(3) the initiation of a visible frond-bud on the stem at the base of the current year's frond is not invariable: percentages varying between 5 and 35 of the apices without visible frond buds were found in late September; while in the case of shoots associated with fronds older than one year, the proportion varied between 5 and 20%. Such stems might, of course, initiate frond-buds at a later time, though at the time of analysis they were not visible;

(4) of the frond population for the next year, roughly two-thirds appear to be formed on stems immediately adjacent to fronds of the present year and one-third on stems older than one year. The period of dormancy which such stems can go through is so far quite undetermined.

The mean figures compiled from the data of Table I are useful as control figures against which data from treated plots may be assessed. It is therefore proposed to use the following data to record the full effect of any treatment:

(1) Frond development: (*a*) the number of fronds on a unit area of treated and untreated bracken. Such data should be compiled for at least three years; (*b*) the heights of 20 fronds from the same sites throughout the experimental period. Little value can be placed on the effects shown by fronds in the first year of treatment: frond development will be of greater significance in the succeeding years.

(2) Rhizome development: analysis of the branches types (*a*) and (*b*) above, with additional data, where necessary, as to whether the thick, deep-running branches (*c*) are healthy—and therefore potentially capable of giving rise to further centres of growth—or dying off.

Part II of this paper reports the results of some recent field trials in which such a form of analysis has been used.

Acknowledgment

The author records her appreciation to the Agricultural Research Council for their continued support of these investigations.

References

[1] Watt, A. S., *New Phytol.*, 1940, **39**, 401

[2] Conway, E., & Stephens, R., *N.A.A.S. quart. Rev.*, 1954, (25), 1

Part II. Effects of various Herbicides on Field Bracken
(Pteridium aquilinum)

by

J. D. FORREST

(*West of Scotland Agricultural College*)

Introduction

This paper is a progress report concluding certain experiments reported at the last conference and outlining some recent ones. The trials were in the nature of field screening tests and had two main aims: (1) to study the effects of the various herbicides on the bracken plant, especially the rhizome; (2) to select those worthy of inclusion into field-scale trials for control of bracken under Scottish hill-farming conditions.

Review of chemicals

Since most of the herbicides under trial have been reviewed previously,[1] only the additional ones are mentioned below.

Borates.—A number of boron compounds, especially borax and crude sodium borate, are used in this country for non-selective weed control and soil sterilisation. Applications rates are usually high, and, depending on formulation, vary from 8 to 40 cwt./acre. Borates are not broken down in the soil but are liable to leaching, the rate of which depends on rainfall, soil type, and particle size of the compound.

Borate–sodium chlorate mixtures have been in use for some years, the primary function of the borate being to suppress the fire risk of the chlorate. Liquid formulations of this mixture are also available. In recently devised borate/organic herbicidal combinations, the function of the stable inorganic compound is to inhibit the microbial breakdown of the organic compound, thus prolonging its activity in the soil. Such formulations include 2,4-D or monuron.[2,3]

Borate formulations have been used on bracken and it has been reported that in Wales sodium borate and 2,4-D applied in the spring prevented bracken growth for two years.[3]

Dalapon (2,2-dichloropropionic acid).—Dalapon is principally used as a selective herbicide for the control of annual and perennial grasses,[4,5] and is readily absorbed and translocated through the foliage. Rates of 10–15 lb./acre are used for the control of couch, and results from recent experiments indicate that at rates of 40 lb./acre complete control may be obtained of other rhizomatous plants such as reedmace (*Typha* spp.).[6] Another report states that dalapon applied to bracken in July 1956 at a rate of 20 lb./acre prevented frond growth throughout 1957.[3]

Experimental

General design

Most of the experiments were fully replicated with plot size 5 yd. × 2 yd., but when only small amounts of chemical were available, single-plot experiments were carried out. The trials were at Drumclog Moor, Dunbartonshire (average rainfall 35 in. for 1956 and 1957) where the bracken stand is fairly uniform with a density of 30 fronds/sq. yd. at an average height of 3½–4 ft. when fully mature. Materials were applied in solution at 100 gal./acre, with the exception of some of the borate compounds, for which a mechanical spreader was used.

Method of analysis

The method of analysis was (*a*) rhizome analysis of the state of stem tips and accompanying frond buds after treatment; (*b*) frond counts particularly in the years following treatment to record reduction in density.

Results

I. Final results of 1955–56 trials (previously reported)

(1) *Foliar applications* of the following materials were used: ammonium sulphamate; maleic hydrazide; MCPB (sodium); aminotriazole; 2,4,5-T; aminotriazole and 2,4,5-T in mixture: only aminotriazole at 20 lb./acre and 40 lb./acre produced any visible effect in the year after treatment. There was a reduction in frond density and the emerged fronds were chlorotic, suggesting that the herbicide had been translocated through the rhizome to the following year's developing frond buds. This was the first time in our trials that a translocated herbicide had produced effects in the year after treatment. Severe chlorosis and stunted growth were also noted on various angiospermic species occurring in the plots.

(2) *Soil applications*.—Ammonium sulphamate, trichloroacetic acid, aminotriazole and monuron applied in the spring as soil applications produced no lasting effects and the plots are now densely covered with fronds.

II. Recent trials 1956–58

(1) *Non-selective herbicides*

(a) *Borates*.—The various borate formulations used in the trials were: B44 and NB (sodium borates), DBG (88·5% sodium borate + 7·5% 2,4-D), U.B. (94% sodium borate + 4% monuron), PC (75% sodium borate + 25% sodium chlorate), MC (liquid formulation based on sodium borate and chlorate).

Experiment 1956.—These materials were not available until June and as borate applications act mainly through the soil and are best applied early in the season the experimental site was cut over with a scythe, thus removing the bracken stand. The experiment was a preliminary guide to laying down a replicated trial in the following spring and consequently treatments were single (with the exception of DBG) and rates per 10 sq. yd. were as follows: DBG ¾ lb. and 1 lb., U.B. 1 lb., DBG ½ lb. + ½ lb. U.B., B44 2 lb., 4 lb. and 8 lb., PC 2 lb. and 4 lb., 2,4-D (ester) 8 lb. soil application and also 8 lb. foliar application.

Of these only B44 gave any real control in the year after treatment. The higher rate of 8 lb. on 10 sq. yd. reduced the number of fronds on the plot from 300 to 7 and a rhizome sample bore no live buds.

The creeping soft grass (*Holcus mollis*) was badly scorched after treatment in 1956 but by September 1957 was luxuriant. By 1958, of the other treatments only 4 lb. B44, 2 lb. and 4 lb. PC and the 8-lb. 2,4-D ester as a foliar application showed any real reduction in density (Table I).

Table I

Reduction in frond density, 2 years after treatment with borate formulations

Treatment 1956	% reduction in frond density 1958
8 lb. B44	93
4 lb. B44	58
2 lb. PC	30
4 lb. PC	38
8 lb. 2,4-D (ester) foliar	36

Experiment 1957.—A replicated experiment using various borate formulations was laid down in spring 1957. Treatments per 10 sq. yd. were: 2 lb. DB, 1 lb. and 2 lb. U.B., ½ lb. DBG+½ lb. U.B., 1 lb. U.B.+1 lb. DB, 2 lb. and 4 lb. PC, 4 lb. and 8 lb. B44. After removal of the previous year's litter the treatments were applied on 4th May just as the croziers were emerging.

A month after treatment only a few fronds were present in all treated plots and these were showing the typical chlorosis of boron toxicity and varying degrees of scorch. Also there was severe epinasty on the DBG plots. Two months later all plots were practically bare but by August showed a flush of fronds, particularly on the U.B. and U.B.+DB plots. By September there were no fronds on the 8-lb. B44 plot and approximately 3 on the 2-lb. and 4-lb. PC and on the 2-lb. DBG plots. In contrast, there were 30 or more fronds on all other treated plots. Rhizome analyses at the end of September 1957 showed that the greatest damage to the lower rhizome was with the B44 and PC treatments where, of 20 lengths of rhizome taken at random, 17–20 were dead or in a moribund condition and, in addition, the stem apices and associated frond buds were rotted away. With the other treatments varying degrees of damage were seen on stem apices and frond buds but the lower rhizome was relatively undamaged. A similar analysis was carried out in October 1958 and, as can be seen in Table II (a), these results are confirmed.

The reduction in frond density by September 1958 (Table IIa) shows that plots treated with 2 lb. and 4 lb. PC and 8 lb. B44 showed no fronds at all, and were practically bare of other vegetation although creeping soft grass and rosebay willow herb were beginning to colonise the plots.

Experiment 1958.—A further series of replicated trials was laid out this spring with DBG, NB and MC. Since it has been reported[8] that 2,4-D is being used in the U.S.A. at high rates for non-selective weed control, rates of 2,4-D (ester) at 40 lb./acre and 80 lb./acre were included.

DGB caused epinasty in a few days. To see whether this was caused by absorption through the soil or foliage, a small plot was laid out and the DBG sprinkled carefully on so that it did not come in contact with emerging fronds. After 2 weeks none of the fronds showed epinasty and the inference is that the material, although granular, must partly adhere to the frond and be absorbed. The same effect was noted with the straight 2,4-D, as only those fronds which received the spray responded. Results so far are preliminary but rhizome analyses carried out in October suggest that, of these treatments, the most effective so far is the chlorate/borate liquid formulation. The high rate of 2,4-D as a soil application produced no real effect on the rhizome.

(b) *Sodium chlorate.*—Experiment 1957. The effect of sodium chlorate on bracken is already known. This trial was to see if it could be applied by mechanical spreader and to compare it with newer non-selective herbicides. Plots were 10 yd. × 2 yd. and single treatments were as follows: 100 lb., 200 lb., 300 lb., 400 lb. and 500 lb./acre were applied on 1st July, 1957. When the bracken was over 3 ft. high a fortnight later all fronds were showing severe scorch.

Rhizome analyses and frond density counts (Table IIb) show that all treatments over 200 lb. were most effective, giving over 97% frond reduction and rhizome kill 1¼ years after treatment. Creeping soft grass has gradually re-colonised the bare ground.

Table II

Effects of herbicides on bracken (treated May 1957; analysed October 1958) (treated July 1957; analysed October 1958)

Treatment	Branch apices associated with: Current year fronds: Rhizome tips/20: Healthy	Current year fronds: Rhizome tips/20: Dead or dying	Current year fronds: Associated frond buds: Healthy	Current year fronds: Associated frond buds: Dead or dying	Current year fronds: Associated frond buds: Not visible	Fronds older than 1 year: Rhizome tips/10: Healthy	Fronds older than 1 year: Rhizome tips/10: Dead or dying	Fronds older than 1 year: Associated frond buds: Healthy	Fronds older than 1 year: Associated frond buds: Dead or dying	Fronds older than 1 year: Associated frond buds: Not visible	Lower lengths of rhizome/20: Healthy	Lower lengths of rhizome/20: Dead or dying	% reduction in frond density 1958
(a) *Borates/per 10 sq. yd.* (treated May 1957, analysed Oct. 1958)													
Control	20	—	20	—	1	10	—	9	—	2	18	2	—
2 lb. DBG	4	—	4	—	—	3	7	3	—	7	4	16	59
1 lb. UB	19	1	22	1	2	10	—	11	—	—	14	6	13†
2 lb. UB	20	—	22	—	2	9	1	10	—	1	14	6	9†
½ lb. UB+½ lb. DBG	20	—	21	1	1	7	3	6	—	3	12	8	29
1 lb. UB+1 lb. DBG	20	—	22	—	4	7	3	7	1	3	12	8	43
2 lb. PC	—	20*	—	20*	—	—	10*	—	10*	—	—	20	100
4 lb. PC	—	20*	—	20*	—	—	10*	—	10*	—	—	20	100
4 lb. B44	—	20*	—	20*	—	1	9*	1	9*	—	1	19	71
8 lb. B44	—	20*	—	20*	—	—	10*	—	10*	—	—	20	100
(b) *Sodium chlorate/acre* (treated July 1957, analysed Oct. 1958)													
Control	20	—	20	—	1	10	—	9	—	2	18	2	—
100 lb.	19	1	27	—	3	10	—	8	—	2	10	10	32
200 lb.	10	—	13	—	—	10	—	10	—	—	2	18	75
300 lb.	—	20*	—	20*	—	1	9*	1	9*	—	1	19	98
400 lb.	—	20*	—	20*	—	—	10*	—	10*	—	—	20	100
500 lb.	—	20*	—	20*	—	—	10*	—	10*	—	—	20	97
(c) *Dalapon or aminotriazole (ATA)*, analysed 8 weeks after treatment (1957)													
Control	20	—	16	1	3	10	—	6	—	4	—	—	—
20 lb. dalapon	20	—	10	—	10	10	—	4	—	6	—	—	—
40 lb. dalapon	19	1	15	—	5	10	—	3	—	7	—	—	—
20 lb. ATA	20	—	13	—	7	10	—	9	—	4	—	—	—
40 lb. ATA	19	1	10	—	10	9	1	6	—	4	—	—	—
10 lb. dalapon+10 lb. ATA	20	—	12	1	7	9	1	4	1	5	—	—	—
15 lb. dalapon+15 lb. ATA	19	1	6	—	14	9	1	5	1	4	—	—	—
(d) *Dalapon or aminotriazole (ATA)*, analysed 1 year after treatment (1958)													
Control	20	—	16	—	4	11	—	5	1	4	—	—	—
20 lb. dalapon	18	2	16	—	6	10	—	8	1	1	—	—	—
40 lb. dalapon	17	3	15	—	8	9	1	6	1	3	—	—	—
20 lb. ATA	19	1	16	—	6	10	—	9	1	1	—	—	—
40 lb. ATA	20	—	18	—	6	9	1	6	—	4	—	—	—
10 lb. dalapon+10 lb. ATA	18	2	14	—	7	11	—	7	1	2	—	—	—
15 lb. dalapon+15 lb. ATA	20	—	13	—	9	10	—	8	1	1	—	—	—

* Completely rotted away † Increase in density over control

Introduction

In one of the routine experiments laid down by the Unit in 1956 to test the toxicity of new herbicides to bracken, it was found that dalapon (Na) at doses between 10 and 40 lb. acid equivalent (a.e.)/acre gave an appreciable reduction of fronds in the year after spraying. Further investigations have, therefore, been carried out with this herbicide to determine its potential value for the practical control of bracken. The results so far obtained are summarised in this report. The programme has been in two phases, the first carried out by the Unit to determine the best method and time of application, the second in collaboration with the National Agriculture Advisory Service to gain experience of the varied reaction of bracken growing in different situations and localities. All experiments have been sprayed using the commercial product Dowpon containing 85% sodium salt of 2,2-dichloropropionic acid and a wetting agent. No additional wetting agent was added. All doses in this report are in terms of lb. of dalapon a.e./acre. The experiments were of randomised plot design with three replicates.

Experimental and results

I. Experiments carried out by the Unit

Eight experiments have been carried out by the Unit in the neighbourhood of Oxford, the principle object being to investigate the following factors of application that could influence the results: date of application, single dose compared with half-doses at two dates, volume rate and method of application. Counts of bracken were made before spraying as well as in the year following spraying. The pre-spraying counts have not been used in presenting the results because it was found that the density of the control plots often varied from one year to another, in some instances by nearly 70%; also considerable errors were inevitable when counting dense mature bracken. The results have therefore been expressed in terms of the percentage reduction of the population on the control plots at each time of assessment. When the assessment was made, a strip 18 in. wide around each plot was discarded.

Relevant details concerning each experiment are given in Table I. The results are briefly summarised in Tables II–VI.

Table I

Details of experiments carried out by A.R.C. Unit

Expt. No.	Stage of development	Vol. rate, gal./acre	Site
W/32/55	Mature fronds, 3–4 ft.	40	Large unshaded area in woodland.
W/15/57	Fronds not fully expanded, 4–5 ft.	20	Oak wood with more or less closed canopy.
W/17/57	June: Fronds still uncurling, 3–6 ft.	20	Sparsely wooded area in parkland.
	July: fronds fully uncurled, 3–6 ft.	20	
	August: fronds mature, 3–6 ft.	20	
	September: lower pinnae turning brown.	20	
W/18/57	Fronds uncurled but not fully expanded, 3–6 ft.	See Table VI	Sparsely wooded area of parkland.
W/19/57	Fronds still uncurling at apex, 4–6 ft.	See Table V	Sparsely wooded area of parkland.
W/21/57	Fronds still uncurling and expanding, 2–4 ft.	20	Open ride between conifer plantations.
W/24/57	Fronds mature, fully expanded and producing spores, 3–4 ft.	40	Large open area on hilltop.

II. Experiments carried out in co-operation with the National Agricultural Advisory Service

Eleven experiments were sprayed in late July 1957. The lay-out was identical at all sites. Treatments were dalapon at 5, 10 and 20 lb. a.e./acre arranged in randomised blocks (one control per block) with three replicates. The plot size was 4 yd. × 6 yd. with 1-yd. paths between plots. Spraying was carried out in each case with the Oxford Precision Sprayer at a volume rate of 20 gal./acre. The sites varied considerably in aspect and contour and in the height and density of the bracken and the associated vegetation. This information is summarised in Table VII. The bracken in each case was completely unfurled or approached this stage although in no instances had the sporing stage been reached. Spores were, however, just beginning to appear on 1st August at the time of the second spraying at Llandrindod. No pre-spraying counts were made.

Tables II–VI

Effect of dalapon on bracken as assessed during the year after treatment

Results (mean of 3 replicates) expressed as % reduction of fronds compared with control at time of assessment. Plots were generally 4 yd. × 6 yd. and were sprayed by means of the Oxford Precision Sprayer. W/19/57 was sprayed with a Land Rover sprayer and plots were 5 yd. × 20 yd. All experiments were of randomised block design.

Table II

Preliminary experiments on dose-response

(frond density as % reduction of control)

	W/32/55		W/15/57			W/21/57	W/34/57		
Sprayed	14.8.56		6.6.57			7.6.57	28.8.57		% ground cover of bracken
Assessed	27.5.57	3.7.57	19.5.58	8.7.58	27.8.58	8.7.58	5.6.58	8.7.58	8.7.58
Dose, lb./acre									
5	—	—	78	42	—	8	60	31	87
10	76	42	72	40	16	6	90	41	18
20	93	72	97	76	42	0	98	54	7
40	97	92	—	—	—	—	—	—	(Control) 100

Table III

Spraying experiment W/17/57 (i)
(assessed 3.6.58)

Frond density as % reduction of control

Sprayed on	20.6.57	25.7.57	26.8.57	26.9.57
Dose, lb./acre				
5	35	14	30	23
10	38	31	33	20
20	53	76	62	30

Table IV

Split application experiment W/17/57 (ii)

Assessed	3.6.58	8.7.58
Dose, lb./acre		
2·5+2·5 lb.	−18	13
5+5 lb.	41	21
10+10 lb. applied on 21.6.57 and 26.8.57 respectively	71	29

Table V

Volume rate experiment W/19/57
(Land Rover application)

Sprayed 26.6.57, assessed 24.7.58; dose 7·5 lb./acre

Volume rate (gal./acre)	7	22	83	control
% reduction of control at time of assessment	36	47	38	—
% reduction based on pre-spraying counts	−12	−8	−17	−68

Table VI

Volume rate experiment W/18/57
(hand application)

Sprayed 26.6.57, assessed 3.6.58; dose 10 lb./acre

Volume rate (gal./acre)	10	40	80*
% reduction of control	9	26	36

Difference between treatments not significant.
* Application by hand lance at 50 p.s.i.; other treatments applied over-all with a spray boom.

Observations made on some of the trials in the autumn of the year of spraying showed that the treatments were slow in producing visible symptoms, which consisted of scorch of the fronds, and that the higher the dose the greater the scorch.

Results

Counts early in the year following spraying indicated a marked effect of treatment (Table VIII). The lower doses had given widely varying results between different sites but at 20 lb. of dalapon/acre in each instance there was 75% or more reduction of frond density, and even 99% reduction at three sites. Counts taken later in the year showed that an increase in fronds on the treated plots had occurred since the previous assessment. At only two sites was there now a 75% or greater reduction in fronds as a result of treatment with 20 lb. of dalapon/acre. As before, the results varied greatly from site to site. At some sites the density on the treated plots had not changed markedly since the early counts, notably at Otley, whereas at other sites what apparently had been an excellent control at the time of the first count turned out later to be a very poor control; the outstanding example of this is the experiment at Caerphilly.

In order to get some assessment of vigour of the treated bracken the average height was measured and the density of the foliage estimated as the amount of ground not covered by bracken (Table IX). The reduction in height varied greatly between experiments. The highest dose of dalapon gave a reduction varying between 0 and 80%. As might be expected the estimates of ground cover varied from site to site, but in each experiment there was generally a marked dose trend, the higher dose being associated with the least cover of bracken.

Table VII

Conditions at each site at time of spraying

(N.A.A.S. experiments)

Site	Aspect and contour	Height of bracken, ft.	Remarks
1. Ringwood, Hants.	Flat, sheltered on east by wood	3	Rain 1 h. before spraying but foliage dry when sprayed. Sharp shower ½ h. after spraying completed
2. Caerphilly, Wales	Slope with northerly aspect. Open	2	Bracken burnt off previous year and ground blackened at time of spraying
3. Llandrindod, Wales	Steep slope with westerly aspect. Open	4–5	Rain fell within 1½ h. of spraying on 20th July: a duplicate set of plots was sprayed on 1st August
4. Brampton Bryan, Hereford	Steep slope with easterly aspect. On wooded hill	4½–5½	Rain ½ h. before spraying and foliage wet when sprayed. Rain within 1½ h. of completion of spraying
5. Oswestry, Salop	Steep slope with northerly aspect. Open	4–5	
6. Otley, Yorkshire	Level area in small valley in moorland. Open	1	The area had been crushed twice a year, in the preceding three years. This had reduced the bracken in height and vigour but apparently not in density of fronds
7. Stanhope, Co. Durham	Slope with easterly aspect. Open	4–5	
8. Blanchland, Co. Durham	Slight slope with south-easterly aspect. Open	1½–2	Bracken open: kept in check as a result of cutting for bedding
9. Edale, Derbyshire	Steep slope with northerly aspect. Open	2–3	Bracken wet when sprayed: drizzle 1 h. after spraying
10. Mildenhall, Suffolk	Flat. Along lane in arable country	6–7	
11. Woburn, Bedfordshire	Flat in open area of woodland	4–5	

Table VIII

Effect of dalapon on bracken

(Frond counts during year following spraying as % reduction of control)

Site	Ringwood		Caerphilly		Llandrindod (a)*		Llandrindod (b)		Brampton Bryan†		Oswestry†	
Date of assessment, 1958	27/5	11/7	27/5	31/7	29/5	1/8	29/5	1/8	4/6	25/7	5/6	—
Dalapon, lb. a.e./acre												
5	79	14	57	−6	85	27	90	27	14	21	5	18
10	79	25	50	5	98	40	97	31	56	36	32	39
20	93	75	91	7	99	54	99	49	89	53	79	68
Approx. no. fronds on control plots (per sq. yd.)	0·3	13	6	18	10	18	10	15	12	13	11	15
Date of spraying, 1957	12/7		1/8		20/7		1/8		19/7		19/7	

Site	Otley		Stanhope		Blanchland		Edale		Mildenhall		Woburn	
Date of assessment, 1958	11/6	6/8	10/6	8/8	20/6	2/9	5/6	14/8	30/5	—	7/7	4/9
Dalapon, lb. a.e./acre												
5	35	29	11	46	8	−7	88	52	—	—	46	20
10	84	72	76	43	15	3	99	61	56	—	92	65
20	99	91	86	58	75	45	99	71	75	—	97	64
Approx no. fronds on control plots (per sq. yd.)	58	42	9	46	24	22	100	104	6	—	12	12
Date of spraying, 1957	22/7		22/7		23/7		24/7		25/7		25/7	

* Heavy rain followed spraying and duplicate plots sprayed on 1.8.57
† Approximate figures based on an estimated density of control plots

Samples of the bracken rhizomes were taken from each plot at the Edale experiment on 10th October, 1958, the numbers of living rhizome apices and frond buds counted and fresh weights recorded. Results are summarised in Table X. Most of the living apices and frond buds from the plots treated with 20 lb. of dalapon/acre were obviously affected, being markedly swollen and internally discoloured and it is probable that many of them will fail to survive. Consequently the figures given may considerably underestimate the full effects.

Discussion

The results of these experiments show a remarkable variation when assessed during the year following spraying, ranging from no appreciable effect after applying 20 lb. of dalapon/acre

Table IX

Effect of dalapon on height and ground cover of bracken 12 months after spraying

(1) Height expressed as % reduction of control
(2) Ground cover expressed as % of ground area not sheltered by fronds

Dalapon, lb. a.e./acre	Ringwood		Caerphilly		Llandrindod (a)*		Llandrindod (b)		Brampton Bryan		Oswestry	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
5	16	7	25	13	13	5	31	5	0	7	10	—
10	25	33	39	17	20	15	27	10	12	15	33	—
20	46	88	57	53	43	47	47	50	45	40	50	—
Control	—	3	—	10	—	0	—	0	—	2	—	—
Date of assessment, 1958	11/7		31/7		1/8		1/8		25/7		—	

Dalapon, lb. a.e./acre	Otley		Stanhope		Blanchland		Edale		Mildenhall		Woburn	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
5	33	35	0	42	16	27	40	—	—	—	2	7
10	53	84	16	45	13	27	60	—	0	0	33	52
20	80	97	46	58	5	58	80	—	0	0	38	58
Control	—	8	—	32	—	13	—	—	—	—	—	0
Date of assessment, 1958	6/8		8/8		2/9		14/8		5/9		4/9	

* see Table VIII

Table X

Effect of dalapon on rhizomes 14 months after treatment

(Experiment at Edale)

Sample per plot = 3 sq. ft. (figures are mean of 3 replicates)

Dalapon, lb. a.e./acre	Number of living rhizome apices	Number of living frond buds	Fresh weight of rhizomes, lb.	oz.
5	86	78	2	12
10	68	61	3	5
20	48	40	1	14
Control	84	89	3	11

to a 90% reduction of fronds being maintained throughout the growing season. Most of the experiments were sprayed at one time of the year with a standardised technique of application, and the variation cannot therefore be attributed to these factors. The experiments designed to find out whether date or method of application are important factors influencing the effect of dalapon on bracken have failed to give accurate information, but even so it seems that an explanation for the varied results must be sought elsewhere. The most successful results were obtained at a site (Otley) where the bracken had been crushed twice a year during the three years preceding the dalapon treatment; this is the only site reported to have received management of this kind. Apart from this, there is no hint of why results should have been different at the various sites.

Of particular interest are the experiments in Blenheim Park (W/17–19/57). Four experiments, including a wide range of treatments, were laid down within an area of 200 yd. × 50 yd. of what appeared to be uniform bracken. Counts of fronds in the control plots before treatment compared with similar counts made the following year are given in Table XI.

Table XI

Variation in frond density of control plots, Blenheim

Experiment No.	Density, fronds/sq. yd. 1957	1958
W/17/57 (i)	13	21
W/17/57 (ii)	13	12
W/18/57	11	4
W/19/57	9	14

With such variation of the untreated frond populations it cannot be expected that experiments of the type described, in which assessments have been confined to recording frond densities, will allow accurate comparison of treatments, although they are useful for assessing over-all effectiveness. The value of assessing the effects of herbicide treatment of bracken by examination of the rhizomes has been emphasised by Conway & Forrest[1] and there is no doubt that much valuable information would have been obtained if more analyses of rhizomes of the kind done by McIntyre[2] for the Edale experiment had been carried out.

The response of bracken to dalapon appears to be similar to that observed for *Agropyron repens* and other creeping perennial grasses:[3] death of aerial growth followed by a dormancy of the rhizome buds which may or may not be permanent according to the dose of dalapon applied, the environmental conditions and other factors. Regrowth from temporarily dormant bracken rhizomes is illustrated in the histogram (Fig. 1).

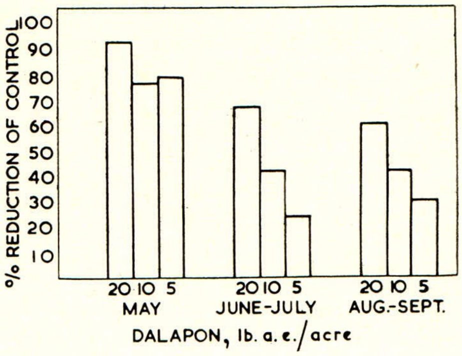


FIG. 1. *Dalapon on bracken, 1956–58*
% reduction of control based on frond counts during the year following spraying (mean results of 18 experiments)

Conclusion

From these results it is clear that dalapon at doses up to 20 lb./acre is unlikely to eradicate bracken, but that a marked suppression of frond density and vigour can often be obtained, the effect increasing with the dose applied. It remains to be seen whether dalapon applied in two successive years can eradicate bracken and experiments with this in view are already in progress.

Acknowledgment

The authors wish to thank those N.A.A.S. officers, farmers and landowners who made these experiments possible by their help and co-operation, and also Mr. G. McIntyre for sampling the plots at Edale.

References

[1] Conway, E., & Forrest, J. D., *Proc. 3rd Brit. Weed Control Conf., 1956*, p. 255

[2] McIntyre, G., personal communication, 1958

[3] Fryer, J. D., & Chancellor, R. J., *Proc. 4th Brit. Weed Control Conf., 1958*, p. 197

GRAZING OF BRACKEN *(PTERIDIUM AQUILINUM)* BY SHEEP IN SOUTH WALES

by

R. GARRETT JONES

(N.A.A.S., Wales)

Bracken has been locally heavily grazed, to the point of near or complete destruction, by sheep in several localities. The phenomenon is described from observations made over the past four years.

Introduction

Large areas of bracken occur on most hill sheep grazings in Wales. Sheep do not normally graze the fern beyond taking a casual bite occasionally, and where the bracken is so strong as to eliminate other species, healthy sheep rarely penetrate it. Over the last four years, however, several cases have come to our notice where obvious and severe grazing of dense fern by sheep is taking place, causing the weakening or eventual destruction of the bracken. In 1954, a farmer informed Brecon N.A.A.S. officers that areas of bracken on his sheep-run at Llangynog on Mynydd Eppynt common had been dying off. Soon after, a similar phenomenon was reported from Llanafan Fawr, several miles farther north. A few further cases at widely-scattered centres on hill grazings in Breconshire, Cardigan, Radnorshire and N. Monmouthshire have since been observed. They occur on both Silurian and Old Red Sandstone formations.

The first line of investigation was to look for a disease, such as those reported by Braid[1] to have caused dying-off of bracken in Scotland. From observations in 1955, however, Dr. J. Bradley Jones (Plant Pathologist, N.A.A.S. Cardiff) concluded that sheep were grazing the bracken. It later transpired that the Brecon farmer was also aware of this, but had been reluctant to admit it; this reluctance has been shared by others, including the author, on first hearing of the phenomenon. Grazing of bracken by cattle and horses is not of course unknown and is frequently the cause of poisoning.[2] In some instances, one sees small patches of fern on enclosed land very heavily grazed, even where there is plentiful herbage. Such grazing does not, however, normally take place on the open hill, and sheep are generally supposed to be less prone than cattle to bracken poisoning, both from being less inclined to take it and from some greater resistance to its effects.[3]

Description

Periodic observations have been carried out at the Llangynog site since 1955 and the following account is based mainly on these. The other sites show similar, but less intensively developed, phenomena.

When inspected in 1955 by N.A.A.S. officers, at least one area (B), approx. 1 acre lying at about 1300 ft. elevation, had been reduced to a stand of only isolated, weak fronds; it was evident here from the paucity of grass cover and from the litter and rhizome remaining, that the bracken cover had recently been dense. A second area (C), down the slope and to the west of B, was currently subject to attack. Here, the bracken litter from 1954 showed clearly the strength and density of the fern, and on an area of about ¼ acre there were practically no grass or other pasture species; the fern growth was distinctly 'hummocky' and many of the hummocks were colonised by *Polytrichum*. Growth during 1955 was much more scanty and less vigorous than it had evidently been before, and there was clear evidence that the sheep were spending a lot of time among it. The young unexpanded fronds had been bitten off several inches above ground level, but the leafy part of the fronds was often left lying on the ground and apparently they had been nipped off without any grazing taking place.

Observations

When the site was visited in 1956, it appeared that an area (A) of some 2 acres 100 yards to east of B had been the first seen to be attacked, in 1954. On further inspection it was evident that both this and other smaller areas now under grass with only sparse bracken had formerly carried dense bracken and this has been confirmed by aerial survey photographs of 1946 which have since been examined. The whole area judged in this way to have been cleared of dense fern in these three blocks runs to some 4–5 acres.

Observations 1957/8

Frequent observations of the Llangynog area over the last two years enable the following description of the development of the phenomenon to be given.

Grazing may occur at any time during the growing season of the bracken. When fully-expanded fronds are attacked, it is generally by the removal of pinnae and sometimes, if not too high for the sheep to reach, of the apex. At two sites newly observed in 1958, however, mature fronds, like the unexpanded fronds at Llangynog, were bitten through below the lowest pinnae and the tops left lying on the ground.

The attack starts in small foci, usually (so far as observations have shown) in mature growth, where practically all fronds are damaged. The concentrated attack continues in subsequent seasons, with a more or less gradual increase in extent; additionally, an extensive surrounding belt may sometimes be subjected to a milder form of grazing. Sometimes (especially in the areas of most vigorous growth at the onset) grazing is continued until the fern is totally destroyed; in other places the sheep seem to lose interest when it is only depleted. The spread of the attack seems to be halted by any discontinuity in the bracken cover, e.g. at a watercourse, even though the gap may be only a few feet.

Ponies, which are the only domestic stock besides sheep running on the Llangynog area, do not appear to have paid any special attention to the grazed areas. It was suggested by one farmer that voles, which were very numerous in 1956, as well as the sheep may have attacked the bracken. According to their owners, there has been no sign of any ill-effect on the sheep running on the grazed areas.

Two plots were fenced early in 1958 to exclude large animals. The fence on area C proved to be too late to preserve any fern, although a few very diminutive fronds appeared there in 1957. The second extends from a focus first observed in autumn 1956, into unaffected bracken. The recovery on the grazed area within this fence appeared normal in 1958, allowing for some weakening by the previous grazing (4 ft. 6 in. high where not grazed, 3 ft. 9 in. where grazed during 1956/7).

Discussion

From the severity of the observed grazing and from the regrowth of the protected area, there is little doubt that the weakening and eventual death in patches of the bracken is attributable directly to grazing. The effect of grazing, continued throughout the growing season for several years, must of course be expected to be more drastic than that of periodic cutting as described for instance by Conway & Stephens,[4] on bracken as on more usually grazed species. Whether there is any associated weakening of the bracken apart from the effect of grazing has not yet been determined; the search for soil factors or fungal pathogens has not revealed anything which could cause such a condition.

From the selectivity of the attack by the sheep it is reasonable to suppose a difference in palatability of the fern. Had this difference been present previously, it seems that the sheep must have discovered it by their habit of taking occasional bites at the fern. The possible causes of such a difference arising, in the pattern observed, seem to be only three: (1) a physiological change due to bracken-sickness of the soil after long-continued bracken dominance; (2) changes in the fern due to physiological ageing of plants; and (3) as a result of invasion by some micro-organism, or of an alteration in the status of one, affecting the fern in some way.

Bracken-sickness of the soil has been suggested by Braid[5] as a possible cause of dying-out of fern in Scotland; but he makes no reference to any grazing by the sheep and it is difficult to believe that its occurrence would not have been observed by him if it were present. Similarly, physiological ageing of the bracken plant, adduced as the cause of the 'ring growth' sometimes seen in bracken, has not been reported elsewhere as leading to increased grazing of the fern by sheep, nor would it seem to be consistent with the vigour of the fern before the onset of grazing at these sites. The third possibility would seem better able to account for the incidence of the phenomenon than the other two. At least it cannot be ruled out so far and it is suggested that a variety of transmission techniques should be tested.

Experimental work with bracken is complicated by the ecology of the plant and the difficulties of artificial culture. In nature, the extent of any one clone of bracken may be very great and physiological differences between clones may be significant, as indeed are sometimes the differences in morphology and phenology. Allowance must be made for these differences in the interpretation of any observations. It would be valuable to know whether similar grazing of bracken can be found on hill pastures in other parts of the country.

References

1 Braid, K. W., *Scot. J. Agric.*, 1934, **17**, 297
2 Stamp, J. T., *J. Brit. Grassland Soc.*, 1947, **2**, 191
3 Evans, C., private communication, 1958
4 Conway, E., & Stephens, R., *N.A.A.S. quart. Rev.*, 1954, (25), 1
5 Braid, K. W., *J. Brit. Grassland Soc.*, 1947, **2**, 181

Discussion on the preceding three papers

Dr. R. E. Slade.—I should like to make a guess about the mode of action of dalapon on bracken. Bracken grows on land which has a very low iron content, and as with deciduous trees growing on this land, the leaves which die and fall on to the ground return the iron to the soil and thence to the next generation of leaves. If dalapon reacts directly or indirectly to interrupt this cycle it would kill the bracken.

Dr. H. P. Allen (Plant Protection Ltd.).—Does the age of the bracken plant affect the susceptibility to herbicides and also what effect has dalapon had on the herbage growing in association with the bracken. This point would be of particular importance where it is desired to spray bracken which had invaded reasonable marginal grazing land.

Mr. J. D. Forrest.—No.

Mr. F. W. Petterson (E. Bjornrud, Agric. Chemical Divn., Oslo).—In work with the systemic herbicides, aminotriazole and dalapon, carried out in Norway for the control of bracken in forest areas, it appears to be of the utmost importance that the fronds are thoroughly wetted. Therefore the equipment used for application is important and in Norway we think that the knapsack mist blower is the best for the purpose. We think that by employing a blast sprayer, the quantity of herbicide could be considerably reduced. We should like to know what type of equipment has been used for the work carried out in Scotland.

Mr. Forrest.—Originally a knapsack sprayer but more recently a mist spray.

TOXICITY OF DALAPON AND AMINOTRIAZOLE TO SOME COMMON BRITISH GRASSES: A PROGRESS REPORT

by

J. D. FRYER and R. J. CHANCELLOR

(*Agricultural Research Council Unit of Experimental Agronomy, Oxford*)

This report gives the results of a series of exploratory experiments on the toxicity of dalapon and aminotriazole to a number of common grasses growing under varied conditions. The chemicals were applied at doses in the range 1–20 lb./acre in August and September 1957. Assessment of the results was made in several ways, but great importance was placed upon the minimum dose required to give complete kill and the maximum doses that allowed (*a*) vigorous regrowth and (*b*) flowering respectively during the spring or summer of the year after spraying.

The results, which must be regarded as preliminary, show that different grasses vary considerably in their reaction to these herbicides.

Introduction

The potential value of any new herbicide can only be assessed by a programme of testing aimed at categorising many species of crop and weed plants according to their susceptibility.

There are no published accounts of any comprehensive evaluation of the toxicity to grasses and other plants of 2,2-dichloropropionic acid (dalapon) and 3-amino-1,2,4-triazole (aminotriazole), herbicides that are well known as being highly phytotoxic to monocotyledons. Information must at present be gleaned from reports scattered throughout the literature on experiments in which the effectiveness of these herbicides for miscellaneous weed control problems in many parts of the world has been tested. Little information is pertinent to the species and conditions found in Great Britain, the most relevant work being from New Zealand, where considerable attention has been given to dalapon during the last three years.[1–5] No results have been published concerning the toxicity of aminotriazole to common British grasses.

Published information on dalapon, obtained from experiments carried out in Great Britain, refers to the following species: *Agropyron repens*, *Agrostis gigantea* and *Arrhenatherum elatius*;[6] *Agrostis gigantea* and *Poa trivialis* in lucerne;[7] *Alopecurus pratensis*, *Dactylis glomerata*, *Poa annua*, *Poa trivialis*.[8] In addition, a general review concerning experience with dalapon in Britain has recently been published.[9]

The experiments described in this report were planned specifically to obtain preliminary information on the toxicity of dalapon and aminotriazole to a range of common British grasses, as a small step towards the goal of having enough knowledge to be able to assess with some accuracy the probable value of these interesting new herbicides in British agriculture and horticulture. The experiments are of a preliminary nature and of limited scope, and the only justification for publishing the results at this stage is that the dearth of information from other sources may make them of interest to other research workers. It is emphasised that much more work of this type is required before the response of common British grasses to these herbicides can be predicted with confidence.

Experimental and results

1. *Cultivated grasses*

The first experiment (W/38/57) was mainly determined by the nature of the site which was kindly made available by Messrs. Twyford Mills Ltd., Banbury. An area at Cottisford, near Brackley, consisting of rows each of a single grass species and approximately 10 yd. long had been sown in the spring of 1956 and kept clean cultivated until the autumn of 1957 without additional management. The opportunity was taken to spray most of the grass rows with dalapon using the small-scale logarithmic sprayer developed at Oxford,[10] to obtain preliminary information on the toxicity of dalapon and aminotriazole to the grass species represented and on the difference of susceptibility between varieties of cultivated grasses where sufficient rows of each variety were available.

Spraying took place during 18th–19th September, 1957, by which time some grasses were showing signs of dying back for the winter but most were in active vegetative growth. Each plot consisted of two rows of the same species and generally of the same variety. In each case the maximum dose was 19 lb. of dalapon acid equiv. or aminotriazole/acre, the minimum 0·8 lb. The volume rate was 66 gal./acre.

Assessments carried out at intervals consisted of records of the dose required in each case to give the following responses: death of aerial growth 3 weeks following spraying, complete kill of the plant 8 months after spraying, suppression of regrowth during the year following spraying, and suppression of flowering.

The plots continued to be clean cultivated for the duration of the experiment; otherwise there was no management.

The main results, expressed as the average of all replicates of each species, ignoring varieties, are summarised in Figs. 1–3. From these, a useful picture of the response of the different grasses to dalapon or aminotriazole during the 10 months following treatment can be obtained. It is emphasised that they are preliminary results and that any comparison between species should be made with reservation because of the limitations of the experimental lay-out, the different numbers of replicates of the various species and the different varieties of which each species was composed.

The experiment could not be planned to reveal accurately differences between varieties, and the results for individual varieties are not therefore presented. In general, there appeared to be little difference in the response of varieties to dalapon, as judged by those for which a sufficient number of replicates were available to justify a comparison. No information was obtained on the response to aminotriazole of different varieties.

From Fig. 1, it will be seen that timothy (*Phleum*) was not killed by the maximum dose of 19 lb. of dalapon/acre and was consistently more tolerant than perennial ryegrass (*Lolium*), meadow fescue (*Festuca*) and cocksfoot (*Dactylis*). During the season following application, timothy flowered normally even after treatment with 19 lb./acre. Ryegrass was very susceptible and was killed by doses above 1 lb./acre. Meadow fescue and cocksfoot were intermediate, about 11 lb./acre being required to kill the plants.

The results for the same species with aminotriazole show a similar pattern (Fig. 2). Timothy during the year following spraying was not appreciably affected by the maximum dose applied (19 lb.). Ryegrass was killed by less than 1 lb./acre. Meadow fescue and cocksfoot were again intermediate.

Fig. 1

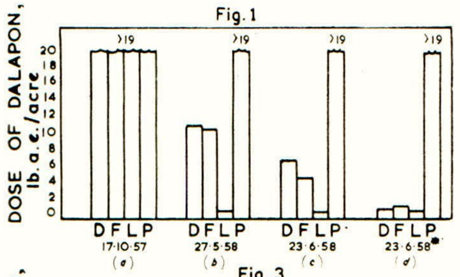


Fig. 2

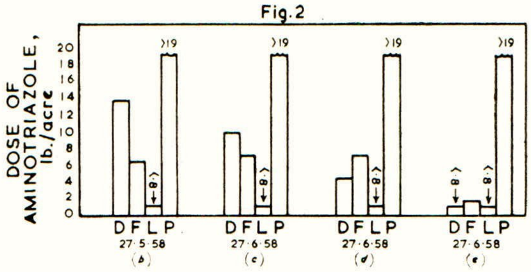
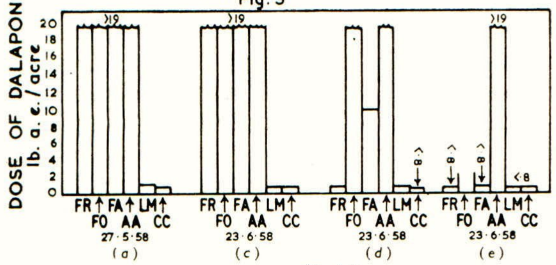


Fig. 3



Response of grasses to (Figs. 1 and 3) *dalapon and* (Fig. 2) *aminotriazole applied in the autumn* (*19.9.57*)

(*a*) minimum dose for 100% kill of foliage
(*b*) ,, ,, ,, ,, ,, ,, plant
(*c*) maximum dose allowing vigorous regrowth
(*d*) dose above which flowering did not occur
(*e*) maximum dose having no effect on flowering
(dates given are when assessments were made)

	Varieties Fig. 1	Varieties Fig. 2
L = *Lolium pratensis*	S.23, S.101, S.24 (11)	S.23, N.Z. (3)
F = *Festuca pratensis*	S.53 (3)	Dutch (1)
D = *Dactylis glomerata*	S.26, S.143, S.37 (11)	S.26, S.37 (5)
P = *Phleum pratense*	S.48, S.50, S.51 (8)	S.48 (4)

* 15.7.48 for *Phleum* which is late in flowering

	Varieties Fig. 3
FR = *Festuca rubra*	S.59, Danish, NIAB Chewings Fescue (7)
FO = ,, *ovina*	(1)
FA = ,, *arundinacea*	(1)
AA = *Alopecurus pratensis*	(1)
LM = *Lolium multiflorum*	(3)
CC = *Cynosurus cristatus*	(1)

Figures in brackets are numbers of replicates

The results of applications of dalapon to other species of grass are summarised in Fig. 3. It should be noted that, with the exception of *Festuca rubra* and *Lolium multiflorum*, the results are based on a single replicate and are only indicative. Eight months after treatment, at doses up to the maximum of 19 lb., the following species were growing vigorously: *Festuca rubra, F. ovina, F. arundinacea, Alopecurus pratensis.* In contrast, the *Lolium* and *Cynosurus* were very susceptible and had been killed by doses between 1–2 lb. As judged by the effect on flowering, the *Alopecurus* was more resistant than the other species, being apparently unaffected by the maximum dose.

The most interesting results of this experiment may be summarised as follows:

(1) Timothy, after an initial check, was not appreciably affected by dalapon or aminotriazole at doses up to 19 lb./acre.

(2) Other species showing marked resistance to 19 lb. of dalapon, as judged both from the point of view of vegetative growth and flower production, were *Festuca ovina* and *Alopecurus pratensis.*

(3) *Dactylis* and *Festuca pratensis* were seriously checked but vigorous regrowth occurred after treatment with doses of less than 5 lb. of dalapon/acre.

(4) *Lolium perenne, L. multiflorum* and *Cynosurus cristatus* were very susceptible and were killed by doses of 1 lb. of dalapon/acre or less.

(5) On the species tested, dalapon and aminotriazole were of comparable toxicity.

2. *Grasses and other plants of acid upland pastures*

In addition to the above, seven experiments were carried out near Brecon to gain preliminary information on the toxicity of dalapon and aminotriazole to grasses and other plants that are characteristic of upland pastures on acid soils. Information of this type is required by those who are studying the possible rôle of herbicides for pasture renovation, for example, the chemical destruction of upland swards prior to re-seeding.

Each site was selected with the aid of Mr. R. Garrett-Jones, National Agricultural Advisory Service, Wales, as a reasonably uniform area consisting of a single dominant species of grass chosen as the main subject of the experiment. Other grasses were generally present, also plants such as *Calluna, Erica* spp. and *Vaccinium myrtillus.* Most sites were on unfenced rough land grazed by sheep at an altitude between 700 and 900 ft. Brief details of each site are given in Table I.

Table I

Details of the sites near Brecon

Experiment No.	
W/27/57	Dry peat dominated by *Erica* spp. and *Calluna* with *Festuca* sp. and *Nardus*.
W/28/57	Dry area dominated by *Nardus* and *Vaccinium* with some *Festuca*.
W/29/57	Lightly grazed, tussocky *Molinia* on waterlogged peaty soil.
W/30/57	Field re-seeded few years previously. Uniform sward of *Agrostis tenuis* and *Trifolium repens*.
W/31/57	Tussocky area dominated by *Agrostis canina* and *Festuca rubra*.
W/32/57	Closely grazed *Agrostis–Festuca* sward on peat.
W/33/57	Heavily grazed *Molinia* on waterlogged peat with *Erica tetralix* and *Sphagnum*.

The experiments were all similar in design. Dalapon at 0·5–15 lb. acid equiv./acre and aminotriazole at 0·7–20 lb. were each applied by means by means of the Oxford Logarithmic Sprayer to plots replicated four times which were 3 ft.×25 ft. in area. The volume rate was 66 gal./acre. Spraying was carried out under ideal conditions during 20th–21st August, 1957.

Assessments were made during the summer of 1958 when plants that had not been killed by the herbicide had started to regenerate, but before the more resistant and healthy plants had begun to compete with surviving but damaged plants. Observations on the direct effect of the treatments on each species were therefore obtained.

The results summarised in Table II indicate (*a*) the minimum dose that killed each species, (*b*) the maximum dose at which normal growth occurred during the year following spraying. Increasing doses between these limits caused an increasing reduction of density and vigour.

As might be expected from the varied nature of the habitats and the variation in size and vigour of the plants at different sites, there is not always close agreement between the results for each species. Nevertheless, there is obviously a marked difference between certain species in their susceptibility to dalapon and aminotriazole under the conditions of the experiments and the results indicate the range of doses likely to be effective when the chemical destruction of upland grasses is required.

In Table II, the species are arranged in the approximate order of their susceptibility to dalapon. Difference in response between species should only be regarded as indicative because of the limited number of experiments and the variation in results. It is interesting that both herbicides gave similar results on all grass species with the exception of *Molinia* and *Anthoxanthemum* which were much more susceptible to dalapon than to aminotriazole. Plants other than grasses were in general little affected by the herbicides. It is worth noting that the resistance of these plants might raise a problem in sward destruction work because most are also markedly resistant to 2,4-D. (*Juncus squarrosus* was exceptional in being extremely susceptible to both herbicides.)

The grasses *Deschampsia flexuosa*, *Cynosurus cristatus*, *Poa trivialis* and *Lolium perenne* are included in the table although no record of the dose required to kill has been obtained. They were not abundant and at the time of spraying and during the earlier assessments they were not recorded, but at the last assessment their flowering heads were easily seen. The figures show that under the conditions of these experiments, these grasses were markedly resistant to the herbicides; for *Lolium* and *Cynosurus* this is in contrast to the results of the experiment at Cottisford described earlier in this report. A suggested explanation is that these grasses had been heavily grazed by sheep at the time of treatment and little foliage was present to catch the spray.

3. *Other experiments*

Two small experiments on *Deschampsia caespitosa* (W/25/57) and *Brachypodium pinnatum* (W/37/57) were also sprayed in 1957 with dalapon and aminotriazole at a volume rate of 100 gal./acre using a hand sprayer on 1-sq. yd. plots. Both were in areas of unmanaged and ungrazed land near Oxford where each grass was growing luxuriantly. W/25/57 was sprayed on 19.8.57 and W/37/57 on 30.8.57; in both instances the grasses were in post-flowering stages.

The kill of leaves was assessed about a month after spraying and further scores and counts of living shoots were made during the following year. The results obtained are presented in Tables III and IV. These show that both *Deschampsia caespitosa* and *Brachypodium pinnatum* were very susceptible to dalapon (90% kill or more obtained at 4 lb./acre); but they differed

Table II

Response to dalapon and aminotriazole of grasses and other plants of acid upland pastures
(sprayed August 1957; assessed June–July 1958)

Grasses

Species	No. of experiment	Minimum dose for 100% kill		Maximum dose at which normal growth occurred	
		dalapon	amino-triazole	dalapon	amino-triazole
Deschampsia caespitosa	W/29/57	3	1	< 0·5	< 0·7
Nardus stricra	W/28/57	0·7	2	< 0·5	< 0·7
,, ,,	W/27/57	4	5	< 0·5	3
Anthoxanthemum odoratum	W/30/57	3	>20	1	14
,, ,,	W/31/57	3	—	0·6	> 6
Molinia caerulea	W/33/57	2	19	0·6	4
,, ,,	W/29/57	5	14	0·7	3
Deschampsia flexuosa	W/32/57	—	—	0·7	1
Agrostis canina	W/31/57	5	5	3	2
Festuca rubra	W/28/57	5	5	3	3
,, ,,	W/31/57	10	5	5	2
,, ,,	W/32/57	14	12	5	2
Agrostis tenuis	W/32/57	12	18	2	4
,, ,,	W/30/57	>15	>20	9	>20
Lolium perenne	W/30/57	—	—	9	7
Cynosurus cristatus	W/30/57	—	—	11	>10
Holcus lanatus	W/30/57	>10	>14	10	14
Poatrivialis	W/30/57	—	—	13	> 8

Plants other than grasses

Species	No. of experiment	Minimum dose for 100% kill		Maximum dose at which normal growth occurred	
		dalapon	amino-triazole	dalapon	amino-triazole
Juncus squarrosus	W/29/57	< 0·5	< 0·7	< 0·5	< 0·7
,, ,,	W/32/57	< 0·5	< 0·7	< 0·5	< 0·7
,, ,,	W/33/57	< 0·5	< 0·7	< 0·5	< 0·7
Trifolium repens	W/30/57	9	3	2	< 1
Calluna vulgaris	W/27/57	9	4	1	0·8
Erica cinerea	W/27/57	9	15	1·5	5·4
,, ,,	W/33/57	—	16	—	5·4
Erica tetralix	W/27/57	9	5	1	1
,, ,,	W/33/57	>15	>20	12	6
Carex sp.	W/29/57	>15	>20	>15	—
,, ,,	W/31/57	>15	>20	10	—
,, ,,	W/33/57	>15	>20	10	—
Vaccinium myrtillus	W/27/57	>15	>20	> 6	>20
,, ,,	W/28/57	>15	>20	>15	>20
Viola palustris	W/29/57	>15	2	>15	—
Sphagnum spp.	W/33/57	>12	>20	>12	>20
Polytrichum commune	W/31/57	>15	>20	>15	>20
,, ,,	W/32/57	>15	>20	>15	>20
Galium hercynicum	W/29/57	>15	>20	>15	>20

Footnotes: (1) The species are arranged in order of their susceptibility to dalapon, but because of the variation in results and the limited number of experiments this should not be taken as more than a preliminary indication.
(2) Doses are in terms of lb. of dalapon a.e./acre or lb. of aminotriazole/acre.

Table III

Response of Deschampsia caespitosa *to dalapon and aminotriazole sprayed on 19.8.57*

Date and type of assessment		24.9.57 Score for leaf kill 0=all dead 10=all living	20.5.58 Score for regrowth 0=none 10=vigorous regrowth	14.7.58 Counts of living shoots, total for three replicate plots each containing three tussocks	14.7.58 Flowering head counts, total for three replicate plots each containing three tussocks
	lb./acre				
Dalapon	2	4.5	1	43	0
	4	4	0·5	8	0
	8	3	0	2	0
	16	1·5	0·5	0	0
Aminotriazole	2	3	1	67	3
	4	3	0	0	0
	8	1·5	0	0	0
	16	1·5	0	0	0
Control		7·5	10	—	531

Table IV

Response of Brachypodium pinnatum *to dalapon and aminotriazole sprayed on 30.8.57*

Date and type of assessment		24.9.57 Score for leaf kill 0=all dead 10=all living	21.5.58 Score for regrowth 0=none 10=vigorous regrowth	6.6.58 Shoot counts	20.9.58 Flowering head shoots	20.9.58 % ground cover of *Brachypodium* shoots
	lb./acre					
Dalapon	2	7·5	0	16	3	57
	4	6	0	0	0	7
	8	4	0	0	3	6
	16	2·5	0	0	1	6
Aminotriazole	2·5	5	8	348	29	90
	5	2·5	6	375	31	72
	10	3	4	264	23	68
	20	3	3	132	23	75
Control		8·5	9	473	29	82

greatly in their reaction to aminotriazole. *Brachypodium pinnatum* was resistant to aminotriazole—even 20 lb./acre gave negligible effect in the year after spraying—while *Deschampsia caespitosa* was equally susceptible to both chemicals.

Discussion

Grasses, whether they are crops or weeds, are variable plants subject to many environmental factors that can modify their growth. An evaluation of the toxicity of herbicides to grasses must inevitably show varied results and must be carried out over an extended period and under a wide range of conditions before the response of each species to a given treatment is fully known. Unless a major research effort can be devoted solely to this subject, the collection of information on the toxicity of aminotriazole and dalapon to grasses must be a gradual process, resulting at first in only a blurred and often incorrect image of the true picture, but nevertheless one that acts at least as a guide to would-be users and experimenters.

References

[1] Matthews, L. J., *Bull. N.Z. Dept. Agric.*, 1956, No. 329, p. 100
[2] Foreman, M. S., *Proc. 9th N.Z. Weed Control Conf., 1957*, p. 44
[3] Bell, J. E., *Proc. 10th N.Z. Weed Control Conf., 1957*, p. 104
[4] Blackmore, L. W., *Proc. 10th N.Z. Weed Control Conf., 1957*, p. 18
[5] Matthews, L. J., *Proc. 3rd Brit. Weed Control Conf., 1956*, p. 285
[6] Le Brocq, P. F., & Beech, C. R., *Proc. 3rd Brit. Weed Control Conf., 1956*, p. 279
[7] Green, J. O., Evans, T. A., & Elliott, J. G., *Proc. 3rd Brit. Weed Control Conf., 1956*, p. 269
[8] 'Chemical Weed Control', *Rep. Exp. Rec. Min. Agric. N. I., 1956*, 1957, p. 225
[9] Elliott, J. G., & Fryer, J. D., *Agriculture, Lond.*, 1958, **63**, 119
[10] Fryer, J. D., *Proc. 3rd Brit. Weed Control Conf., 1956*, p. 585

CONTROL OF *AGROPYRON REPENS* BY TRICHLOROACETIC ACID. RESULTS FROM EXPERIMENTS AND PRACTICAL USE IN NORWAY

by

ARNE BYLTERUD

(*Norwegian Plant Protection Institute, Vollebekk, Norway*)

A report is given of 117 trials during 1949–57 and of the effects on couch grass and on crop yields on 230 ha. at 123 sites during 1956 and 1957. Poor control of the grass is obtained by spraying during the active growth period (50–100 kg./ha.), but satisfactory results are given by spraying as soon as possible after snow has melted in the spring. Good yields of root crops, potatoes, kale and cabbage were obtained from the sprayed plots.

Introduction

Couch grass (*Agropyron repens* P.B.) presents the most urgent weed problem in Norway today, as during recent years it has become more widespread, particularly in the districts where cereals are not grown in rotation with other crops. Many farmers will have to consider fallowing if new methods for couch grass eradication are not found. During the last 25 years fallow has very seldom been used in Norway, and if possible the farmers avoid it, the loss of yield and the costs being too high. There is accordingly a great demand for effective chemicals against couch grass.

The demands made on the chemicals for control of couch grass are numerous. The effect against the weed must be satisfactory at a reasonable price, the application harmless to the operator, and last but not least, the chemicals must enable crops of economic value to be grown every year without any appreciable loss of yield.

A number of herbicides have been tested at the Norwegian Plant Protection Institute and 125 trials were made during the years 1947–57. Trials in series are carried out in collaboration with the experimental stations.[1] TCA, dalapon, sodium chlorate, MH, ATA, Chlorosol A, monuron, CIPC, propham and ammonium sulphamate were tried. Although TCA has so far been of the greatest interest to the farmers, it does not solve the whole problem of couch grass, since cereals cannot be grown after TCA treatment and the cropping has to be limited to species with high resistance to TCA. This is undoubtedly an advantage, as the farmers are forced to use crops other than barley, oats and wheat in rotation.

The recommendations for the use of TCA in Norway differ in some respects from those of most other countries, and therefore a summary is given below of the results of experiments which have lead to our present recommendations, and of the experiences gained by the farmers themselves.

Climate and soil conditions in Norway

The distribution of rainfall varies widely in different parts of Norway. In the districts best for cereal production, it ranges from 500 to 1500 mm. yearly. Normal rainfall and normal air temperature at the Agricultural College of Norway, Aas (about 30 km. south of Oslo), are shown in Figs. 1 and 2.

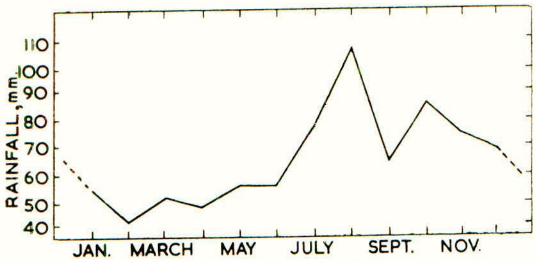
The growing season is short, lasting from about 1st May to 1st October. From late October to April, frost and snow may occur to greater or lesser degree. The change from winter to spring and from spring to summer is very rapid and the interval between snow melting and planting is often only 2–3 weeks.

The soil type changes within small areas. The humus content is higher than in warmer countries, and this probably leads to a greater activity of the micro-organisms. Sand, loam and peat are the most common soil types.

Experimental results

Time of application

TCA was first of all recommended for use during the active growing season of the couch grass, but to avoid loss of yield the treatment had to take place in early autumn after harvest.



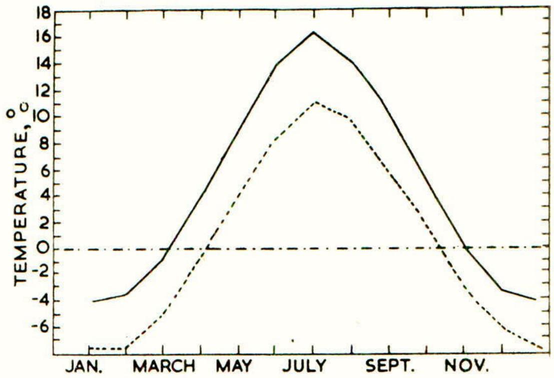


FIG. 1.—*Monthly means of rainfall at Aas, 1901–30*

FIG. 2.—*Monthly means of air temperature at Aas, 1901–30*

——— mean temperature
- - - - - - - minimum temperature

As, however, experiments during the first years showed clearly that early autumn was an unfavourable time for application, single trials and series of trials were made to determine the best time of application.

Table I shows the effect of TCA on couch grass in 26 field trials carried out in 1950–55. Early spring and late autumn treatments seem to have been most effective. In 1954 a series of trials were started, but at that time the best rate of application was not known, and 75 kg./ha. was chosen. This rate was too heavy, but the influence of the time of spraying will be clearly seen from Table II. Only trials laid out on wet soil early in the spring have been included in the table.

Table I

Control of couch grass

TCA sprayed at different times in 26 field trials

	% killed after the following rates of TCA, kg./ha.				
Time of spraying	30	40	50	75	100
Early spring, wet soil	97†	98†	99‡	97†	100*
Spring, dry soil	—	47*	42*	—	75*
Summer	—	—	13†	—	—
Autumn, before ploughing	—	—	41§	56†	53§
Autumn, on ploughed land	—	—	53†	79†	81†
Late autumn, just before frost	—	—	85*	95†	99*

* 1 trial † Mean of 2 trials ‡ Mean of 3 trials § Mean of 14 trials

Table II

Importance of time of application

Mean results of 11 field trials carried out all over Norway, 1954–57

	Untreated	TCA, 75 kg./ha. In early autumn	In late autumn	In early spring
% couch grass plants killed at time of 1st row cultivation	—	67	64	97
% cover of couch grass estimated at harvesting	48	21	18	2

An effective control of couch grass is obtained only by application of TCA in late autumn or early spring. In both cases TCA must operate while the couch grass starts growing in the spring. In 1956 it was postulated that smaller amounts of TCA are required to prolong the natural winter dormancy of the rhizomes than to induce dormancy or kill the rhizomes during the period of active growth.[2]

In 1956–57 a glasshouse experiment was conducted to ascertain whether frost might have any influence upon the effect of TCA, and to test the validity of the above hypothesis.

The results have been published[3, 4] and Tables III and IV include results from this experiment in which 80 pots were used. There is no doubt that frost may depress the viability of couch grass to a considerable extent, especially if the rhizomes have not gone through a natural, or suitable, process of hardening. The experiment showed plainly that the frost may kill the rhizomes (cf. Table III).

Table III

Effect of frost on hardened and unhardened rhizomes

Treatment	Shoot segments per pot harvested 8 weeks after the frost period, 1957 Number	g.
Hardened rhizomes		
Not frozen	40·3	16·5
Frozen 8 weeks	37·0	17·6
Unhardened rhizomes		
Not frozen	44·5	12·4
Frozen 8 weeks	3·0*	1·4*

*Mean of 12 pots

The best time for TCA applications was just before the frost period, although treatment at the end of the frost period was also quite effective. Least effect was obtained for treatments on growing plants 4 weeks after the frost period (cf. Table IV).

Table IV

TCA treatment before and after a period of frost and dormancy

Treatment in Series II		18/12	15/1	12/2	12/3	9/4	7/5	4/6	2/7
				Number of plants at harvesting					
(a) Untreated	not frozen	32·0	28·3	34·8	40·3	36·3	32·5	37·0	32·3
Treated with TCA, 20th Nov.									
(b) 15 kg./ha.	not frozen	7·0	3·5	6·3	11·8	13·5	19·8	19·3	26·3
(c) 30 kg./ha.	,, ,,	0	0	0	0·3	1·0	1·8	4·5	7·5
(d) 15 kg./ha.	frozen 8 weeks	—	—	0	0	0·8	1·7	2·3	4·7
(e) 30 kg./ha.	,, ,, ,,	—	—	0	0	0	0	1·0	1·0
Frozen 8 weeks									
(f) Untreated		—	—	29·0	37·0	34·2	23·2	30·3	23·5
Treated with TCA, 15th Jan.									
(g) 15 kg./ha.		—	—	2·8	1·8	5·0	5·3	6·0	11·0
(h) 30 kg./ha.		—	—	0	0	0	0·3	0·8	1·5
Treated with TCA, 12th Feb. (after 4 weeks' growth)									
(i) 15 kg./ha.		—	—	30·5	23·8	17·8	11·5	9·5	11·3
(j) 30 kg./ha.		—	—	33·5	22·3	3·3	1·8	1·8	4·0
					g. couch grass plants				
(a) Untreated	not frozen	9·9	9·3	12·5	16·5	20·0	18·8	17·5	23·3
Treated with TCA, 20th Nov.									
(b) 15 kg./ha.	not frozen	0·8	1·1	2·9	5·9	8·1	23·1	51·0	27·6
(c) 30 kg./ha.	,, ,,	0	0	0	+	0·2	2·9	26·0	35·5
(d) 15 kg./ha.	frozen 8 weeks	—	—	0	0	+	1·7	10·5	11·1
(e) 30 kg./ha.	,, ,, ,,	—	—	0	0	0	0	1·2	10·6
Frozen 8 weeks									
(f) Untreated		—	—	8·6	17·6	6·7	2·7	4·8	17·2
Treated with TCA, 15th Jan.									
(g) 15 kg./ha.		—	—	0·5	0·5	0·5	2·4	8·6	23·9
(h) 30 kg./ha.		—	—	0	0	0	+	2·3	7·3
Treated with TCA, 12th Feb. (after 4 weeks' growth)									
(i) 15 kg./ha.		—	—	10·3	3·5	0·9	3·5	8·6	17·8
(j) 30 kg./ha.		—	—	10·1	1·7	0·1	0·4	1·5	5·2

Table IV shows also that TCA influences the dormancy of the buds of the rhizomes. In pots treated with 30 kg./ha., shoots of couch grass emerged 16–20 weeks after application. No TCA reaction was noticed on these plants. This fact stresses the importance of growing TCA-resistant row crops which permit cultivation during the season. Crops which give effective shadow in the autumn are preferable.

Rate of application

In 1955 it was realised that the actual rate of application was below 50 kg./ha. and in 1956 a series of trials was started in order to find the best rate of application. Colleagues in other Scandinavian countries were interested in collaborating and trials including the same rates of application are now being carried out in Denmark, Sweden and Norway. Table V shows the Norwegian results from 61 field trials in 1956–57, showing only the effect on couch grass. The yields obtained in the same trials are shown in Table VI.

Table V

Effect on couch grass in field trials carried out all over Norway in 1956 and 1957

	No. of trials	Row cultivated only	TCA, kg./ha. 12·5	25	50
1956					
Sprouts of couch grass as % of control at time of 1st row cultivation	20	—	38	26	20
% Cover of couch grass estimated at harvesting	14	18	6	3	2
1957					
Sprouts of couch grass as % of control at time of 1st row cultivation	41	—	20	11	6
% cover of couch grass estimated at harvesting	35	32	7	5	2

Table VI

Yields after application of TCA early in the spring

(65 trials: control results in kg./ha.)

Crop	No. of trials	Row cultivated only (control)	TCA, kg./ha. 12·5 (% of control)	25	50
1956					
White oil senap	4	1120	96	83	62
Rape	8	1540	97	88	76
Turnip rape	5	1160	109	95	85
Potatoes	5	27,720	102	98	80
Swedes	1	42,740	105	124	115
1957					
Rape	6	1490	106	107	94
Turnip rape	7	1210	104	95	93
Carrot	2	37,390	109	104	91
Cabbage	3	35,400	90	90	78
Cauliflower	1	10,260	56	32	28

Crop	No. of trials	Row cultivated only (control)	TCA, kg./ha. 12·5 (% of control)	25	50
1957					
Potatoes, mean	18	18,240	109	105	90
,, var. Kerrs Pink	7	17,360	109	107	100
,, ,, Jossing	6	19,060	114	111	93
,, ,, Marius II	2	15,730	100	84	57
,, ,, King George	1	29,790	99	96	89
,, ,, Rosen	1	16,280	114	79	42
,, ,, Abundance	1	14,890	114	127	111
Tubers > 50 mm., all varieties	15	9200	107	106	95
Swedes	3	64,130	105	107	100
Turnips	1	56,740	105	98	73
Beets	1	67,050	94	89	—

The effect of TCA was not identical for the two years. The spring of 1956 was very dry, the total rainfall in April and May at Aas being only 31·6 mm. In these trials soils with high moisture content gave satisfactory control of couch grass (the number of sprouts counted at the first row cultivation). On dry soil 50 kg. of TCA/ha. did not give much better eradication than 25 kg., but the chemical was not distributed in the dry soil before the couch grass started growing. The row cultivation, however, was more effective in 1956 than in 1957. In 1957, precipitation in April was somewhat below normal, but in May it was approximately normal. The effect of TCA was much more uniform in 1957 than in 1956, but the final effect of TCA was the same for the two years. In 1957 row cultivation was ineffective.

In these 61 trials 25 kg. of TCA/ha. gave satisfactory control of couch grass.

Yields after the use of TCA treatment

There is no point in including all the figures for yields obtained after TCA application as in the earlier tests the recommendations for time of spraying and rate of application were obviously incorrect. The results from a series of 65 trials, carried out all over Norway, are given in Table VI. TCA and dalapon were sprayed as early as possible in the spring after snow melting. Each rate of application in the trials was replicated 5 times in Latin square. The plot size was 6·0 m. × 6·0 m.

The TCA resistance of the potato varieties varies, a fact first discovered in practical spraying with TCA in 1956.

Results from practical use of TCA

As a result of these investigations, it was recommended in March 1956 that late autumn, and particularly early spring, are very favourable times for treatment with TCA. Unfortunately the rate of application recommended was too high, and 40 kg. of TCA/ha. caused severe injury to some varieties of potatoes. Nevertheless, the differences in TCA resistance proved an interesting and valuable discovery, and it is now being studied in further experiments.

In order to take advantage of all the experience gained by farmers, a survey was carried out in 1956 and 1957, 123 sites being visited and samples collected from 230 ha. Many growers had cultivated many crops after TCA treatment, which makes the survey all the more valuable for further recommendations. Although the recommendations have had to be altered somewhat, the results obtained from experiments and practical experience appear now to agree very well.

The first year survey covered treatments in both autumn and spring, but in the last year only one grower sprayed in the autumn. The interest was concentrated on early spring applications, which were considered to give more reliable results.

The farmers' opinions have been summed up in Tables VII–X. The farmers were more satisfied with the results in 1957 than in 1956. The more exact rate of application is of vital importance. In all the trials 'TCA Kvekedreper' containing 83·7% of TCA was used.

Table VII

Control of Agropyron repens *after different rates of application of TCA in early spring*

1956			*1957*		
TCA*, kg./ha.	No. of sites	% kill	TCA*, kg./ha.	No. of sites	% kill
17–20	6	87	17–20	15	87
21–30	17	93	21–25	21	89
31–40	28	92	26–30	13	92
>41	8	98	>31	2	98

Table VIII

Yields estimated by the farmers

(Spring application 1956)

	TCA*, kg./ha. 17–20		21–30		31–40		>41	
	No. of sites	Yield in %	No. of sites	Yield in %	No. of sites	Yield in %	No. of sites	Yield in %
Cruciferous oil crops	3	100	3	113	2	100	—	—
Kale	2	100	3	123	1	100	—	—
Swedes	3	103	4	124	8	104	3	96
Turnips	1	100	3	107	—	—	2	90
Ensilage turnips	2	100	1	130	2	140	1	85
Cabbage	—	—	—	—	3	102	—	—
Carrots	—	—	1	100	1	130	—	—
Potatoes, mean	8	95	26	106	25	76	10	89
,, var. Marius II	2	92	8	93	8	69	1	100
,, ,, Kerrs Pink	2	95	8	120	4	95	2	99
,, ,, Åspotet	3	100	5	109	2	50	3	80
,, ,, Parnassia	1	85	1	90	3	89	—	—
,, other var.	—	—	4	103	8	75	4	87
Beets	—	—	1	110	3	87	—	—
Mean of all crops	19	99	44	109	46	90	16	87

Table IX

Yields estimated by the farmers

(Spring application 1957)

	TCA*, kg./ha. 17–20		21–25		26–30		>30	
	No. of sites	Yield in %	No. of sites	Yield in %	No. of sites	Yield in %	No. of sites	Yield in %
Cruciferous oil crops	3	113	4	100	2	99	1	150
Kale	2	120	3	107	1	120	1	100
Swedes	5	114	9	111	3	126	1	90
Turnips	2	125	3	83	1	120	—	—
Beets	—	—	1	120	1	100	—	—
Cauliflowers	1	100	1	100	—	—	1	100
Cabbage	1	100	1	100	—	—	1	100
Potatoes, mean	6	93	15	96	8	98	2	84
,, var. Kerrs Pink	2	110	5	101	2	100	1	87
,, ,, Åspotet	—	—	4	95	1	100	1	80
,, ,, Marius II	1	100	1	80	1	100	—	—
,, ,, Prestkvern	1	70	2	90	—	—	—	—
,, ,, King George	—	—	1	110	1	110	—	—
,, ,, Parnassia	2	85	2	95	—	—	—	—
,, other var.	—	—	—	—	3	91	—	—
Mean of all crops	20	108	38	101	16	106	7	101

* The T.C.A. used was a Norwegian preparation, 'Kvekedreper', containing 83·7% of trichloroacetic acid.

Experimental and results

The results of experiments carried out during the last two years are summarised (pp. 211–213) in terms of percentage reduction of the control population. Information concerning each experiment is given to allow interpretation of the results. All experiments were sprayed with the commercial product 'Dowpon' containing 85% of dalapon (sodium) and a wetting agent. No additional wetting agent was added. An Oxford Precision Sprayer[4] was used to apply the treatments. There were three replicates of each treatment in randomised blocks unless otherwise stated. All dosages are given as lb. acid equivalent/acre.

Discussion

A high degree of control has been achieved by doses as low as 5 lb./acre, but it is clear that even 20 lb. cannot always be relied upon to eradicate the three species tested. As the dose is reduced so the chance of an effective control diminishes.

Six months or more after the application of dalapon at 5 lb./acre more than 50% reduction of shoots was obtained in three out of seven experiments with a maximum reduction of 70%; at 10 lb./acre there was more than 50% reduction in five out of seven experiments with a maximum of 90%; at 20 lb./acre more than 80% reduction occurred in five out of seven experiments and more than 90% in three. These results are in general agreement with those reported for *Agropyron repens* in America and Canada.

A reliable comparison of the relative susceptibility to dalapon of *Agropyron repens*, *Agrostis gigantea* and *A. stolonifera* cannot be made because of the wide range of results for each species. There is little published information on the effects of dalapon on these two species of *Agrostis*.

It is difficult to assess the practical significance of these results because the value to the farmer of reduction as opposed to eradication of couch (*Agropyron repens*) and other perennial grass weeds is a matter of personal opinion and in any case varies from site to site and year to year. Couch is generally tolerated on farms until it has built up to a level when its harmful effects are obvious. A change of cropping or a fallow is then introduced to reduce the infestation to an acceptable level, a procedure that is often expensive and inconvenient and one that generally results in a reduction rather than eradication of the weed. Recently, sodium chlorate, TCA and now dalapon have become available as alternatives to cultural methods for controlling couch. While *eradication* must always be the target to be aimed at, *reduction* whether by cultural or chemical means may have to be accepted if it can be achieved at much lower cost. With this limitation, the results of the present experiments are additional evidence to that which has already been published in Great Britain[2,5,6] showing that dalapon can be an effective weapon against couch and its allies and that unlike TCA[7] associated cultivations are not essential for good results. From those experiments in which ploughing was carried out within 6 weeks of treatment (W/2/56, W/20/56, W/43/57) there is no suggestion that the ultimate kill of grass by dalapon was affected by the ploughing or that the interval between spraying and ploughing is critical. Results from America, however, suggest that post-spraying cultivations may under certain conditions aid the effects of dalapon in controlling *Agropyron*.[8]

From the one experiment in which dalapon was applied at monthly intervals from May to October (W/10/56) it appears that the date of application during the growing season is not an important factor in influencing the effectiveness of dalapon. Good results were also obtained from treatments made in spring and early summer (W/2/56 and W/20/56) and in autumn (October–November). The results of the autumn trials varied greatly, two being particularly ineffective (W/42/57 and W/38/56) without any obvious explanation. In two out of the three experiments in which spraying was carried out at two dates in the autumn (W/40/57 and W/44/57), the later applications were less effective than the earlier. Reduced effectiveness of dalapon on *Agrostis gigantea* during the winter months has been reported by Green *et al.*[9]

In two experiments (W/42/57 and W/45/57) which were designed to test whether dalapon at half doses applied at two dates was more effective than when applied at the whole dose at either date, no difference between single and split applications was apparent. Intervals between spraying were 17 and 34 days respectively. This does not agree with American results, which claim that split applications of dalapon are more effective on *Agropyron repens*[10] and *Sorghum halapense*.[11]

W/2/56. THAME

Species	*Agropyron repens.*
Stage of development	Rhizomes were 12–18 in. long with one to many shoots each. Shoot density was 0–80/sq. ft. (average about 48).
Site	Light soil on lower Greensand; arable field ploughed during winter 1955–56.
Date of spraying	26.3.56.
Volume rate	50 gal./acre.
Plot size	4 × 12 yd.
Post-spraying management	Field rotovated once on 4.4.56, harrowed and rolled on 17.4.56 and sown to barley on 18.4.56.

Results

% *reduction of control* (mean of 3 replicates)
Assessment, type and date

Dalapon	Score for density 26.5.56	Score for density 13.7.56	Shoot counts in stubble 2.11.56 (40 × 6 in. quadrats per plot)
5 lb.	76	66	67
10	96	80	78
20	100	96	87
Control density	—	—	21 shoots/sq. ft.

The barley was sown 23 days after spraying and was severely damaged by dalapon at all doses. An estimate of the likely loss of crop was made on 13.7.56. The values were (mean of three replicates) 19% for 5 lb., 83% for 10 lb. and 100% for 20 lb. of dalapon. (Yields could not be obtained because of foot-and-mouth restrictions.)

W/20/56. CAVERSHAM

Species	*Agropyron repens.*
Stage of development	Shoots 12–16 in. high, each with 3–5 leaves.
Site	Clay with flints overlying chalk; derelict agricultural land; dense infestation; ploughed early spring 1956, then untouched until spraying.
Date of spraying	23.5.56.
Volume rate	15 gal./acre.
Plot size	4 × 12 yd.
Post-spraying management	Ploughed 2–3 weeks after spraying, then left until early spring 1957, when ploughed twice and rotovated twice for couch control prior to sowing to kale and roots. This crop was inter-row cultivated several times.

Results

% *reduction of control* (mean of 3 replicates)
Assessment, type and date

Dalapon	Score for density 4.7.56	Shoot counts 8.8.56	Score for density 29.8.56	Score for density 24.10.57
10 lb.	65	93	90	75
20	85	100	96	86
40	90	99	100	89
Control density	—	32 shoots/sq. ft.	—	93% ground cover

W/38/56. WALLINGFORD

Species	*Agropyron repens.*
Stage of development	Shoots 8 in. high each with 2–3 leaves. Density 80–120 shoots/sq. ft.
Site	Sandy soil; heavily infested bean stubble.
Date of spraying	16.11.56.
Volume rate	20 gal./acre.
Plot size	4 × 6 yd.
Post-spraying management	Nil. Field later used as building site.

Results

% *reduction of control*
(mean of 4 replicates)
Assessment, type and date

Dalapon	Shoot counts 6.5.57 (20 × 1 ft. quadrats per plot)
5 lb.	11
10	17
15	29
20	43
Control density	31 shoots/sq. ft.

On 9.1.57, the foliage on all plots was partially brown and little effect of the treatments was visible. Rhizomes obtained from plots sprayed with 20 lb. of dalapon grew normally when replanted in a warm greenhouse, although they produced less shoots than untreated specimens.

W/40/57. SULGRAVE

Species	*Agropyron repens.*
Stage of development	(i) Shoots up to 12 in. in height; vigorous growth. (ii) Shoots beginning to die back, 1–3 green leaves per shoot, some already turning brown.
Site	Heavy loam; moderate infestation in barley stubble.
Date of spraying	(i) 27.9.57; (ii) 14.11.57.
Volume rate	20 gal./acre.
Plot size	4 × 8 yd.
Post-spraying management	Untouched until 15.5.58, when field ploughed. A second ploughing followed by further cultivation on trial area during July.

Results

% *reduction of control*
(mean of 3 replicates)
Assessment, type and date

Spraying dates	Dalapon	Score for ground cover of green shoots, 13.5.58	Shoot counts 13.5.58 (15 × 1 ft. quadrats per plot)
27.9.57	5 lb.	70	80
	10	95	95
	20	97	97
14.11.57	5	65	63
	10	63	66
	20	85	83
Control density		—	59 shoots/sq. ft.

W/43/57. EAST HENDRED

Species	*Agropyron repens.*
Stage of development	Height 4–13 in., fairly lush and green.
Site	Thin, chalky soil overlying chalk; moderate infestation in cereal stubble.
Date of spraying	27.9.57.
Volume rate	20 gal./acre.
Plot size	4 × 8 yd.
Post-spraying management	Ploughed early November and again in early spring followed by four cultivations prior to sowing a spring cereal in the second week of April.

Results

% *reduction of control*
(mean of 3 replicates)
Assessment, type and date

Dalapon	Shoot counts 19.5.58
5 lb.	41
10	61
20	66
Control density	14 shoots sq. ft.

W/10/56. CHIPPING NORTON

Species	*Agrostis gigantea.*	
Stages of development	May:	3–4½ leaves per shoot, 4–5 in. high.
	June:	4–6 leaves per shoot, 4–12 in. high, flowers well developed in sheath.
	July:	First flowers almost fully developed; average height 18 in.
	August:	In full flower.
	September:	Late flowering stage.
	October:	Mature seed heads and numerous young vegetative shoots.
Site	Light sandy soil. Neglected arable field that had been ploughed in late winter 1955–56.	
Date of spraying:	May: 3.5.56; June: 11.6.56; July: 10.7.56	August: 9.8.56; September: 14.9.56; October: 3.10.56
Volume rate	30 gal./acre.	
Plot size	4 × 6 yd.	
Post-spraying management	Nil.	

Results

Density of shoots (mean of 2 replicates)
Assessment, type and date

Month of spraying	Dalapon	Shoots/sq. yd. 3.10.56 (9 × 1 ft. quadrats per plot)	Shoots/sq. yd. 30.5.57 (20 × 1 ft. quadrats per plot)	Month of spraying	Dalapon	Shoots/sq. yd. 3.10.56 (9 × 1 ft. quadrats per plot)	Shoots/sq. yd. 30.5.57 (20 × 1 ft. quadrats per plot)
May	7·5 lb.	15	45	August	7·5 lb.	26	86
	15	0	9		15	3	14
	30	0	4		30	1	0
June	7·5	1	6	September	7·5	290	7
	15	1	4		15	384	0
	30	0	2		30	288	0
July	7·5	5	10	October	7·5	—	0
	15	1	9		15	—	0
	30	0	0		30	—	0
				Control density		1472	485

W/45/57. EYNSHAM

Species	*Agrostis gigantea.*
Stage of development	(i) Vigorous growth, shoots with up to 3 leaves, 4 in. high. Rhizomes on surface as well as in plough slices. (ii) Vigorous growth, shoots with 3–5 leaves up to 4 in. high. Many new shoots from surface rhizomes; all nodes with shoots.
Site	Heavy soil, liable to flooding. Dense infestation on arable land that had been neglected for 2 years. Ploughed 9–10 in. deep a month before first spraying.
Dates of spraying	(i) 10.10.57; (ii) 13.11.57.
Volume rate	20 gal./acre.
Plot size	4 × 6 yd.
Post-spraying management	Field untouched until third week in March, then ploughed and frequently cultivated during a summer fallow and then sown to grass. By the time the farmer wished to plough, little regrowth had taken place and it was necessary to sample the plots if any results were to be obtained. Five cores 7 in. square and 10 in. deep were dug, the rhizomes washed and weighed and then potted in sand. The pots stood out of doors until the middle of June and were kept well watered.

Results

Shoot counts from rhizomes grown in pots

	Dalapon	Visual estimate of ground cover of green shoots, 13.2.58 (% reduction of control)	Shoots per 4 pots 13.5.58	% reduction of control 13.5.58	Shoots per 4 pots 19.6.58	% reduction of control 19.6.58
10.10.57	5 lb.	100	165	−11	552	−4
	10	100	47	69	377	29
	20	100	49	67	276	48
13.11.57	5	40	83	44	361	32
	10	63	56	62	314	41
	20	73	30	80	231	57
Half dose at each date	2·5+2·5	80	169	−13	482	10
	5+5	100	89	40	501	6
	10+10	100	11	93	110	79
Control counts—shoots per 4 pots		—	149	—	533	—

(continued on next page)

Rhizomes of *Agrostis gigantea* (W/45/57) and *Agropyron repens* (W/38/56) and stolons of *Agrostis stolonifera* (W/39/57) obtained from plots 128, 54 and 129 days respectively after being treated with 20 lb. of dalapon/acre made normal growth when grown in pots under suitable conditions although they appeared, when they were collected, to be seriously affected by the treatment. This confirms similar observations made by Le Brocq & Beech[2] and suggests that

W/39/57. EYNSHAM

Species	*Agrostis stolonifera.*
Stage of development	(i) 1–8 in. high, shoots with 1–3 leaves, active growth. (ii) 3 in. high, numerous actively growing shoots 4–5 green leaves on each.
Site	Medium loam liable to flooding; virtually 100% ground cover of *Agrostis* in cereal stubble.
Dates of spraying	(i) 10.9.57; (ii) 15.11.57.
Volume rate	20 gal./acre.
Plot size	4 × 8 yd.
Post-spraying management	Field first ploughed in January 1958, then cultivated end of March prior to sowing barley.
Results	*Ground cover of green shoots assessed by scoring*

% *reduction of control* (mean of 3 replicates)

Spraying dates	Dalapon	*Date of assessment* 26.9.57	13.11.57	24.3.58 (prior to cultivation)
10.9.57	5 lb.	37	53	91
	10	53	80	99
	20	70	93	98
15.11.57	5	—	—	100
	10	—	—	100
	20	—	—	100

Further assessment has not yet been possible.

W/42/57. CAVERSHAM

Species	*Agrostis stolonifera.*
Stage of development	Dense mat of *Agrostis*, post-flowering stage; little dieback apparent. Height less than 6 in. (at both dates of spraying).
Site	Heavy clay soil; derelict field that had been ploughed up two years prior to spraying and then abandoned.
Dates of spraying	(i) 7.10.57; (ii) 24.10.57.
Volume rate	20 gal./acre.
Plot size	4 × 6 yd.
Post-spraying management	Nil.

Results

% *reduction of control* (mean of 4 replicates)

Assessment, type and date

Spraying dates	Dalapon	Visual estimate of shoot density (regrowth) 12.5.58	Visual estimate of shoot density (regrowth) 4.6.58
7.10.57	5 lb.	38	20
	10	43	25
	20	73	50
24.10.57	5	30	30
	10	53	45
	20	62	55
Half dose	2·5+2·5	32	30
at each	5+5	42	20
date	10+10	69	45

By the time of the second assessment, the *Agrostis* was growing vigorously in all plots and many sprayed plots were barely distinguishable from controls. Spraying was carried out in good weather conditions and rain did not fall shortly after spraying.

W/44/57. RAMSDEN

Species	*Agrostis stolonifera.*
Stage of development	(i) Height 3–10 in, luxuriant growth. (ii) Little growth since (i). Foliage beginning to die back.
Site	Heavy, badly drained clay soil; almost 100% ground cover of strongly growing *Agrostis* in cereal stubble.
Dates of spraying	(i) 26.9.57; (ii) 22.10.57.
Volume rate	20 gal./acre.
Plot size	4 × 8 yd.
Post-spraying management	Plots ploughed at end of February then left untouched until autumn 1958.

Results

% *reduction of control* (mean of 3 replicates)

Assessment, type and date

Spraying date	Dalapon	Shoot counts (20 × 1 ft. quadrats per plot) 5.6.58	Plant counts (10 × 2 ft. quadrats per plot) 11.8.58	Area ground cover, visual estimate 11.8.58
26.9.57	5 lb.	72	63	66
	10	90	73	84
	20	94	79	90
22.10.57	5	60	51	58
	10	82	61	71
	20	85	62	61
Control		21 shoots/sq. ft.	6 plants/sq. ft.	49% ground cover

the main effect of dalapon at the doses applied in these experiments is to induce dormancy or to prolong natural overwintering dormancy of the perennating organs rather than to kill them outright. The variable results obtained in these experiments must in no small measure be due to this dormancy-inducing mechanism of dalapon.

Acknowledgments

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References

[1] Elliott, J. G., unpublished work, 1958
[2] Le Brocq, P. F., & Beech, C. R., *Proc. 3rd Brit. Weed Control Conf., 1956*, p. 279
[3] Bylterud, A., 'Bekjempelse av kveke med TCA og diklorpropionsyre', *Samvirke*, 1956, No. 5
[4] Fryer, J. D., & Elliott, J. G., *Proc. 2nd Brit. Weed Control. Conf., 1954*, p. 375
[5] Ripper, W. E., *Fmrs' Wkly*, 1958, **49**, (12), 101
[6] Elliott, J. G., & Fryer, J. D., *Agriculture, Lond.*, 1958, **63**, 119
[7] Jary, S. G., *Proc. Brit. Weed Control Conf., 1954*, p. 195
[8] Buchholtz, K. P., & Petersen, D. R., *Down to Earth*, 1957, **12**, 4
[9] Green, J. O., Evans, T. A., & Elliott, J. G., *Proc. 3rd Brit. Weed Control Conf., 1956*, p. 269
[10] Barrons, K. C., *Down to Earth*, 1958, **13**, 4
[11] Santleman, P. W., & Meade, J. A., *Down to Earth*, 1958, **13**, 4

Discussion on the three preceding papers

Dr. W. E. Ripper (Dow Agrochemicals Ltd.).—British farming owes a great debt to the Weed Control Unit of the Agricultural Research Council, at Oxford, for their work on the chemical control of grass weeds. The paper by Fryer & Chancellor on the effect of dalapon on couch is another very valuable contribution to ascertain the conditions under which dalapon can be used effectively for the control of perennial grasses in the temperate zones.

The farmer is, in the first place, interested in a couch suppression because on highly mechanised farms with small farm staffs, weed-free farming without chemical grass control is not possible without fallows or an increase in the root shift. An increase in the root shift is impracticable with a small labour force and the fallows are uneconomic. Couch control with dalapon seems to fill this need for the suppression of perennial grasses and for this a reduction of over 70% of the regrowth of the couch would be necessary.

An economic couch eradication would be even better because we can now stop the creeping in of this weed by barrier treatments.

The paper by Fryer & Chancellor has pointed out that dalapon sometimes effects a splendid kill of the rhizomes, but sometimes at the economic application rate of 10 lb. it requires additional help. Cultivation, i.e., ploughing about 8 in. deep after dalapon application, has been recommended by the manufacturers. When the data for the reduction of couch after applications of 10 lb./acre of dalapon submitted by these authors, are analysed, it will be seen that in the eight cases where there was no ploughing after the dalapon application, six showed under 70% control and in some cases the reduction of the couch was as low as 17% and 25%, and the average reduction of all eight cases is 49%. Of the six cases which were ploughed within 5 months of the dalapon treatment, only two showed a control of under 70% but above 60%, and one of these was ploughed again in spring so that the soil was reinverted and the rhizomes brought to the surface; and the other was a stubble which was sprayed fairly late. The average reduction of couch in these six cases is 80%.

In nearly all cases the ploughing was carried out much later than was recommended by the manufacturer (2–6 weeks after the dalapon treatment). The data of Fryer & Chancellor, therefore, bear out the hypothesis that more reliable couch suppression can be obtained by ploughing after dalapon spraying.

This interesting paper again underlines the necessity for more basic research in the physiology of the couch grass rhizomes and the effect of systemic grass weedkillers on them.

Mr. L. Jones (Grassland Research Institute).—In Fig. 1 of the first paper by Fryer & Chancellor, the dose of dalapon above which flowering of rye grass, fescue and cocksfoot and timothy did not occur is quoted. In the same figure the maximum dose allowing vigorous regrowth is quoted. In the case of cocksfoot and fescue, flowering is prevented by a dose of dalapon far below the dose which prevents vigorous regrowth. This could have far-reaching results, as the digestibility of grasses falls rapidly at the time of flowering. Did Mr. Fryer notice any increase in vegetative growth where dalapon prevented flowering?

Mr. J. G. Elliott (Oxford).—In an experiment to test the effect of dalapon at up to 8 lb./acre on cultivated grasses in their first year, Italian and perennial rye grass were found to be slightly more resistant to dalapon than was timothy. This result does not agree with the results of Mr. Fryer's paper.