Gloucestershire	300	Moderate E slope without shade or shelter	3.7	4	Warm, dry and settled. Light N E wind
				24.8	4½	Drought conditions. Light N E wind
Barden	Yorkshire	1,000	Moderate S slope without shade or shelter	7.7	2	Warm, dry and settled. Light S S W wind
				15.9	2½	Cool and overcast. Light N wind
Cartmel Fell	Lancashire	500	Moderate N E slope without shade or shelter	8.7	4	Warm, dry and settled. Moderate W wind
				15.9	4	Drought conditions. Moderate N E wind
Eggleston	Durham	1,200	Level site with no shade or shelter	9.7	2	Cool, overcast but dry. Light W wind
				16.9	2	Cool, overcast with light drizzle after spraying. Moderate N E wind
Capheaton	Northumberland	700	Slight S slope without shade or shelter	10.7	4	Cool, cloudy but dry. Light S wind
				16.9	4	Drizzle in a.m. following drought. Dry at time of spraying. Moderate N wind

TABLE I (Contd.)

Site	County	Approx height above sea level ft	Aspect and contour	Date of application 1959	Height of bracken ft	Weather conditions
Euston Park	Suffolk	100	Level site. Shelter to S and E but no shade	15.7	3½	Warm, dry and settled. Light, variable wind.
				27.8	3½	Drought conditions. No wind
Bruton	Somerset	500	Steep N slope in fairly narrow valley. Ridge of valley provides some shelter. No shade Bracken had been cut annually for many years previously	23.7	1½	Hot and dry. Moderate S wind
				24.8	1½	Hot and overcast. Very light S W wind

TABLE II. EFFECT OF DALAPON ON BRACKEN AS ASSESSED ON TWO OCCASIONS IN THE YEAR AFTER TREATMENT.

Results (mean of 3 replicates) expressed as percentage reduction compared with control at the time of assessment.

N.C = No apparent control. No count made.

Site	Date Assessed 1960	Date of Application 1959		percentage reduction frond numbers				percentage reduction in mean height of fronds			
				10 lb/ac		20 lb/ac		10 lb/ac		20 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Darley Dale	24.6 12.9	29.6	17.9	20 24	24 17	39 11	59 32	36	36	58	58
Edale	24.6 13.9	10.7	17.9	22 28	68 16	66 36	42 36	31	66	42	66
Ruthin	16.6 8.8	30.6	3.9	12 16	34 24	37 28	46 26	19	33	33	52
Machynlleth	17.6 9.8	1.7	3.9	26 19	37 22	39 32	22 12	21	36	21	78
Pontesbury	15.6 10.8	2.7	2.9	66 - 2	72 - 6	91 38	94 13	35	35	70	55
Leebotwood	15.6 9.8	2.7	2.9	66 20	76 15	80 22	88 24	31	31	62	62
Lydney	14.6 7.9	3.7	24.8	35 N.C	42 N.C	69 N.C	85 N.C	0	0	0	0
Barden	20.6 16.8	7.7	15.9	91 22	96 26	90 35	98 38	50	52	61	66

TABLE II. (Contd.)

Site	Date Assessed 1960	Date of Application 1959		percentage reduction frond numbers				percentage reduction in mean height of fronds			
				10 lb/ac		20 lb/ac		10 lb/ac		20 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Cartmel Fell	21.6 17.8	8.7	15.9	38 30	45 36	86 56	74 48	28	36	57	38
Eggleston	22.6 18.8	9.7	16.9	12 N.C	23 19	70 43	48 30	0	0	40	40
Capheaton	22.6 18.8	10.7	16.9	58 40	74 61	90 68	92 74	42	48	64	66
Euston Park	30.6 9.9	15.7	27.8	22 N.C	37 N.C	58 46	51 36	0	0	32	28
Bruton	13.6 8.9	23.7	24.8	-16 2	22 14	8 5	- 8 3	13	20	13	20

TABLE III (a). EFFECT OF 4-CPA ON BRACKEN AS ASSESSED ON TWO OCCASIONS IN THE YEAR AFTER TREATMENT.

Results (mean of 3 replicates) expressed as percentage reduction compared with control at the time of assessment
N.C = No apparent control. No count made.

Site	Date Assessed 1960	Date of Application 1959		percentage reduction in frond number									
				nonyl ester				butyl ester				invert emulsion	
				5 lb/ac		10 lb/ac		5 lb/ac		10 lb/ac		10 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Darley Dale	24.6 12.9	29.6	17.9	25 24	18 16	50 50	26 18						
Edale	24.6 13.9	10.7	17.9	35 29	15 8	72 66	24 21						
Ruthin	16.6 8.8	30.6	3.9	30 30	7 8	32 32	2 12	18 14	- 11 - 12	23 15	- 12 - 2		10 12
Machynlleth	17.6 9.8	1.7	3.9	26 20	5 26	34 32	12 21						
Pontesbury	15.6 10.8	2.7	2.9	60 26	12 0	44 28	14 9						
Leebotwood	15.6 9.8	2.7	2.9	54 30	8 12	84 59	26 16						

TABLE III. (a). (Contd.)

Site	Date Assessed 1960	Date of Application 1959		percentage reduction in frond number									
				nonyl ester				butyl ester				invert emulsion	
				5 lb/ac		10 lb/ac		5 lb/ac		10 lb/ac		10 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Lydney	14.6 7.9	3.7	24.8	42 N.C	31 N.C	63 42	30 N.C		30 N.C	49 N.C	34 N.C	53 N.C	45 N.C
Barden	20.6 16.8	7.7	15.9	34 24	56 14	58 20	41 16			45 15	50 11	62 26	56 30
Cartmel Fell	21.6 17.8	8.7	15.9	56 42	6 20	76 67	30 40					80 67	18 16
Eggleston	22.6 18.8	9.7	16.9	49 44	22 N.C	74 64	13 26			84 75	18 N.C	76 64	23 N.C
Capheaton	22.6 18.8	10.7	16.9	48 39	4 10	63 59	18 14			66 62	20 22	63 52	22 20
Euston Park	30.6 9.9	15.7	27.8	0 N.C	- 2 N.C	- 1 N.C	28 N.C						
Bruton	13.6 8.9	23.7	24.8	6 6	32 36	41 52	32 25						

TABLE III (b). EFFECT OF 4-CPA ON BRACKEN AS ASSESSED ON TWO OCCASIONS IN THE YEAR AFTER TREATMENT

Results (mean of 3 replicates) expressed as percentage compared with control at the time of assessment.
N.C = No apparent control. No counts made.

Site	Date Assessed 1960	Date of Application 1959		percentage reduction in mean height of fronds									
				nonyl ester				butyl ester				invert emulsion	
				5 lb/ac		10 lb/ac		5 lb/ac		10 lb/ac		10 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Darley Dale	24.6 12.9	29.6	17.9	22	19	42	0						
Edale	24.6 13.9	10.7	17.9	20	16	36	12						
Ruthin	16.6 8.8	30.6	3.9	19	4	38	14	19	10	42	- 4		14
Machynlleth	17.6 9.8	1.7	3.9	5	10	32	10						
Pontesbury	15.6 10.8	2.7	2.9	45	10	25	15						
Leebotwood	15.6 9.8	2.7	2.9	25	12	62	12						
Lydney	14.6 7.9	3.7	24.8	0	0	8	0		0	0	0	8	0
Barden	20.6 16.8	7.7	15.9	25	25	30	11			28	30	42	25

TABLE III (b). (Contd.)

Site	Date Assessed 1960	Date of Application 1959		percentage reduction in mean height of fronds									
				nonyl ester				butyl ester				invert emulsion	
				5 lb/ac		10 lb/ac		5 lb/ac		10 lb/ac		10 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Cartmel Fell	21.6 17.8	8.7	15.9	48	16	60	31					54	24
Eggleston	22.6 18.8	9.7	16.9	32	14	36	4			54	14	40	0
Capheaton	22.6 18.8	10.7	16.9	24	0	42	0			39	21	39	0
Euston Park	30.6 9.9	15.7	27.8	0	0	0	0						
Bruton	13.6 8.9	23.7	24.8	20	20	53	36						

TABLE IV. EFFECT OF AMINO TRIAZOLE ON BRACKEN
AS ASSESSED ON TWO OCCASIONS IN THE YEAR AFTER TREATMENT.

Results (mean of 3 replicates) expressed as
percentage reduction compared with control at time of assessment.
N.C = No apparent control. No count made.

Site	Date Assessed 1960	Date of Application 1959		percentage reduction in frond numbers				percentage reduction in mean height of fronds			
				10 lb/ac		20 lb/ac		10 lb/ac		20 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Darley Dale	24.6 12.9	29.6	17.9	64 78	22 20	82 90	24 18	64	36	66	28
Edale	24.6 13.9	10.7	17.9	76 76	12 8	84 82	27 24	66	0	66	16
Ruthin	16.6 8.8	30.6	3.9	72 70	42 32	64 64	36 27	52	28	52	24
Machynlleth	17.6 9.8	1.7	3.9	84 82	44 38	80 80	42 42	78	26	84	36
Pontesbury	15.6 10.8	2.7	2.9	92 68	84 17	92 64	88 14	85	65	85	60
Leebotwood	15.6 9.8	2.7	2.9	94 85	66 24	97 91	77 27	81	50	81	56
Lydney	14.6 7.9	3.7	24.8	84 82	60 44	92 87	54 36	62	8	56	38
Barden	20.6 16.8	7.7	15.9	12 10	34 29	24 23	33 12	38	25	52	36

TABLE IV. (Contd.)

Site	Date Assessed 1960	Date of Application 1959		percentage reduction in frond numbers				percentage reduction in mean height of fronds			
				10 lb/ac		20 lb/ac		10 lb/ac		20 lb/ac	
		Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Cartmel Fell	21.6 17.8	8.7	15.9	89 82	54 40	96 90	60 53	66	48	69	33
Eggleston	22.6 18.8	9.7	16.9	85 78	6 N.C	74 70	12 8	64	9	72	9
Capheaton	22.6 18.8	10.7	16.9	74 64	18 12	80 71	16 6	58	3	58	12
Bruton	13.6 8.9	23.7	24.8	73 78	4 7	67 58	- 4 5	60	26	33	13

Presentation by G. L. Hodgson of preceding three papers

All three papers deal with the effectiveness of dalapon, 4-CPA and amino triazole in the control of bracken. In general dalapon gave disappointing control when applied at doses up to 20 lb/ac. From these and previous results (Fryer J. D. et al. 4th British Weed Control Conf. 1958) it seems reasonable to conclude that the sodium salt of dalapon shows little promise for bracken control. The effectiveness of 4-CPA varied considerably from site to site and the general level of control achieved was poor when compared with the results of trials made previously in the West of Scotland. Amino triazole "activated" with ammonium thiocyanate gave most encouraging results at a high proportion of the sites but the trials show that time of application may be extremely critical. The majority of applications were made at 10 and 20 lb/ac and the results suggest that these doses may be greater than the optimum required to give a satisfactory level of control. It should be borne in mind that this compound has been tested in a rather unusual season and we must await the results of further trials before attempting to assess its reliability for the control of bracken.

The trials demonstrate that we have three chemicals which are, under certain circumstances, toxic to bracken. However it is obvious that bracken varies in its susceptibility to these compounds and as yet we have no reliable information as to the factors affecting this susceptibility. In a single unreplicated trial Erskine has compared the effectiveness of 4-CPA applied at 7½ lb/ac at short intervals from the end of June to late September. In this isolated trial it appeared that there was a definite pattern of susceptibility of the bracken to the herbicide with susceptibility increasing to a maximum in early August and remaining steady for approximately 14 days, before decreasing again as the season advanced.

Further work must now be designed to (a) assess the extent to which this general pattern is modified by variations in the environment and (b) to determine the morphological and physiological factors which control the penetration and uptake of the three chemicals.

Discussion on preceding six papers on bracken

Mr. A. F. J. Wheeler. We have heard much of the erratic behaviour of chemicals towards bracken and of bracken towards chemicals. In the limited amount of work that I have done on bracken it appears to me that two other major variables exist. I refer to volume of application used and formulation, particularly with regard to 4-CPA.

Mr. J. Norris. We found no differences from various volumes of application in 1957 and so decided to adopt 20 gal/ac for trial purposes. Other workers have tried higher and lower volumes; some say one thing, some say another, but, at the moment, we are not sure what the right answer is. This year we have again put down trials at application rates from 5-100 gal/ac to gain further information on this point. I think that there is no doubt that formulation can affect results. In 1958 we observed different results between the normal oil-in-water ester formulation and the 'invert' water-in-oil ester formulation. In fact these effects did not show up again when we repeated the work in 1959. We therefore blamed the season for the previous years erratic results.

Mr. F. C. Cooke. There are yet other variables, viz droplet size and method of application. The various chemicals have been compared at two or three doses