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THE TOLERANCE OF STRAWBERRIES TO PHENMEDIPHAM

D.V.Clay

ARC Weed Research Organization, Begbroke Hill, Sandy Lane, Yarnton, Oxford

H.M.Lawson

Scottish Horticultural Research Institute, Invergowrie, Dundee.

K.G.Stott

Long Ashton Research Station, Bristol.

Summary. In experiments at three centres in Great Britain phenmedipham was applied to strawberries at different times of the year and at different time intervals after planting. Chlorosis of sprayed leaves frequently occurred following applications at the recommended rate (1.1 kg a.i./ha) in spring and summer but leaves that unfolded after spraying were unaffected.

There was generally more post-spraying leaf chlorosis on cv.Cambridge Favourite and Redgauntlet than on the other three cultivars tested but there were no significant reductions in growth or yield with any of the cultivars sprayed at the recommended rate.

Higher rates of application resulted in more leaf injury but generally had no effect on growth or yield. Variations in the degree of leaf chlorosis in spring and summer were thought to be more related to the amount of young leaf present at the time of spraying than to weather conditions at that time.

INTRODUCTION

The successful use of phenmedipham for post-emergence weed control in strawberries was reported from W.Germany in 1968 (Germany, 1969) and later from the USA (Putman and Kesner, 1969) and Ireland (Robinson and Rath, 1970; Allott and Uprichard, 1970). The herbicide appeared to be of particular value in strawberries in the UK for controlling annual weeds such as Veronica and Viola spp. that were resistant to lenacil (Stott and Jefferies, 1972). Following commercial trials it was introduced for use in Great Britain in 1972 (Ellis, 1973). Since most reports of its performance indicated some foliar injury to the crop shortly after spraying, experiments were commenced in 1971 and 1972 at research stations in England and Scotland to assess the importance of this injury on growth and yield. Crop response was examined in relation to herbicide dose, crop cultivar and age at spraying, and season of treatment. The experiments were carried out at the Weed Research Organization, Oxford (WRO), the Scottish Horticultural Research Institute, Dundee (SHRI) and Long Ashton Research Station, Bristol (LARS).

METHOD AND MATERIALS

Full details of cultivars used, experiment design, management and application details are given in Table 1 for all three centres. Planting and treatment dates for WRO experiments are given in Tables 2 and 3. In all the experiments the 11.4% e.c. formulation of phenmedipham ('Betanal E') was used, and all rates of application are quoted in terms of kg a.i/ha.

In four experiments at WRO phenmedipham was applied at 1 kg/ha to Cambridge Favourite on twelve different dates after planting in March, July or October 1972. In a further experiment rates of 1 and 2 kg/ha were applied to four cultivars on two dates during the summer.

Two experiments were carried out at SHRI on spring-planted crops. In the first in 1971 phenmedipham was applied at three doses (1.1, 2.2 and 3.3 kg/ha) at intervals of 1 day, 1 month and 2 months after planting; in the second (1972) a single dose of 2.2 kg/ha was sprayed on five dates after planting. Planting and treatment dates are shown in Tables 4 and 5.

Table 1

Experimental and cultural details for the three centres

	WRO	SHRI	LARS
Cultivar	C.Favourite C.Vigour Redgauntlet Senga Sengana	C.Favourite	C.Favourite C.Vigour Redgauntlet C.Prizewinner
Expt. design	Randomised blocks	Randomised blocks	Randomised blocks
Replicates	3	4	4
Initial plant no/plot	10	15	24
Plant spacing (m)	0.5 x 1.5	0.45 x 0.9	0.45 x 0.9
Crop management			
Residual herbicides	lenacil chloroxuron simazine	lenacil	lenacil simazine
Runners	Matted rows	Runners removed in autumn	Matted rows
Phenmedipham application			
Sprayer	Oxford Precision	Oxford Precision	Knapsack
Volume rate (l/ha)	225	225	330

In an experiment at LARS on an autumn-planted crop phenmedipham was applied in March (2kg/ha), May (1kg/ha) and August 1972 (3kg/ha) to four cultivars. The March and May treatments were repeated in 1973. Treatment dates are shown in Table 6. Any weeds that developed on the experiments were removed by shallow hoeing or hand weeding. Visual effects of treatments on leaf condition were scored at intervals in the WRO and SHRI experiments; crop response was measured by recording plant size, runner production or fruit yield.

Table 2

The response of strawberries cv.C.Favourite to phenmedipham applied at 1 kg/ha at different dates after planting in 1972 (WRO expts.)

Expt.No.& Planting Date	Date of Treatment (1972/3)	Air temp. at spraying (°C)	Max.degree of leaf injury (0 - 3)*	Runners (No rooted/m²)	Fruit Yield (t/ha) 1973
Expt.1	Apr.12	9	0	75+	
Mar.23	Apr.21	8	0.3	78	
	May 2	10	2.0	70	
	May 11	10	0	69	
	May 19	11	1.0	69	
	Control		0	73	
	S.E.means±			4.8	
Expt.2	Jul.19	17	1.0	88	
Mar.23	Jul.28	15	2.0	91	
	Aug.22	21	1.0	86	
	Control		0	83	
	S.E.means±			7.8	
Expt.3	Jul.19	17	1.0		10.3
Jul.13	Jul.28	15	2.0		9.2
	Aug.22	21	1.3		11.3
	Dec.21	3	0		9.8
	Jan.31	0	0		11.6
	Apl.27	13	0		10.7
	Control		0		10.1
	S.E.means±				1.16
Expt.4	Nov.15	3	0	127++	
Oct.19	Dec.21	3	0	118	
	Jan.31	0	0	126	
	Apl.27	13	0	129	
	Control		0	127	
	S.E.means±			8.7	

* 0 - normal leaves; 3 - severe chlorosis and some necrosis of sprayed leaves

Runner counts, + 14.11.72; ++ 21.3.74

RESULTS

The results from the three centres are detailed in Tables 2 - 6 and follow a similar pattern at all three sites. Slight effects on leaves were often apparent one week after spraying; the effect was confined to younger leaves exposed to the spray. The oldest sprayed leaves were not affected nor were any new leaves that unfolded after spraying. The injury took the form of leaf yellowing either in irregular patches over the upper surface of leaves or on a broad band around the leaf margins. Frequent small necrotic spots on the surface of sprayed leaves were noted in some experiments at WRO and LARS. Leaf injury was assessed over a period of weeks after

Table 3

The effect of phenmedipham on four strawberry cultivars planted March 1972 (WRO expt)

Date of application 1972	Dose (kg/ha)	Max. leaf injury score (0-3) F^+	R	S	V	Runners (No. rooted/m^2) Nov.72 F	R	S	V	Mean
Jul.28	1	2.0	1.7	1.0	1.0	74	85	101	69	82
	2	2.3	2.0	1.3	1.3	65	91	104	71	83
Aug.22	1	1.0	1.0	0.7	0.7	59	89	91	69	77
	2	1.7	2.0	1.3	1.0	68	92	100	75	84
Control		0	0	0	0	71	92	104	62	83
S.E.means$\pm$							11.1			5.6

\+ F - Cambridge Favourite, R - Redgauntlet, S - Senga Sengana, V - C.Vigour

Table 4

The effect of a range of doses of phenmedipham on growth and yield of strawberries cv. C.Favourite planted on 31 Mar. 71. (SHRI expt.)

Application date 1971	Dose (kg/ha)	Max. leaf injury score (0-10)*	Wt(g) runners removed/plant Oct.71	Crown no. per plant Feb. 72	Fruit yield (t/ha) 1972
Apr.1	0	0	265	3.20	7.46
	1.1	0.6	243	2.78	6.61
	2.2	0	303	3.10	6.29
	3.3	0	265	2.70	7.24
Apr.30	0	0	238	2.98	6.74
	1.1	1.3	210	2.80	6.77
	2.2	2.3	285	2.63	5.64
	3.3	3.0	283	2.85	6.71
May 28	0	0	310	2.83	6.01
	1.1	1.8	305	3.03	7.73
	2.2	1.5	240	2.93	6.82
	3.3	2.3	303	2.93	6.98
	S.E.mean$\pm$		23.5	0.160	0.653
Combined dates	0	0	271	3.00	6.74
	1.1	0.9	253	2.87	7.04
	2.2	1.1	278	2.88	6.23
	3.3	1.4	284	2.83	6.98
Apr.1	(1.1,2.2,3.3)	0.2	272	2.36	6.71
Apr.30	(combined)	2.2	259	2.76	6.37
May 28	( )	1.8	283	2.96	7.17
	S.E.mean$\pm$		13.5	0.092	0.377

* 0 - no injury, 10 - complete chlorosis of sprayed leaves

Table 5

The response of strawberries cv.C.Favourite to phenmedipham applied at 2.2 kg/ha at different dates after planting on 28 March 72. (SHRI expt.)

Application date 1972	Max.leaf injury score (0-10)	Wt(g) runners removed/plant (Oct.72)	Crown no. per plant (Dec.72)	Fruit yield (t/ha) 1973
Apr.12	2.3	352	2.33	8.10
Apr.26	1.1	377	2.50	9.57
May 10	1.8	381	2.36	9.36
May 30	1.8	371	2.38	8.93
Jun.14	0.9	326	2.23	8.07
Control	0	375	2.27	9.01
S.E.mean$\pm$		34.9	0.141	0.632

spraying but only the maximum degree of injury occurring is presented (Tables 2-5). Leaf injury was most severe following some spring or summer applications; no injury was observed following autumn or winter treatments (Table 2), nor did age of plant at spraying appear to affect susceptibility. Where effects on the foliage of different cultivars were compared Cambridge Favourite and Redgauntlet were more affected (Table 3). In some cases increasing the dose led to an increase in leaf injury (Tables 3,4).

Effects on leaves were outgrown a few weeks after spraying. No significant reductions in crop growth or yield were found from any of the applications at the three centres except after a March application of phenmedipham at 2 kg/ha at LARS. Yields of Cambridge Vigour and to a lesser extent Cambridge Favourite were reduced (Table 6). The increased yields from the August application in this experiment resulted from plots in this treatment developing as matted beds.

DISCUSSION

The increase in leaf damage with increased dose found in the experiments at WRO and SHRI agrees with the results of Robinson and Rath (1970) and Uprichard (1972), yet in all cases subsequent growth and yield were not significantly affected in comparison with untreated controls. In an observation trial Jefferies and Stott (1972) found only temporary leaf injury to cv.Cambridge Favourite from rates of up to 16 kg/ha applied in September. There appears therefore to be an adequate margin of safety in most conditions. Plant age did not appear to affect the degree of leaf injury; at WRO applications of phenmedipham to newly-planted and to established plants on the same dates in July and August resulted in the same degree of leaf injury (Table 2). The variation in degree of leaf injury that developed following the different applications suggests that a combination of plant and climatic factors determine response. In sugar beet severe plant injury can result from spraying on hot days when there is much new leaf growth. Application is not recommended on this crop with air temperatures >20°C but this limitation does not apply to strawberries. Maximum leaf injury in the experiments reported here occurred in spring and summer when growth was most rapid and much young leaf was present but spraying even on a relatively hot day did not result in increased leaf injury (Table 2, application on 22.8.73). Climatic differences between S.England and E.Scotland may account for slight leaf necrosis developing following some applications in spring at WRO and LARS

Table 6

The effect of phenmedipham on growth and yield of four cultivars of strawberry (LARS expt.)

Treatment	Application dates	Air temp. (°C) when sprayed	Plant size 31 Jul.72 (Ht. x spread (cm)) F+	P	V	R	Mean	Fruit yield 1973 (t/ha) F	P	V	R	Mean
Control			808	709	961	895	843	17.88	4.39	13.38	14.76	12.59
2 kg/ha	9 Mar. 72 4 Apr. 73	11 13	784	659	904	863	802	15.28*	4.46	8.88**	14.15	10.67*
1 kg/ha	24 May 72 18 May 73	16 18	870	759	841	947	854	18.59	5.16	11.96	12.95	12.16
3 kg/ha	3 Aug. 72	18	884	750	982	885	875	20.46	9.08**	14.55	23.06***	16.77***
			Within cultivar		Any Mean		Treatment Means	Within cultivar		Any Mean		Treatment Mean
S.E. of means ±			56.3		80.8		28.1	1.005		2.023		0.493

*, **, ***, indicates significant difference from control at 5%, 1% and 0.1% level

+F - Cambridge Favourite; P - Prizewinner; V - C.Vigour; R - Redgauntlet whereas these symptoms did not appear at SHRI.

There was some variation in response of the different cultivars to phenmedipham but none of the applications at 1.0 or 1.1 kg/ha reduced crop growth or yield. More leaf yellowing was observed on Cambridge Favourite and Redgauntlet than on the other cultivars tested (Table 3) which agrees with the results of Uprichard (1972). The result from LARS where there was yield reduction in C.Favourite and C.Vigour from an application of 2 kg/ha in April 1973 suggests that there may be circumstances where exceeding the recommended application rate can result in significant crop reduction. Nevertheless, these experiments confirm the general safety to strawberries of phenmedipham applied at any time after planting. While leaf chlorosis may result from applications of phenmedipham at 1.1 kg/ha this should not affect leaves subsequently produced or cause any reduction in growth or fruit yield on commonly grown cultivars. In general applying the herbicides at two or three times the recommended rate has not resulted in significant crop injury.

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NOTES

NEW HERBICIDES FOR STRAWBERRIES: CROP TOLERANCE AND WEED CONTROL PERFORMANCE

D.V. Clay and S.J. Rutherford
ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford OX5 1PF.

J.S. Wiseman
Scottish Horticultural Research Institute, Invergowrie, Dundee, DD2 5DA.

Summary The response of strawberries to a number of new herbicides was tested at the Scottish Horticultural Research Institute and the Weed Research Organization. N-(1-ethylpropyl)-2,6-dinitro-3,4-xylidene (AC 92553), N-isobutyl-2-oxo-imidazolidine-1-carboxamide (BAY 94871), chlorthal - dimethyl, ethofumesate, terbacil and trietazine + simazine applied in spring, at rates normally used for annual weed control in other crops, caused no long-term foliage injury or any significant reductions in growth and yield compared with lenacil. Results with bentazone and bifenox varied between centres. At WRO both caused severe leaf injury after spraying but with subsequent recovery; growth and yield was reduced by bentazone at SHRI. Metoxuron and metribuzin caused very severe leaf injury and crop loss at SHRI.

The pre and post-emergence activity on annual weeds of most of these herbicides was tested at WRO. AC 92553 (pre-em.) and bifenox (post-em.) were the only herbicides to be effective in the very dry conditions. Control of annual weeds with the standard herbicides (lenacil and simazine) was very poor.

INTRODUCTION

Herbicides currently recommended for use in strawberries in the U.K. do not give satisfactory control of weeds in a number of situations. None of the widely-used residual herbicides are very effective if dry soil conditions occur after application. Even in favourable conditions these, and the foliage-acting herbicide phenmedipham fail to control certain important annual weed species. In addition broad-leaved perennial weeds, particularly Cirsium arvense, are an increasing problem. With a view to finding suitable treatments for these situations the tolerance of a number of herbicides to strawberries was tested in field experiments at the Scottish Horticultural Research Institute, Dundee (SHRI) in 1973 and 1974 and at the Weed Research Organization, Oxford (WRO) in 1974. In addition the performance of most of these herbicides against annual weeds was examined in trials at WRO in 1974.

METHOD AND MATERIALS

The following herbicides and formulations were used in the experiments: N-(1-ethylpropyl)-2,6-dinitro-3,4-xylidine (AC 92553), 33% e.c.; N-isobutyl-2-oxo-imidazolidine-1-carboxamide (BAY 94871), 80% w.p.; bentazone, 50% w.p.; bifenox, 24% e.c. and 80% w.p.; chlorthal-dimethyl, 75% w.p.; ethofumesate, 20% e.c.; lenacil, 80% w.p.; metoxuron, 80% w.p.; metribuzin, 70% w.p.; phenmedipham, 11.4% e.c.; simazine, 50% w.p.; terbacil, 80% w.p.; trietazine, 50% w.p.

Crop tolerance experiments. Experiments were carried out at SHRI on established plants (Expts. 1 and 2) and at WRO on newly-planted runners (Expt. 3). Details of the sites, plot size, planting and herbicide applications are shown in Table 1. In all three experiments a randomised block design was used. The strawberries cv. Cambridge Favourite were maintained as spaced plants, runners being removed at intervals during the growing season. The plants in Expts. 1 and 2 were treated with lenacil in the year prior to the start of the experiments.

Table 1

Design, crop, herbicide application and rainfall details (crop tolerance expts.)

	SHRI		WRO
	Expt. 1	Expt. 2	Expt. 3
Soil type	Sandy clay loam	Sandy clay loam	Sandy loam
Replication	3	4	4
Plot size (m)	6.8 x 0.9	3.2 x 0.9	1 x 1
Plant no/plot	15	7	9
Planting date	1.4.71	29.3.72	22.3.74
Herbicide application			
Date	26.4.73	29.3.74	1) 28.3.74 2) 7.5.74
Spray volume (l/ha)	618	730	400
Rainfall (mm)+			
March	11 (-35)*	49 (+2)	37 (0)
April	24 (-19)	13 (-30)	5 (-38)
May	52 (- 2)	52 (- 2)	27 (-30)
June	38 (-13)	47 (- 5)	78 (+19

+year of treatment *deviation from long-term average

The herbicide treatments in experiments 1 and 2 were applied to an 0.9m swath centred on the crop row, while at WRO an area 1.5 x 1.0m was treated. At both sites applications were made using an Oxford Precision Sprayer. Plots were kept weed free by hand-weeding and shallow hoeing. In Expt. 3 the first flush of weeds after planting was allowed to reach the second true-leaf stage before hand-weeding. Visual assessments of crop condition were made at intervals after treatment. In Expts. 1 and 2 plant size in June, fruit truss numbers, fruit yield and berry size were recorded. Crown number was recorded in September in Expt. 1. In Expt. 3 counts of numbers of runners removed per plot were made on two dates and runner weight on three dates. Crown numbers were recorded in mid-August. The herbicides and doses used are shown in Tables 2-4.

Weed control experiments. Weed control data were obtained from three other experiments at WRO in addition to Expt. 3 described above. A herbicide-tolerance trial on newly-planted blackcurrants in which some of the same herbicides had been used (Expt. 4), gave additional information on weed control in the 2 months after planting. Two experiments (5 and 6) were carried out specifically on weed control in uncropped plots, to test pre-emergence and post-emergence activity respectively of a range of herbicides. Design, plot size and herbicide application details for all these experiments were the same as for Expt.3. There were six replicate plots on Expt. 4 and three on Expts. 5 and 6.

Blackcurrants were planted on Expt. 4 on 7.3.74 and cut down after planting. Simazine (1 kg/ha), bifenox (2 and 6 kg/ha w.p.) and BAY 94871 (4 and 12 kg/ha) were applied to soil with a cloddy tilth on 20.3.74. Bifenox (2 and 6 kg/ha e.c.) and a mixture of bifenox (2 kg/ha e.c.) + simazine (1 kg/ha) were applied to other plots on 17.4.74. The land for Expts. 5 and 6 was cultivated to a medium tilth a few days before the application of the pre-emergence herbicides on 8.4.74. Post-emergence herbicides were applied to experiment 6 on 14.5.74 when the first flush of weeds was between first and second true-leaf stage. The herbicides and doses used are shown in Tables 6 and 7.

Weed growth was assessed on a 70 x 70 cm area in the centre of each plot. Visual estimates were made of % ground cover of weeds as a whole and the frequency of individual species scored. The first weed assessment was made on Expts. 5 and 6 on 10.6.74 when there was a dense cover on the untreated plots with the canopy up to 5cm high. To test whether the soil-acting herbicides would have any residual activity after removal of the weed growth a mixture of paraquat + diquat was sprayed over the whole area on 12 and 17.6.74. This killed all weeds apart from occasional plants of Polygonum aviculare which were cut off by hand. Regrowth was assessed on 9.8.74.

Results on the control of particular weeds in Expts. 3 and 5 are given for the four species that occurred in both experiments (Table 5). The following code is used in the Table: Polygonum aviculare - Pav; Veronica persica - Vp; Fumaria officinalis - Fo; Stellaria media - Sm. Species were regarded as being controlled when there were less than five plants present on a plot, all showing severe effects of the herbicide.

RESULTS

Crop tolerance

Expt. 1. Metribuzin and metoxuron resulted in leaf yellowing and growth reduction soon after treatment (Table 2). Bentazone had little visible effect and did not significantly reduce plant or truss numbers. However a reduction in numbers of berries produced per truss contributed to a 32% lower fruit yield than on untreated plots. Both other herbicides caused considerably greater loss of fruit as a result of reductions both in numbers and productivity of fruit trusses. Berry size was, however, not affected by treatment. All herbicide treatments also significantly reduced the number of crowns per plant counted at the end of August.

Expt. 2. Both rates of terbacil and trietazine + simazine caused temporary yellowing of new foliage in late April but this was rapidly outgrown. In late May foliage of plants treated with bifenox produced leaf-curling symptoms, evident for a week but then outgrown. There were no other visible effects on the crop. Records of plant size in June, truss numbers, berry size and total yield showed no adverse effects of any of the herbicides compared with the standard lenacil. (Table 3). There was no evidence that doubling the dose increased the risk of crop injury even with those herbicides that showed transient leaf symptoms.

Expt. 3. No symptoms of herbicide injury were seen on the lenacil-treated plots or on those treated with the chlorthal-dimethyl + lenacil mixture (Table 4). AC 92553 caused slight yellowing and curling of sprayed leaves immediately after treatment but these effects were soon outgrown and there were no effects on runner production or on crown numbers in August. Both rates of BAY 94871 caused marginal chlorosis and slight necrosis of leaves unfolding immediately after spraying but these effects were outgrown in May and June and there were no significant reductions in growth. Results with the mixture with lenacil were similar except that at the higher rate most plants on one plot developed leaf necrosis and died in June. Remaining plants grew normally. Ethofumesate caused slight leaf margin necrosis and leaf curling after spraying and new leaves were shiny in appearance for some weeks. Later growth was normal.

Bifenox (w.p.) immediately after planting caused leaf distortion and necrotic patches on veins soon after treatment. The veinal necrosis continued to develop on young leaves for a long period (4 months) after treatment. Runner production and

Table 2

Response of established strawberries to herbicides applied in spring 1973 (Expt. 1 - SHRI)

Herbicide	Dose (kg/ha)	Yellowing score (0-10) May 23	Mean plant ht (cm) June 15	Wt (g) /100 berries	Total fruit yield (t/ha)	No. Crowns /plot Sept 1
Untreated		0	25	759	11.3	165
Metoxuron	3.5	2.3	22**	737	5.4	145**
Metribuzin	1.0	4.3	20***	728	3.2***	124***
Bentazone	1.7	1.3	24	808	7.6***	162*
S.E. mean ±			0.5	53.5	0.31	5.1

*; **; *** indicates significant difference from Untreated at the 5%, 1%, 0.1% level

Table 3

Response of established strawberries to herbicides applied in spring 1974 (Expt. 2 - SHRI)

Herbicide	Dose (kg/ha)	Mean plant height (cm) June 26	Mean truss count /plant	Mean no.berries /truss	Wt (g) /100 berries	Total fruit yield (t/ha)
Lenacil	2.24	21	11.1	5.4	9.80	13.9
"	4.48	25	14.0	5.4	10.40	17.6
AC 92553	2.24	23	11.0	5.4	9.80	13.3
"	4.48	24	12.7	4.9	10.20	15.0
Bifenox	3.36	22	12.6	4.7	9.50	13.5
"	6.72	25	12.1	5.1	9.60	13.8
Chlorthal-dimethyl	10.1	24	14.3	5.0	10.00	15.1
"	20.2	24	13.5	4.9	9.50	13.7
Terbacil	0.28	24	12.6	5.1	10.50	14.9
"	0.56	23	12.0	5.0	10.20	13.5
Trietazine + Simazine	1.47 + 0.21	24	13.2	4.9	10.40	15.0
"	2.94 + 0.42	24	12.2	5.2	10.80	15.3
S.E. mean ±		0.8	1.02	0.30	33	1.12

crown number were not affected by the 2 kg/ha rate but were reduced, though not significantly by 6 kg/ha. Post-emergence application of bifenox (e.c.) to rapidly growing plants caused considerable leaf injury which was only slowly outgrown. Runner weight was reduced but crown number was not affected. The w.p. formulation caused less plant injury. Bentazone applied in early May caused leaf chlorosis and necrosis after spraying but effects were outgrown during the summer and runner production and crown numbers were not affected.

Weed Control

Weed growth on the lenacil-treated plots was vigorous (Table 5) and none of the seven commonest weed species had been controlled when compared with some untreated

Table 4

Response of newly-planted strawberries cv C. Favourite to new herbicides 1974 (Expt. 3 - WRO)

Herbicide	Dose (kg/ha)	Crop Vigour Score (0-9) 26/4	3/7	29/8	Runners/plot No.	Wt(g)	Crown No. / plant
Pre-emergence							
Lenacil	1.5	8.9	8.9	8.9	136	742	3.2
AC 92553	1.5	8.0	9.0	9.0	164	787	3.4
"	4.5	7.7	9.0	9.0	157	756	3.2
Bifenox w.p.	2.0	7.5	7.0	9.0	156	762	3.6
"	6.0	6.7	5.0	6.7	112	511	2.8
Chlorthal-dimethyl	6.0 + 1.5	9.0	9.0	8.7	124	691	2.8
+ lenacil	12.0 + 1.5	9.0	9.0	8.7	135	719	3.0
Bay 94871	2.5	7.0	9.0	8.5	137	742	3.8
"	7.5	6.7	7.5	8.5	122	625	3.3
Bay 94871	2.5 + 0.5	7.0	9.0	9.0	152	786	3.9
+ lenacil	7.5 + 1.5	6.7	6.5	8.2	111	596	4.2
Ethofumesate	2.0	7.2	9.0	8.7	129	672	3.7
"	6.0	6.5	7.5	8.2	128	654	3.6
Post-emergence							
Bifenox w.p.	2.0		7.0	8.5	128	646	3.9
" e.c.	2.0		6.0	8.5	132	609	3.5
Bentazone	1.5		7.2	8.7	140	686	3.9
S E Means ±					11.5	75.4	0.23

plots (those due to receive post-em. herbicide treatments). AC 92553 gave good control of weeds (<15% cover) at both rates (Poa annua and Aethusa cynapium were resistant). Other herbicides controlled some weed species completely but overall cover was >15% in mid-May. No information was obtained on weed control by the post-em. treatments.

Experiment 4. Simazine (1 kg/ha) failed to control weeds there being a 45% cover on plots 2 months after treatment. Bifenox (w.p.) at 2 and 6 kg/ha pre-em. gave good control of weeds compared with the standard, simazine (<20% cover). The same material, as an e.c. formulation, with or without simazine gave excellent control of all weeds (<5% cover) except occasional P. annua and S. media. Bay 94871 at 4 and 12 kg/ha gave similar results to simazine.

Expt. 5. The standard pre-em. weed killers failed to give any appreciable control of weeds (Table 5). AC 92553 at the 4.5 kg/ha rate gave the best control (6% cover) when assessed 2 months after treatment, A. cynapium and P. annua again being resistant. This herbicide at 1.5 kg/ha and trietazine + simazine at 2.74 kg/ha (total a.i.) were the only other treatments to give <25% weed cover. After overall paraquat + diquat treatment in June weed growth on most of the plots previously treated with residual herbicides was very limited up to the time of the final assessment in August.

Expt. 6. None of the post-emergence applications gave complete control of weeds when assessed 1 month after treatment (Table 6). Bifenox (e.c.) + simazine gave the best results (<20% cover); the w.p. formulation of bifenox gave much poorer results than the e.c. with or without simazine. Terbacil and trietazine + simazine, had no appreciable effect on total weed growth, though specific weeds were controlled. All the herbicides apart from phenmedipham gave good control of weeds for the 2 month period following the paraquat + diquat treatment in June.

Table 5

Control of weeds by pre-em herbicides applied 28.3.74 (Expt.3) and 8.4.74 (Expt. 5)

Herbicide	Dose (kg/ha)	Weed Cover % Expt. 3 20 MAY	Experiment 5 ++ 10 JUNE.	9 AUG.	Spp. controlled in one (1) or both (2) expts. Pav	Vp	Fo	Sm
Lenacil	1.5	75	100	3	.	.	.	.
BAY 94871	2.5	60	100	20	.	.	.	.
"	7.5	52	90	18	.	2	.	1
BAY 94871 + lenacil	2.5 + 1.0*	46	93	3	.	1	.	.
" "	7.5 + 1.0*	34	58	0	.	2	.	1
Chlorthal-dimethyl + lenacil	6.0 + 1.5	65	83	0	.	.	.	.
" "	12.0 + 1.5	55	77	0	1	1	.	.
Bifenox (w.p)	2.0	26	83	10	1	1	2	.
" "	6.0	24	80	8	1	2	2	.
AC 92553	1.5	10	23	13	2	2	.	1
" "	4.5	8	6	5	2	2	2	2
Ethofumesate	2.0	67	90	30	.	.	.	2
"	6.0	19	93	38	.	1	1	2
Expt. 5 only								
Simazine	1.2	-	83	0	.	.	.	.
Trietazine	1.2	-	87	11	.	.	.	.
"	2.4	-	57	0	.	1	1	.
Trietazine + simazine	1.2 + 0.17	-	73	3	.	.	.	.
" "	2.4 + 0.34	-	21	0	.	.	1	1
Terbacil	0.25	-	80	4	.	.	.	.
"	0.50	-	57	1	.	.	.	.
Untreated		-	96	42	.	.	.	.

*lenacil rates 0.5 and 1.5 kg/ha in Expt. 3 +paraquat + diquat applied 12+17.6.74

Table 6

Post-emergence activity of herbicides and herbicide mixtures against annual weeds (Expt.6)

Herbicide	Dose (kg/ha)	Weed cover (%) 12.6.74.	9.8.74*	Herbicide	Dose (kg/ha)	Weed cover (%) 12.6.74.	9.8.74.
Untreated		98	23	Trietazine	1.2	87	3
Phenmedipham	1.1	52	23	"	2.4	70	0
Bifenox e.c.	2.0	44	5	Trietazine + simazine	1.2 0.17	63	3
" w.p.	2.0	83	4				
Bifenox e.c. + simazine	2.0 1.5	18	1	Trietazine + simazine	2.4 0.34	63	0
Bifenox w.p. + simazine	2.0 1.5	87	0	Terbacil	0.25	77	3
				"	0.50	67	0

* paraquat + diquat applied to all plots on 12 and 17.6.74.

DISCUSSION

Crop Tolerance. The substantial injury to strawberries by metoxuron and metribuzin confirmed the results from earlier pot experiments (Clay, 1972) and indicate that these herbicides do not have adequate selectivity for use in strawberries. Bentazone has given variable results; at SHRI there was little foliar injury but severe crop loss; crown numbers produced for fruiting in the following year were also reduced. At WRO there was leaf injury but subsequent recovery in vigour and no depression in growth. Earlier results had shown that bentazone can cause severe leaf necrosis (Clay, 1972). In view of its activity against Cirsium arvense (Menck and Behrendt, 1972) further work may be justified to gain more information on crop response. AC 92553 showed promising selectivity at both centres even at relatively large doses (Tables 3 and 4). It caused some leaf abnormality initially, but as has been shown with phenmedipham, this type of effect may not lead to reduction in later growth or yield (Clay et al, 1974). Tests so far have been carried out in relatively dry conditions (Table 1) and further experiments in a range of soil and climatic situations are needed to establish its margin of tolerance. This was the only herbicide to give satisfactory control of weeds. P. annua and A. cynapium were relatively resistant as are some other important annual weeds (Cyanamid, 1974) but in mixture with a complementary herbicide, this herbicide could be particularly useful in dry soil conditions.

Response to bifenox differed at the two sites; at SHRI there was only slight leaf injury and no reduction in growth or in fruit yield; at WRO all applications gave appreciable and relatively persistent leaf injury but no reduction in crown number in August. Weed control with bifenox applied post-emergence as an e.c. was good, although P. annua and S. media were resistant. In view of its reported activity against Convolvulus arvensis and other problem weeds (Richardson and Dean, 1973; Mobil, 1974) further investigations of crop tolerance and effectivesness in the UK may be justified. Chlorthal-dimethyl was safe on the crop in the conditions of these experiments even at relatively high rates. It is used in N. America on strawberries in mixture with other herbicides such as chloroxuron (Diamond Shamrock, 1970). The mixture with lenacil however controlled few of the important weeds in the dry conditions.

Terbacil is used in strawberries as a spot treatment for control of Agropyron repens. In view of its activity against annual weeds at lower rates there was interest in its use in the crop. The SHRI results indicate good tolerance and confirmed previous findings (Lawson and Wiseman, 1969) but other reports suggest inadequate tolerance (Rath and O'Callaghan 1968). This may be a treatment which is safe in some parts of U.K. and not others. Further work is needed if the safety and effectiveness of the treatment is to be established. Activity of terbacil against weeds in the dry conditions of the WRO experiments was poor. Trietazine in mixture with simazine has given better weed control than lenacil in established strawberries and acceptable selectivity (Ellis, 1973); there was no indication of significant crop injury in the SHRI experiment. The higher dose mixed with simazine and applied pre-em. gave moderate weed control in dry conditions but not when applied at a relatively advanced stage of seedling growth (Tables 5 and 6). Further evaluation of tolerance is needed in relation to all the factors influencing response. BAY 94871 with or without lenacil, caused initial leaf injury at both doses during April and May but later growth was normal apart from the severe damage on one plot. In other work BAY 94871 has shown activity against weeds in dry conditions thought to be linked with its extremely high solubility (Hack and Schmidt, 1972), but it failed to control most weeds in all three experiments at WRO. Ethofumesate appeared selective in the crop in the dry conditions of the WRO experiment. Overall weed control was poor but in view of its effectiveness against certain weeds such as grasses and Galium aparine and the possibilities of using it in conjuction with lenacil and phenmedipham further work on crop tolerance may be worthwhile.

Mixtures of simazine and bifenox resulted in no antagonistic effects. A combined spray of foliage-acting and residual herbicide would often be valuable to control emerged and later-germinating weeds with a single application.

The results of the 1974 experiments must have been influenced by the small amount of rain in spring (Table 1). Interpretation of the crop tolerance data must take account of this, less activity on the crop being expected from residual herbicides in the absence of rainfall. The activity of the residual herbicides on the weed control experiments after paraquat + diquat treatment emphasises their dependence on adequate soil moisture for effectiveness - heavy rain fell a few days after the contact herbicide was applied.

While conditions in spring 1974 may not have been typical the experiments have shown that a number of these herbicides will be worth further testing in this crop as well as high-lighting the need for more effective residual herbicides in dry seasons.

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PRELIMINARY INVESTIGATIONS ON THE CONTROL OF WILD-OAT (AVENA FATUA L.) CULTIVATED OAT (AVENA SATIVA L.) AND BLACKGRASS (ALOPECURUS MYOSUROIDES HUDS.) IN SEED CROPS OF VARIOUS VARIETIES OF PERENNIAL AND ITALIAN RYEGRASS

H. Mead, B. L. Ross and R. J. Finch
Agricultural Development and Advisory Service, Cambridge

Summary Logarithmic spraying studies carried out in 1974 on crop and weed effect are reported. In addition replicated finite experiments based on information gained from 1973 studies (Mead et al 1973) were made and an interim report is made on these. Most of the herbicides used are those employed for the control of the named weeds in cereal crops. Several of the herbicides employed have been shown to give good control of the weeds named and herbicide/variety effects are reported.

INTRODUCTION

EEC regulations, which came into effect in July 1974 and which govern purity in the marketing of herbage seed, lay down mandatory standards for A. fatua and A. myosuroides. A. myosuroides seed is difficult to separate from ryegrass, fescue and cocksfoot seed because of similarity in size and shape. A. fatua seeds vary in size to a great extent and although the larger seeds are fairly easily cleaned out of the species mentioned, smaller ones are troublesome. The problems are exacerbated in the seeds of tetraploid ryegrasses which are much larger than those of diploid varieties and consequently can harbour much larger seeds of A. fatua. The EEC standard for certified herbage seed is 1 seed of A. fatua or A. ludoviciana in 300 grams of crop seed sample and a maximum by weight of 0.3% of A. myosuroides.

Studies carried out in 1973 on commercial crops had indicated that there were several herbicides selective between commonly grown herbage grasses and other grass species and which had no apparent effect on germination, or 1000 seed weight, of crop seed subsequently tested up to a year after harvest.

Germination studies after herbicide treatments are most important as there are lower limits laid down by statute for germination. Seed which does not attain these levels cannot legally be sold in EEC countries.

METHOD AND MATERIALS

All the trials except the 1974 logarithmic series on variety tolerance were conducted on commercial crops where there was a presence of either A. fatua, A. sativa or A. myosuroides. All trials were sprayed with a Van der Weij precision sprayer using Allman 00 jets at 3.164kg/cm^2 at low volume except in the case of herbicides such as chlorfenprop-methyl where the manufacturer's recommendations of 40 gals water per acre at a pressure of 45 psi and a forward speed of not more than 3 mph were followed. Plots were 3 metres by 10 metres in three randomised blocks. Plots for logarithmic spraying were 2 metres wide and of varying length and crops were sown specially for this work.

1974 A. fatua and A. sativa control

Trials to study Avena control were laid down on four commercial crops. Two were abandoned for reasons of low crop and weed population. Of the remaining two, one had a very heavy infestation of A. fatua and the other of A. sativa. Sites are:

Site 1: Pattiswick, Essex - A crop of perennial ryegrass (cv S23) drilled under barley (cv Berac) in March 1973. The soil type is a silty clay loam. A high level of A. fatua present.

Site 2: Kelvedon, Essex - A crop of perennial ryegrass (cv S101) drilled under spring oats (cv Mostyn) in March 1973. The soil is a sandy clay loam. A high level of A. sativa (cv Mostyn) present. There are reputed to be no wild-oat on this holding and none were found in the experimental area.

Table 1

Treatments applied on sites 1 and 2 Pattiswick and Kelvedon in 1974

Treatment	Dose kg/ha ai	Application date		Growth stage of A. sativa & A. fatua			
				Site 1		Site 2	
		Early	Late	Early	Late	Early	Late
Benzoylprop-ethyl	1.12	17/4	30/4	6	7	6-8	8
Chlorfenprop-methyl	4.84	14/2	5/3	3-5	5-6	5-6	6+
Difenzoquat	1.11	13/3	4/4	6	6+	5-6	6
Ethofumesate	1.68	21/3	4/4	6	6+	6	6
"	2.80	21/3	4/4	6	6+	6-7	6-7
Flamprop-isopropyl	0.99	26/3	4/4	6	6+	6	6-7
Hoe 23408	3.36	26/3	-	6	-	6	-
Iso-proturon	2.11	14/2	5/3	3-5	5-6	5-6	6+

Wild-oat populations were estimated prior to applying treatments by using a metre quadrat applied at random to each plot and giving a 25% plot sample of area utilised. Figures are as shown in Table 2.

Table 2

Pre treatment means of three replicates of A. fatua and A. sativa plants m^2 at sites 1 and 2 Pattiswick and Kelvedon

Treatment	Site 1 (A. fatua) Early	Site 1 (A. fatua) Late	Site 2 (A. sativa) Early	Site 2 (A. sativa) Late
Control	124		240	
Benzoylprop-ethyl	47	50	154	121
Chlorfenprop-methyl	147	72	326	183
Difenzoquat	6	68	28	235
Ethofumesate 1.68 kg/ha	67	43	252	192
" 2.80 kg/ha	50	62	176	272
Flamprop-isopropyl	47	43	162	188
Hoe 23408	54	-	155	-
Iso-proturon	101	60	229	115

1974 Alopecurus myosuroides control

Many crops were examined in early 1974 but only one was found having a regular population of A. myosuroides suitable for critical study. Site 3 at Parham, Suffolk on a crop of diploid perennial ryegrass (cv Melle) was laid down as a randomised block experiment using three treatment replicates on the dates and at the stages described in Table 4. The crop was sown direct in autumn 1973 on a Beccles series sandy clay loam. Further unreplicated treatments were added at various manufacturers suggestions.

Table 3

Treatments for control of A. myosuroides at Parham in 1974

Treatment	Dose kg/ha ai	*A. myosuroides* tillers	Date applied
AC 92553 *	1.39	12 +	19/4
Ethofumesate	1.68 + 2.80	3-4	11/3
"	1.68 + 2.80	4-6	25/3
" *	5.60	4-6	25/3
Hoe 22870 *	2.24	3-5	20/3
" *	2.24	6-8	3/4
Iso-proturon	1.40 + 2.80	3-4	11/3
"	1.40 + 2.80	4-6	25/3
" *	5.60	4-6	25/3
Metoxuron-simazine	2.52 + 5.32	3-5	20/3
"	2.52 + 5.32	6-8	3/4
Oxadiazon	0.84, 1.68 + 3.36	3-4	11/3
"	0.84, 1.68 + 3.36	4-6	25/3

* not replicated

Herbicide Tolerance Studies

Observation studies were laid down on herbicide tolerance of three varieties of ryegrass, sown on 4.4.74 on a sandy loam of the Melton Series at Trumpington, Cambs. Treatments were applied with a logarithmic sprayer except in the case of tri-allate granules which were applied at five doses and hand raked for incorporation. Treatments were not replicated.

Table 4

Treatments applied logarithmically to cv Premo, S 24 and Maris Ledger in 1974 at Trumpington sites. Crops drilled 4.4.74

Treatment	Starting dose kg/ha ai	State of crop	Date applied
Control		Pre-emergence	9.4.
Chlortoluron	10.8	"	"
Iso-proturon	7.6	"	"
Terbutryne	8.4	"	"
Linuron & trifluralin	2.02 and 4.03	"	"
WL 29226	1.96	"	"
Tri-allate granules	at 2.02, 1.68, 1.34, 1.01 and 0.67	"	"
Tri-allate emulsion	4.2	"	"
AC 92553/330E	1.49	"	"
Oxadiazon	1.68	"	"
Chlortoluron	9.41	Early post-emergence 1-1½ leaves	1.5.
Iso-proturon	6.31	"	"
Methabenzthiazuron	9.41	"	"
Chlortoluron	9.41	Start of tillering	21.5.
Iso-proturon	6.31	"	"
Chlortoluron	9.41	Tillers formed	30.5.
Iso-proturon	6.31	"	"
Metoxuron	10.8	"	"
Metoxuron & simazine	0.62 and 9.72	"	"
Cyanazine	4.03	"	"
Difenzoquat	2.71	Leaf sheath lengthened	20.6
Ethofumesate	4.48	"	"
Barban	1.01	Tillers formed	30.5

Germination and establishment of all three varieties was good and even but the season was very dry and the soil light and well drained.

RESULTS

Avena spp. control

The results of the experiments on A. fatua and A. sativa control on sites 1 and 2 are presented in Table 5.

Table 5

Post treatment means of three replicates of A. fatua panicles at site 1 Pattiswick (9.7.74) and A. sativa panicles at site 2 Kelvedon (8.7.74)

Treatment		Panicles m^2		Panicles dry weight g/m^2		% reduction treatment/control dry weight basis	
		Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Control		259	390	242	249	-	-
Benzoylprop-ethyl	early	46	77	56	6	77	98
"	late	66	24	22	7	91	97
Chlorfenprop-methyl	early	109	484	87	333	64	34 *
"	late	228	412	153	358	37	44 *
Difenzoquat	early	51	92	28	49	88 †	80
"	late	90	85	120	50	50	80
Ethofumesate 1.68	early	135	132	86	60	65	76
" "	late	121	256	109	226	55	10
" 2.80	early	40	63	24	59	90	77
" "	late	53	169	83	120	65	52
Flamprop-isopropyl	early	199	64	76	36	69	86
"	late	161	179	90	71	63	72
Hoe 23408		88	506	48	174	80	30
Iso-proturon	early	223	173	165	106	32	58
"	late	244	320	215	205	11	18

† misapplication - ignore result at Site 1   * increase

Good controls of A. fatua (77% and 91%) were obtained from benzoylprop-ethyl, the later applications giving a better level of control than the earlier. Excellent controls of A. sativa were obtained at both times of application.

Earlier applications of ethofumesate gave better control of both A. sativa and A. fatua, whilst later applications of benzoylprop-ethyl gave the best control.

Chlorfenprop-methyl gave only moderate levels of control of A. fatua but its makers do not claim control of A. fatua once it has tillered. Although early applications of this chemical were applied on 14 February the A. fatua plants were mainly at growth stage 3-5. The chemical had no visible effect on A. sativa (cv Mostyn).

Hoe 23408 also shows promise for A. fatua control but its effect on the two perennial ryegrass varieties cv S 23 and cv S101 was very severe as it reduced their populations to unacceptably low levels, there being a complete kill on some plots.

Isoproturon gave a moderate control of Avena spp. also had a severe effect on ryegrass varieties and reduced crop population below an acceptable level.

Flamprop-isopropyl gave moderate controls of both Avena spp. with no visible effects on ryegrass population or vigour.

Difenzoquat unfortunately was misapplied and it was too late when the error was discovered to repeat the early application. The late application on A. fatua gave only a moderate level of control. Previous experience of the chemical reported elsewhere was promising and the errors are regretted.

Alopecurus myosuroides control

The effects of treatments imposed at site 3 Parham are listed in Table 6.

Table 6

Site 3 Parham % reduction of A. myosuroides treatment/control, based on mean counts of heads m^2 on three replicates on 31.5.74

Treatment			% reduction of A. myosuroides
AC 92553 *			53 increase
Ethofumesate	1.68	early	73
"	1.68	late	49
"	2.80	early	91
"	2.80	late	55
"	5.60 *	late	99
Hoe 22870 *		early	100
" *		late	100
Iso-proturon	1.4	early	39
"	1.4	late	13 increase
"	2.8	early	73
"	2.8	late	23
"	5.6 *	late	93
Metoxuron/simazine	2.5	early	33 increase
"	2.5	late	23
"	5.32	early	13
"	5.32	late	2
Oxadiazon	0.84	early	21 increase
"	0.84	late	29 increase
"	1.68	early	53 increase
"	1.68	late	42 increase
"	3.36	early	9
"	3.36	late	19 increase

* not replicated

Ethofumesate at all doses and all times has given control of A. myosuroides but early applications at a low dose have given better control (ie 73%) than high doses 14 days later (ie 73% as against 55%). The extremely heavy dose of ethofumesate on the unreplicated area gave an almost complete control when applied just before A. myosuroides inflorescence emergence. No crop damage was recorded at any dose of ethofumesate.

Iso-proturon did not have the lethal effect on cv Melle as it had on cv S23 and cv S101 at sites 1 and 2 and gave good A. myosuroides control at the high dose applied early, the later application being disappointing. The very high dose applied at the inflorescence emergence stage of A. myosuroides gave excellent control with little effect on crop vigour. The only effects of iso-proturon on cv Melle at this centre was to make the crop slightly lighter green in appearance and more erect in habit (cv Melle is a late pasture type with a prostrate habit).

Oxadiazon at all rates and times caused extensive foliar discolouration and damage but both ryegrass and A. myosuroides recovered after a period of 14-21 days.

Although Hoe 22870 appears to have given excellent control of A. myosuroides the chemical was applied outside the experimental area where there was comparatively little weed and consequently results could be misleading. No effect was observed on cv Melle. The herbicide will be included in future experiments if available.

The metoxuron-simazine mixture gave poor A. myosuroides control at the stages of growth noted but only a slight degree of crop damage was noted.

Herbicide tolerance studies

Tolerance levels to the treatments are as detailed in Table 7 and are in the same order of application as in Table 4.

Table 7

Trumpington sites. Effect of treatments. Sward scored 0-10
0 = complete sward destruction 10 = control assessment 11.7.74

Treatment	Start			½ starting treatment dose			¼ starting treatment dose			⅛ starting treatment dose		
	Premo	S24	Ledger	Premo	S24	Ledger	Premo	S24	Ledger	Premo	S24	Ledger
Chlortoluron	4	4	0	4	4	½	8	7	7	9	9	8
Iso-proturon	1	4	0	2	4	0	6	7	5	7	9	8
Terbutryne	9	8	4	9	9	6	9	10	10	9	10	10
Linuron & trifluralin	9	8	4	9	9	5	9	10	10	9	10	10
WL 29226	9	9	8	9	10	9	9	10	10	9	10	10
Tri-allate gran						See text						
Tri-allate em	7	7	1	9	8	4	9	9	7	9	10	7
AC 92553/330E	8	9	2	9	10	4	9	10	7	9	10	9
Oxadiazon	7	9	10	8	10	10	9	10	10	9	10	10
Chlortoluron	3	½	0	4	½	0	9	1	2	9	3	6
Iso-proturon	2	1	0	4	1	0	9	2	2	9	5	6
Methabenzthiazuron	8	9	4	8	9	8	9	10	10	9	10	10
Chlortoluron	1)	Not applied		4)	Not applied		9)	Not applied		8)	Not applied	
Iso-proturon	1)			1)			6)			8)		
Chlortoluron	½	½	0	½	½	1	3	½	5	8	4	9
Iso-proturon	½	1	0	½	2	1	3	4	5	8	5	9
Metoxuron	½	1	½	1	2	½	3	2	3	8	5	7
Metoxuron/simazine	1	1	½	1	1	½	3	2	3	8	5	6
Cyanazine	4	10	4	4	10	7	8	10	9	9	10	10
Difenzoquat	8	10	3	8	10	8	8	10	10	9	10	10
Ethofumesate	9	10	6	9	10	10	9	10	10	9	10	10
Barban	9	10	2	9	10	5	9	10	9	9	10	10

Herbicidal effect on the crop was estimated by scoring the well established control as 10 and completely killed crop as 0. The logarithmic strips were divided into four parts to correspond to the rates described in Table 6.

Although the method of assessment can be criticised from the point of view of subjectivity it was considered to be the only one applicable under these particular circumstances. The control plots were frequently used as references during assessment. It must be noted that spring and summer of 1974 were very dry at Cambridge and this factor coupled with the light soil may have reduced toxicities particularly at the pre-emergence stage.

Indications from these studies are that iso-proturon and chlortoluron are unacceptable for ryegrass weed control work using the three varieties quoted. Cv Melle however seems to tolerate iso-proturon when applied to adult plants (see Table 5).

The only other herbicides to which there appears to be any pre-emergence sensitivity are AC 92553/330E, terbutryne and linuron + trifluralin which all seriously affected Maris Ledger which was also sensitive to tri-allate granules and emulsion. The tri-allate effect on the two perennial ryegrasses was not serious even at the high initial dose.

Post-emergence scores show iso-proturon, chlortoluron, metoxuron and metoxuron/simazine to be extremely toxic to all three varieties.

Ethofumesate which appears to have very little effect on perennial ryegrass in this and other work considerably reduced the population of cv Maris Ledger when applied to young plants at the high initial rate of 4.48 kg ai/ha but this effect rapidly vanished as the dose decreased down the logarithmic strip.

Barban had a lethal effect on cv Maris Ledger and was quite unacceptable even at half dose, but had little effect on the two perennial ryegrass varieties at the stage of growth described. Cv Maris Ledger also appears most sensitive to difenzoquat at the young stage but this effect rapidly decreased with the dose.

DISCUSSION

Although it is dangerous to draw conclusions from the results of single experiments over one season some tentative indications can be discussed.

A. fatua control

The chemical benzoylprop-ethyl applied late, ie at the end of April showed good control and had little or no visible effect on the varieties named. However the latest application was made on 30 April to cv S23, the ear emergence of which starts towards beginning of June. The effects that the herbicide would have if applied after or during the ear emergence period is conjectural.

Ethofumesate has also shown good control of A. fatua, the earlier applications being the more efficient. It is suspected that autumn or very early spring applications might be more effective than those described. The material is soil persistent and consequently its effect may be long lasting. The manufacturers do not recommend sowing cereals until 5 months after the date of application and then only with complete soil inversion.

A. myosuroides control

Ethofumesate gave good results in the trial and as with A. fatua control, earliness of application appears to be beneficial. A. myosuroides infestation of grass swards is however extremely difficult to detect at the early stage of development as the species has few definite botanical characters and whether growers will be able to decide when they have an infestation at an early stage is debatable and the later, heavier doses may have to be employed.

Iso-proturon has given variable results and there appears to be evidence of some varietal interaction.

The pre- and post-emergence study in the absence of weeds has shown that some herbicides used primarily for A. fatua control in cereals may be suitable for use in ryegrass seed crops. The use of these herbicides in this manner is by no means common and further studies will be made with autumn sown crops where a parallel may be drawn with the herbicides in use in winter wheat where there is a considerable volume of knowledge of A. fatua and A. myosuroides control.

Data still to be determined on the three series of experiments are 1000 seed weight and germination percentage. Any effect on yield would have to be carried out on larger plots as these crops are usually lodged at harvest and present considerable difficulty to any yield determination techniques on small plots. *A. fatua* seed present at harvest time will be sampled and sorted for seed size and germination. The criterion for mechanical separation of *A. fatua* and the ryegrasses in seed cleaning operations appears to be one of length. Fully grown *A. fatua* seeds are not difficult to separate but immature seeds can approximate to ryegrass seed size which varies from the largest in tetraploid Italian ryegrass at 8-10 mm to the smallest in diploid perennial ryegrass at about 4-7 mm.

Acknowledgements

Gratitude is due to the farmers who permitted so many liberties to be taken with their crops and to the Plant Breeding Institute at Cambridge for the use of land and technical facilities.

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THE TOLERANCE OF TEN GRASS VARIETIES TO SIX HERBICIDES WITH A POTENTIAL FOR WILD OAT CONTROL IN HERBAGE SEED CROPS

A.K. Oswald and R.J. Haggar

ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford OX5 1PF

Summary The effects of six herbicides, applied at two rates and two stages of crop growth, on ten grass varieties were measured in terms of green material reductions during 35 days after spraying. All varieties were susceptible to isoproturon, except at the tillering stage, and to difenzoquat applied at 3.0 kg/ha. Perennial and Italian ryegrass varieties were resistant to all other herbicides. All high-rate applications, and the normal rate of difenzoquat, checked S 352 timothy. Reductions in S 37 cocksfoot resulted from ethofumesate at 5.0 kg/ha and benzoylprop-ethyl at 3.36 kg/ha sprayed at tillering. "Rossa" meadow fescue was also checked by ethofumesate at both stages of growth.

The effects of the same herbicides and rates applied to S 24 perennial ryegrass at four growth stages were measured in the same way. Isoproturon at both rates was damaging at all growth stages, especially pre-emergence and the 2-3 leaf stage. Difenzoquat at the high rate was damaging at the 4-5 leaf stage. Other herbicides had little effect.

INTRODUCTION

The low level of wild oat contamination of herbage seed acceptable in the European Economic Community has accentuated the need for reliable control of this weed in crops grown in Great Britain.

The tolerance of grass varieties to several new herbicides already used for wild oat control in other crops was unknown. Therefore two experiments, both located on a sandy/light loam soil at Begbroke, Oxon, were set up. The object of the first experiment was to measure the effects of six herbicides at two rates applied at two stages of growth to ten popular grass varieties. The second experiment involved measurement of the effects of the same six herbicides and rates applied at four growth stages specifically to S 24 perennial ryegrass. All effects were assessed in terms of visible reductions in green material.

METHODS AND MATERIALS

Experiment 1. The tolerance of ten grass varieties to six herbicides

Details of the grass varieties that were used, plus the herbicide treatments that were applied, are given in Table 1. Each of the herbicide treatments was applied when the majority of the grasses were at the 2-3 leaf stage, and at the tillering stage of growth. A plaid design of two replicates was used.

Table 1

The grass varieties drilled and herbicide treatments applied

Grass variety sowing rate (kg/ha)		Herbicide application rates (kg a.i./ha	
1. S 24 perennial ryegrass	15.7	1. Isoproturon	2.1 and 6.3
2. "Gremie" " "	"	2. Difenzoquat	1.0 " 3.0
3. "Barlenna" " "	"	3. Flamprop-isopropyl	1.0 " 3.0
4. S 23 " "	"	4. Chlorfenprop-methyl	4.75 " 14.25
5. "Taptoe" " "	22.4	5. Ethofumesate	1.68 " 5.0
6. "Barpastra"" "	"	6. Benzoylprop-ethyl	1.12 " 3.36
7. RvP Italian "	16.8		
8. S 352 timothy	9.0		
9. S 37 cocksfoot	11.2		
10. "Rossa" meadow fescue	15.7		

Each of 10 grasses was drilled in plots measuring 22.5 m by 2 m on 5 April 1974, using an Øyjord seed drill, after which the area was rolled. At right angles across these plots, herbicide treatments were applied in 1.5 m wide strips. Thus the area of each grass variety treated with a particular herbicide treatment measured 2 m x 1.5 m. All herbicide treatments were applied on 8 May 1974 (2-3 leaf stage) and 22 May 1974 (tillering stage) in 337 litres per ha aqueous spray solution at 2.07 bars pressure with Tee jets fitted to a 1.5 m boom using an Oxford Precision Sprayer. Assessing the growth stage of 100 randomly selected plants from each variety at the time of spraying (Table 2) showed that, although the majority of the ryegrasses were at the correct growth stage, some of the other species (notably timothy) were not as far advanced.

Table 2

The percentage of each grass variety having reached the required stage of growth at spraying

Grass variety	2-3 leaves on 8.5.74	Tillered on 22.5.74
Perennial ryegrasses	68	84
Italian "	58	83
S 352 timothy	17	1
S 37 cocksfoot	6	32
"Rossa" meadow fescue	22	87

The remaining percentage of each variety was at a younger stage of development.

Herbicide effects were measured as scores of the amount of green material present compared with unsprayed vegetation. Each plot was scored periodically by two people independently and a mean of the two scores recorded. The response of broadleaved species to the herbicides was obtained by a presence/absence assessment; a 30 cm^2 quadrat was thrown ten times at random over the relevant 20 m by 1.5 m spray strip and the frequency of the main broadleaved species within each quadrat was recorded.

Experiment 2. The effects of timing of applications of six herbicides on S 24 perennial ryegrass

Six herbicides were compared at two rates and at four growth stages of ryegrass development, as shown in Table 3. Each treatment at every stage of growth was replicated three times. Plot size was 4 m by 1.5 m.

Table 3

Herbicide treatments and the percentage of grass having reached the required growth stage at spraying

Herbicide application rates (kg a.i./ha)				Stage of growth	%	Date sprayed
1. Isoproturon	2.1	and	6.3	1. Pre-emergence	-	11 April 1974
2. Difenzoquat	1.0	and	3.0	2. Two-three leaves	54	8 May 1974
3. Flamprop-isopropyl	1.0	and	3.0	3. Four-five leaves	83	17 May 1974
4. Chlorfenprop-methyl	4.75	and	14.25	4. Tillering	84	22 May 1974
5. Ethofumesate	1.68	and	5.0			
6. Benzoylprop-ethyl	1.12	and	3.36			

All herbicide treatments were applied in 337 litres per ha aqueous spray solution at 2.07 bars pressure with Tee jets fitted to a 1.5 m boom using an Oxford Precision Sprayer. Herbicide effects were assessed as in Experiment 1.

RESULTS

Experiment 1. The tolerance of ten grass varieties to six herbicides

Vegetative scores. Isoproturon caused severe damage (at least 50 per cent reduction in green material), especially when applied early, and at the high dose (Figs. 1 and 2). Effects generally reached a maximum fifteen days after the 2-3 leaf stage application and between seven and fifteen days after spraying at the tillering stage. Full recovery was not achieved after 35 days by any of the grasses except after the normal rate applied at the tillering stage. The effects of the high rate at this time were still developing at 35 days on all varieties except S 37 cocksfoot.

Difenzoquat was tolerated by all grasses, apart from S 352 timothy, at the normal rate, but at the high rate caused some effect on all varieties. However, almost complete recovery had occurred by 35 days, apart from S 352 timothy.

Flamprop-isopropyl, even when applied early and at high dose, had no marked effect on any of the grass varieties, except for S 352 timothy which was moderately checked by the high rate applied at the tillering stage. This effect reached maximum after 15 days and was maintained at least up to 35 days.

Chlorfenprop-methyl caused little damage at the normal rate at either date of application. A slight short-term check to all varieties was noted following high rate applications, the damage to S 352 timothy being more severe especially at the 2-3 leaf stage.

Ethofumesate caused no damage on the ryegrass varieties at the normal rate applied at either date, but the other grasses were checked. However, the high rate

Fig. 1. Normal dose. Scores for effect on presence of green material on 5 occasions during period up to 35 days from spraying at 2-3 leaf (——) and tillering (- - -) stages

Scored 0 = absence, to 9 = equal to unsprayed control.

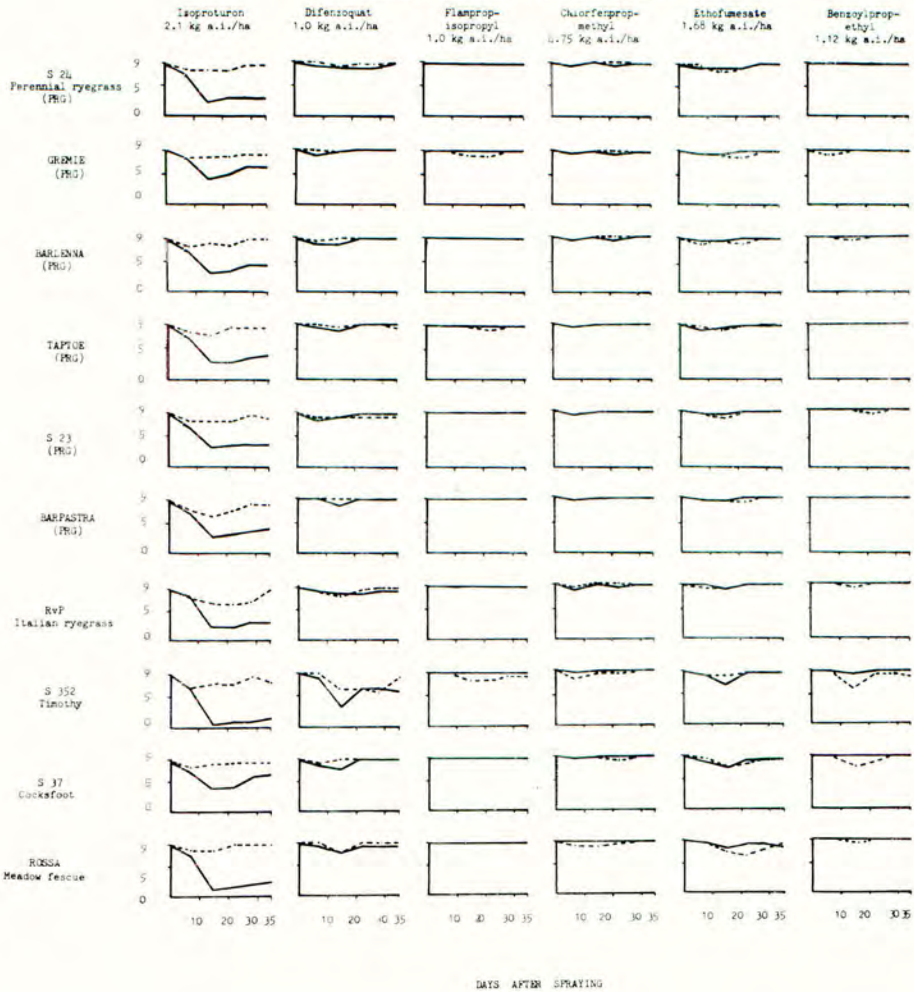


Fig. 2. High dose. Scores for effect on presence of green material on 5 occasions during period up to 35 days from spraying at 2-3 leaf (——) and tillering (- - -) stages

Scored 0 = absence, to 9 = equal to unsprayed control

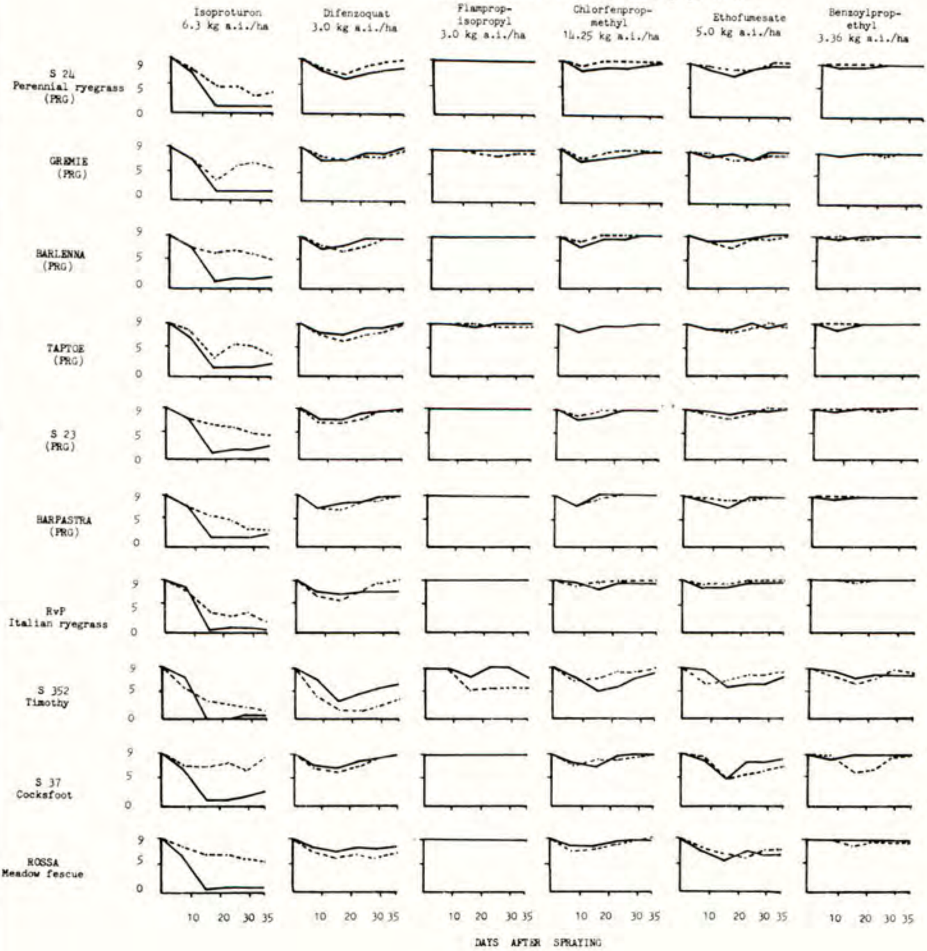
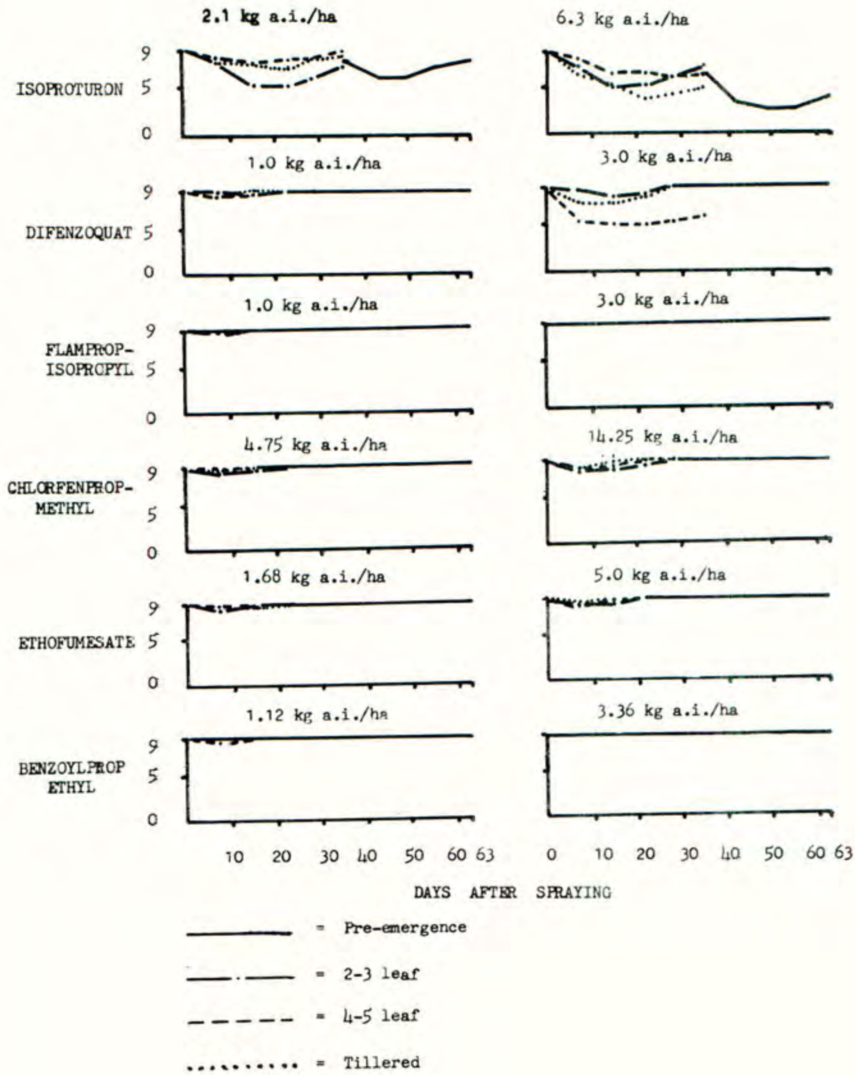


Fig. 3. Scores for effect on presence of green material on 5 occasions after spraying

Scored 0 = absence, to 9 = equal to unsprayed control



was slightly more damaging to all varieties. Effects reached a maximum usually after 15 days; S 352 timothy, S 37 cocksfoot and "Rossa" meadow fescue had not fully recovered after 35 days.

Benzoylprop-ethyl did not cause any damage to any of the ryegrass varieties. The normal rate checked S 352 timothy especially at the late stage of growth: the high rate damaged S 352 timothy at both stages and S 37 cocksfoot at the tillering stage.

Broadleaved weeds. Ethofumesate was notable in reducing the cover of broad-leaved species on plots sprayed at the 2-3 leaf stage of the ryegrass (Table 4). Reductions of Chenopodium album, Stellaria media and Polygonum convolvulus were achieved by both herbicide rates, Capsella bursa-pastoris was reduced by the high rate only. No effect on Polygonum aviculare was shown.

Table 4

Broadleaved species recorded 22 days after spraying
(Mean presence per 10 x 30 cm quadrats)

Species	Unsprayed Control	Ethofumesate 1.68 kg a.i./ha	Ethofumesate 5.0 kg a.i./ha
Chenopodium album	10	5	3
Stellaria media	10	1	0
Polygonum convolvulus	7	2	0
Capsella bursa-pastoris	6	4	1
Veronica spp.	4	3	0
Polygonum aviculare	3	6	4
Galium aparine	2	0	0
Senecio vulgaris	2	2	3
Fumaria officinalis	2	2	1
Urtica urens	2	1	0
Papaver rhoeas	2	0	0
Viola arvensis	1	0	0
Total	51	26	12

Experiment 2. Timing of six herbicides on S 24 perennial ryegrass

The effects of the herbicides, applied at the four dates of application, in terms of the reduction of green material are shown in Fig. 3. The ryegrass was tolerant to all herbicides, applied at normal rates and at all growth stages, with the exception of isoproturon, which caused most damage at the 2-3 leaf stage. At the high rate of application Flamprop-isopropyl still caused no damage to the grass at any of the growth stages, while chlorfenprop-methyl, ethofumesate and benzoylprop-ethyl were only slightly damaging. However, the high rate of difenzoquat, applied at the 4-5 leaf stage, caused a 45 per cent reduction in green material. Effects were less severe when applied at the other dates.

Isoproturon, at the high rate, was even more severe with green material reductions of 66 per cent after the pre-emergence application and 33 per cent when sprayed at the 4-5 leaf stage, being recorded.

DISCUSSION

It has been shown that at the rates used, isoproturon cannot safely be applied to any of the grasses used, even when fully tillered. Difenzoquat is also damaging when applied at 3.0 kg a.i./ha to all emergent grasses to at least the tillering stage, although at 1.0 kg a.i./ha (the rate recommended for use in cereal crops) little damage was apparent. None of the other herbicides appeared to have any marked effects on the grasses used in this investigation.

The ryegrass varieties did not vary singificantly in their relative tolerance to the herbicides. In general, S 352 timothy, S 37 cocksfoot and "Rossa" meadow fescue appeared to be more susceptible than the ryegrasses. However, it must be stressed that, often, a relatively larger proportion of these apparently susceptible grasses had not reached the appropriate growth stages when they were sprayed. Further work is therefore required to overcome this limitation. Also, more long-term investigations are required to record possible harmful effects on the reproductive growth and seed production of these grasses, plus confirming that wild oats can be adequately controlled in grass seed crops by these herbicides.

Some studies along these lines, including work on undersown grass crops, are currently in progress at WRO.

Acknowledgements

The authors wish to thank Messrs. F.W. Kirkham and C.J. Bastian for assistance with the experimental work and to R.J. Dale and the WRO Farm staff for their co-operation in site preparation. The supply of grass seed by Twyford Seeds Ltd., is also acknowledged.

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OBSERVATIONS ON THE EFFECT OF THREE HERBICIDES WITH PROMISE IN THE CONTROL OF GRAMINACEOUS WEEDS ON THE SEED PRODUCTION OF RYEGRASS

A. W. Evans and D. S. Muncey
National Institute of Agricultural Botany, Cambridge

Summary Benzoylprop-ethyl at 1 lb/ac. a.i. in 40 gal/ac water was applied to single plots of three perennial and two Italian ryegrass varieties in the spring of the harvest year to simulate an application for wild oat control; seed yield appeared to be slightly reduced but germination not affected. Ethofumesate at 1 and 2 lb/ac. a.i. and methabenzthiazuron at 2 and 4 lb/ac. a.i. applied to three replicates of S.24 perennial ryegrass at the tillering stage of the sowing year, to simulate an application for control of grass weeds, did not significantly affect yield or seed germination immediately after harvest.

Résumé Du benzoylprop-ethyl à raison d'une livre par acre diluée dans 40 galons d'eau a été appliqué seulement à trois parcelles de variétés de ray-grass anglais et à deux de variétés de ray-grass d'Italie, au printemps de l'année de la récolte, pour simuler une application pour le contrôle de la folle avoine. Le rendement s'est trouvé être légèrement réduit, mais la germination non affectée. Du ethofumesate à raison d'une livre et deux livres d'ingrédient actif par acre et du methabenzthiazuron à raison de deux livres et de quatre livres d'ingrédients actif par acre ont été appliqués à trois réplicats de ray-grass anglais S.24 au stade du tallage de l'année d'ensemencement, pour simuler une application pour le contrôle des mauvaises herbes, ces applications n'ont pas affecté d'une manière significative le rendement ou la germination des graines immédiatement après la moisson.

INTRODUCTION

Observation plots were incorporated into a programme on the assessment of the seed production potential of ryegrass varieties to obtain information on the effect of benzoylprop-ethyl, ethofumesate and methabenzthiazuron on ryegrass seed production and seed quality. The effects of pre and post-emergence treatments of methabenzthiazuron on ryegrass seed crops for the control of Poa trivialis have previously been reported (Budd 1970, Budd and Evans 1972).

METHOD AND MATERIALS

Experiment 1 The effect of benzoylprop-ethyl on several ryegrass varieties.

A benzoylprop-ethyl treatment (1 lb/ac. a.i. in 40 gal/ac. of water) was compared with a control treatment (no herbicides) on three perennial ryegrass and two Italian ryegrass varieties, during the spring of the 1973 harvest year (Table 1). Plot size was 1/25 acre (8 x 217.8ft) There were no replications.

TABLE I

Species	Variety	Date sprayed	Growth stage
Perennial ryegrass	Aberystwyth S.24	2 May 1973	2 days before ear emergence
	Premo	2 May	4 days " " "
	Perma	23 May	3 days " " "
Italian ryegrass	Aberystwyth S.22	7 June 1973	100% emerged
	Combita	7 June	100% emerged

All the ryegrass varieties, sown previously in July 1972, were managed for optimum seed production. They were topped over twice in the autumn to control growth. The two Italian varieties were cut for silage at the beginning of May 1973.

Seed harvesting was by direct combining, seed moisture assessment being used to determine the time of harvest, which is very critical to avoid losses from shedding. The perennial ryegrass was harvested after reaching 28% and the Italian ryegrass 38% seed moisture content.

Moisture determinations by oven drying were made on samples of the harvested seed, which was dried immediately after harvest to 12-14% moisture for storage. The purity of the harvested seed was determined by measuring the cleanings of a representative sample of approximately 8 lbs. of the harvested seed, and obtaining a purity analysis of the cleaned seed. All plot yields are expressed as seed of 99% purity and 14% moisture content.

Germination tests were carried out on the harvested seed in October and again in February to check for any deterioration.

Experiment 2 A comparison of ethofumesate and methabenzthiazuron on S.24 perennial ryegrass

Ethofumesate at two rates (1 and 2 lbs/ac. a.i.) and methabenzthiazuron at two rates (2 and 4 lbs/ac. a.i.) were applied in 40 gal/ac. of water during mid-August 1973 to a well-tillered establishing crop of perennial ryegrass Aberystwyth S.24, sown six weeks previously on 3 July.

The treatments were replicated three times. Plot size was 1/25 acre (8 x 217.8ft) The seed was harvested and processed as in experiment 1.

RESULTS

Experiment 1

The results in Table 2 show that a reduction in seed yield of between 4%(Combita) and 8%(Premo) was obtained from the benzoylprop-ethyl treatment. A yield reduction was significant at P = 0.01. However, 1,000 seed weights tended to be slightly higher from the herbicide treatment.

TABLE 2

Effect of benzoylprop-ethyl treatment on seed yield and quality of five ryegrass, 1973 harvest

Variety	Yield of clean seed (99% purity, 14% moisture)		1,000 seed wt.	
	Control cwt/ac	Treatment as % control	Control g	Treatment as % control
Aberystwyth S.22	14.35	94.4	2.41	102.1
Combita	14.46	96.8	2.37	100.4
Aberystwyth S.24	11.95	95.1	2.12	100.9
Premo	11.52	93.6	1.99	103.5
Perma	13.64	92.0	1.65	106.7
SE (mean diff. between control and treatment)	0.108		0.017	
Level of significance	0.01		0.05	

Seed germination was not affected by the herbicide treatment (Table 3)

TABLE 3

Effect of benzoylprop-ethyl treatment on seed germination after 1973 harvest

Variety	% Germination October 1973		% Germination February 1974	
	Control	Treatment	Control	Treatment
Aberystwyth S.22	96	95	93	94
Combita	96	96	96	96
Aberystwyth S.24	94	97		
Premo	92	93		
Perma	94	97	94	96
SE (mean diff.)	0.843 NS		1.08 NS	

Experiment 2

Neither herbicide at either rate of application had any significant effect on seed yield. (Table 4)

TABLE 4

Ethofumesate and methabenzthiazuron treatments on S.24 perennial ryegrass 1974 harvest results

Treatment	Yield of clean seed (99% purity, 14% moisture) cwt/acre	% control	1000 seed wt. g	% Germination of harvested seed
Control	7.14	100	1.93	98
Ethofumesate, 1 lb/ac.	7.87	110	1.77	96
Ethofumesate, 2 lb/ac.	7.69	108	1.84	95
Methabenzthiazuron, 2 lb/ac.	6.59	92	1.80	94
Methabenzthiazuron, 4 lb/ac.	7.05	99	1.78	95
SE (treatment mean)	0.33	4.66		
	NS			

DISCUSSION

After bearing in mind the limited scope of the observations in experiment 1, in that only one application rate and one time of application was used, they suggest a slight reduction in seed yield caused by using benzoylprop-ethyl. There was no evidence of any reduction in germination and a slightly higher 1,000 seed weight was obtained from the treated plots. The tendency for slight yield reduction and slight increase in 1,000 seed weight from the treated plots possibly indicates a small reduction in the number of fertile florets.

Higher rates for methabenzthiazuron were used in experiment 2 than those recommended for pre and early post-emergence treatment to control Poa trivialis. Both treatment rates caused some yellowing and slight plant losses; it is possible that this could have been caused by an interaction with a herbicide applied 14 days earlier which contained ioxynil and mecoprop. No such effect was observed from the application of ethofumesate.

None of the herbicide treatments gave seed yields significantly different from the control , though ethofumesate tended to increase yields. Satisfactory germination results, too, were obtained from all treatments when tested after harvest. Hence on this limited evidence there is no evidence here to suggest that either herbicide is unsafe to use on perennial ryegrass seed crops.

The difference in yields of Aberystwyth S.24 perennial ryegrass in each experiment can be accounted for by differences in site conditions.

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THE USE OF ETHOFUMESATE FOR WEED CONTROL IN RYEGRASS SEED CROPS

A.P. Ball and A.R. Roberts
Fisons Limited, Chesterford Park Research
Station, Saffron Walden, Essex.

Summary Early findings of the safety of ethofumesate in ryegrass and some other grasses have been followed up in greenhouse, small plot and field experiments. In New Zealand, after several seasons' work, ethofumesate at 1.0 - 1.5 kg a.i./ha has proved to be an effective herbicide for the control of *Hordeum murinum* in ryegrass/clover pastures, when applied as a winter treatment. In the USA and UK trials have been carried out to evaluate the use of ethofumesate for the control of certain problem weeds in ryegrass seed production. Weed species which showed some susceptibility to ethofumesate were *Alopecurus myosuroides*, *Hordeum murinum*, *Poa annua*, *Poa trivialis*, *Bromus* spp., *Avena fatua*, *Stellaria media* and *Galium aparine*.

This paper reviews work by the authors and a number of other workers in several countries on the development of the selective use of ethofumesate in ryegrass.

INTRODUCTION

The biological properties of ethofumesate were first described at the 3rd Symposium on New Herbicides, Versailles (Pfeiffer 1969). Although at that time the author indicated a marked selectivity in the sugar beet crop, with a wide spectrum of weeds controlled, it was also noted that a number of other crops appeared to be highly resistant to ethofumesate. Amongst these was *Lolium multiflorum*.

In New Zealand, where large areas of ryegrass are severely infested with *Hordeum murinum*, ethofumesate was shown to control this weed. In the UK and the USA, sufficient areas of ryegrasses are grown, both for seed and for pasture, to justify further investigations of the possible use of ethofumesate. This paper reviews research work to date on the use of ethofumesate in crops of ryegrass, both *Lolium multiflorum* and *L. perenne*.

RESULTS

(a) Work on the tolerance of ryegrass and of other grass species

A number of greenhouse and field experiments were carried out by the authors at Chesterford Park Research Station in the period 1968-1973 to investigate the range of activity and selectivity of ethofumesate.

One series of greenhouse experiments was designed to ascertain the lowest rate of ethofumesate required to produce an effective control of ten grass weed species and four broad-leaved weed species. All species were sown at 0.5 - 1 cm depth.

Overhead watering was given before chemical application to the surface at a volume of 200 l/ha. A visual assessment for percentage effect was made three weeks after chemical application, followed by harvesting of the plants to give percentage fresh weight reduction compared with untreated. The results on (i) ten grass species and (ii) four broad-leaved species are presented in the table.

Table 1

ED values and percent effect of ethofumesate (mean of visual scores and percent fresh weight reduction on four replications)

Species	3200	1600	800	400	200	100	50	ED30	ED50	ED80
	g a.i./ha									
Triticum aestivum	-	96	91	72	41	5	-	160	250	480
Hordeum vulgare	-	87	64	16	0	0	-	480	640	1040
Alopecurus myosuroides	-	-	93	87	32	0	0	200	240	360
Avena fatua	-	97	96	81	62	15	-	125	160	400
Hordeum murinum	-	97	93	81	49	15	-	140	200	400
Lolium perenne	39	11	0	0	0	-	-	2700	>3200	>3200
Festuca arundinacea	-	30	0	0	0	0	-	1600	>1600	>1600
Echinochloa crus-galli	-	87	79	47	17	8	-	280	440	800
Setaria italica	-	-	98	93	54	20	1	130	190	300
Digitaria sanguinalis	-	-	99	99	91	67	50	<50	50	140
Panicum miliaceum	-	97	92	64	48	28	-	110	220	560
Sorghum halepense	-	99	96	81	47	20	-	130	210	400

Table 2

ED values and visual score for percent effect of ethofumesate (mean of three replications)

Species	2000	1500	1000	800	600	400	200	100	ED30	ED50	ED80
	g a.i./ha										
Galium aparine	60	55	50	50	45	40	-	-	<400	900	>2000
Chenopodium album	-	-	80	75	75	50	35	10	180	400	1000
Stellaria media			95	95	95	93	80	70	<100	<100	200
Veronica agrestis	70	70	70	65	60	40	-	-	<400	500	>2000

Although all the panicoid grass weed species showed moderately high susceptibility to ethofumesate, the most susceptible was Digitaria sanguinalis with an ED80 of 140 g a.i./ha. Alopecurus myosuroides, Avena fatua and Hordeum murinum were also controlled at low rates (ED80's of circa 400 g a.i./ha) as was wheat. Barley was rather more tolerant with an ED80 of 1040 g a.i./ha and tall fescue and ryegrass both showed marked tolerance to ethofumesate with ED80's of 1600 g a.i./ha and 3200 g a.i./ha respectively.

Of the four broad-leaved weed species tested Stellaria media is shown to be highly susceptible with an ED80 of only 200 g a.i./ha.

Further greenhouse trials confirmed these results and showed that the greatest tolerance of ryegrass is achieved by surface application of the chemical, rather than by soil incorporation.

In the series of field observation trials which followed, ethofumesate at doses of up to 8 kg a.i./ha was applied to a large number of established grass species including 53 varieties of Lolium. No effect could be detected on any of the ryegrass varieties. In a further field trial, on a limited number of grass species, ethofumesate was applied at early post-emergence, and two later stages. Visual assessments showed no effect on Lolium at any rate up to 8 kg a.i./ha; at rates up to 4 kg a.i./ha, no effect on Festuca arundinacea, Dactylis glomerata and Phleum pratense. At the same time it was noted that ethofumesate caused some reduction of stand and vigour of Agropyron repens, Poa annua, Molinia caerula, Festuca rubra, Poa trivialis, Poa pratensis and Agrostis canina. White clover (Trifolium repens) was severely affected at rates of 2-4 kg a.i./ha.

(b) Work on the specific control of Hordeum murinum in New Zealand pastures

In New Zealand, Hartley (1972) demonstrated promising selectivity of ethofumesate in ryegrass pastures infested with Hordeum murinum. Following this initial study, and subsequent detailed trials by Hartley (unpublished information) on many aspects of the control of Hordeum murinum in ryegrass with ethofumesate, Minter carried out further efficacy trials in 1973 (Minter 1974).

Results from these small plot trials are recorded in Table 3. No visible phytotoxic effect was noted on ryegrass following ethofumesate treatment, but as in some trials in UK there was some visible stimulation of the ryegrass with plants having a darker green appearance. The TCA/Dalapon mixture gave relatively lower control of barley grass in both areas, and severe damage was noted to the ryegrass, particularly in the drier mid-Canterbury area.

Observations on other pasture weeds present in these trials showed ethofumesate to give some degree of control of:-

Poa trivialis	Stellaria media
Poa annua	Capsella bursa-pastoris
Bromus mollis	Cerastium viscosum
Bromus uniloides	Vulpia spp.

It was also shown that where control of dense barley grass infestations resulted in bare ground, ryegrass could be re-seeded on such patches at any time following ethofumesate application, with excellent establishment of a new sward.

(c) Work in UK on ryegrass as a crop

In 1969/71 Blair (1972) examined the herbicidal effect of ethofumesate on grass plots containing pure and mixed populations of Lolium perenne, Festuca rubra, Poa trivialis and Holcus lanatus. This work confirmed the selectivity of ethofumesate in Lolium perenne with good control of the other three species at 2.24 kg a.i./ha.

Table 3

Barley grass control with ethofumesate - New Zealand 1973

	Percent control of barley grass seec heads					
	Ethofumesage kg a.i./ha					TCA/ Dalapon
	0.5	1.0	1.5	2.0	4.0	
Average of 15 trials sprayed early (May/June) when barley grass < 5 cm high mid-Canterbury area (dry)	95.7 (2 sites only)	97.0	98.2	98.9	99.5 (7 sites only)	86.5 (8 sites only)
Average of three trials sprayed late (August) when barley grass > 5 cm high mid-Canterbury area (dry)	61.6 (1 site)	63.5	78.9	90.3	-	81.0
Average of four trials sprayed early (June) when barley grass > 5 cm high Waikato region (wet)	-	88.1	88.4	96.6	100.0 (1 site)	84.5 (1 site only)
Average of five trials sprayed late (August) when barley grass > 5 cm high Waikato region (wet)	-	68.4	80.0	84.8	99.8 (1 site)	80.6 (4 sites)

Jemmett and Rivett (personal communications) used ethofumesate at doses down to 1 kg a.i./ha to give excellent control of Poa annua in plots of ryegrasses, timothy and cocksfoot. Stellaria media was also well controlled in these trials. In 1974 trials Jemmett achieved significant control of Poa annua at a dose as low as 250 g a.i./ha.

Mead (1974) observed good control of Poa trivialis by ethofumesate at 2 kg a.i./ha applied as an April treatment to September sown S24 perennial ryegrass with no damage to the crop. A dose of 1 kg a.i./ha did not give adequate control when applied at this time. Work on Avena fatua control indicated useful activity by ethofumesate; excellent control of volunteer cereals was also shown. In the same group of trials meadow fescue was not damaged by a dose of 2.4 kg a.i./ha.

Following these preliminary observations, a series of 26 field trials were carried out on ryegrass seed crops in spring 1974. Ethofumesate was applied through normal farm machinery at the rates of 1 and 2 kg a.i./ha or in certain cases at 2 and 4 kg a.i./ha to plots of approximately 0.2 ha.

Stellaria media and Poa annua occurred on a number of sites, and in all cases were completely controlled by an application of 1 kg a.i./ha ethofumesate. On one site where cleavers (Galium aparine) occurred this was also well controlled. In two trials in Kent, barley grass (Hordeum murinum) was controlled 95-100 percent from an early application. Although useful activity was observed on Poa trivialis, Bromus spp. and Avena fatua it is thought that the material was applied too late to give acceptable control, although the severe drought conditions of 1974 could be a contributory factor to this low level of control of these species. Volunteer cereals were checked at several sites, and early applications at the 2 kg a.i./ha dose rate gave 90 percent control of volunteer barley.

Blackgrass was present on two sites, and on one of these, despite application at the 8 + tiller stage, a 60 percent control was achieved with 2 kg a.i./ha ethofumesate.

On none of the 26 sites was there any recorded damage to the ryegrass (Italian, perennial and tetraploid) although on a crop of Sabrina (tetraploid) ethofumesate at both 1 and 2 kg a.i./ha gave apparent stimulation of the crop, with a measurable difference in both height and colour of the crop. Seed samples were taken from a number of sites for analysis for purity, germination and 1000 grain weight, and this aspect is being checked.

Mead and other ADAS workers conducted a series of trials in 1974 using a number of herbicides, including ethofumesate, in ryegrass seed crops for Avena fatua control. Although activity was apparent on Avena fatua from early spring applications of a dose of 1.68 kg a.i./ha this did not give adequate control. However, on one site in Suffolk this rate of ethofumesate applied in early spring gave 98 percent control of blackgrass with no damage to the ryegrass crop. A similar report from a collaborator's trial in Holland (personal communication) indicated 98 percent control of blackgrass with 1.00 kg a.i./ha ethofumesate. These results confirm the extreme susceptibility of Alopecurus myosuroides which has been evident in trials in sugar beet crops in UK and Europe.

DISCUSSION

Ethofumesate at rates of between ½ and 3 kg a.i./ha appears to be well tolerated by Lolium spp. when applied either pre-emergence or post-emergence. A number of grass weed species are controlled at this dose rate, and providing the timing of application can be optimised, as has been shown by the New Zealand work on Hordeum murinum, ethofumesate could be of value in controlling volunteer cereals, Hordeum murinum, Poa trivialis, Poa annua, Alopecurus myosuroides, Bromus spp. and possibly Avena fatua in ryegrass seed crops. Additionally a number of broad-leaved weeds notably Stellaria media and Galium aparine can also be controlled.

With a large proportion of the UK ryegrass seed crops undersown, pre-emergence treatments are not possible. Work to date has shown that early spring treatment does not always give adequate control of the major weed species. Further trials involving autumn applications, i.e. pre-emergence of autumn sown crops, or early emergence of undersown crops are planned to substantiate the results obtained in New Zealand, where early applications in autumn/winter gave better control of Hordeum murinum than applications at a later growth stage in early spring.

The evidence available indicates that an autumn treatment of 1.0 - 1.5 kg a.i./ha ethofumesate to ryegrass seed crops will be tolerated by the crop. At this time, when grass weeds such as Alopecurus myosuroides, Poa trivialis, Hordeum murinum are less than 5 cm in height, these can be controlled. Extensive studies on ethofumesate use in sugar beet show that the herbicide can give adequate control of later germinating plants of these species throughout the winter. Other less important weed species are also controlled, including Stellaria media. The evidence on Avena fatua is rather less conclusive, and higher doses and/or earlier application may give some control of this weed.

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THE CONTROL OF YORKSHIRE FOG (HOLCUS LANATUS L.) IN TIMOTHY SWARDS

R.D. Harkess and R.A. Hope

The West of Scotland Agricultural College, Auchincruive, Ayr, KA6 5HW

Summary Yorkshire fog (*Holcus lanatus* L.) is an important weed species in Scots timothy seed crops in the Carse of Stirling. An experiment was initiated in March 1974 to study the effects of three rates of spraying of five herbicides on *Holcus* content of swards. Linuron (at 0.56-2.24 kg ai/ha) proved to be the most successful in controlling *Holcus*; it gave the highest yields of timothy at the hay cut and the heaviest individual seed heads. Glyphosate (at 0.14-0.56 kg ai/ha) was particularly severe on timothy growth. Asulam offered a reasonable degree of control at a high rate of spraying (2.24 kg ai/ha). Results with paraquat and dalapon were disappointing and these chemicals may be better applied in autumn/winter.

INTRODUCTION

The important weed species in the timothy swards of the Carse of Stirling, is Yorkshire fog (*Holcus lanatus* L.). The difficulties in cleaning timothy seed contaminated with *Holcus* are well documented (Hunt, 1966). Experiments to study chemical control of this grass weed commenced in 1966 and showed the value of linuron for this purpose (West of Scotland Agricultural College 1968, 1973). More recently farmers' experiences with both paraquat and dalapon have given promising results. The current experiment was set up to assess the immediate and long term effects on sward *Holcus* content following spring applications of several herbicides.

METHOD AND MATERIALS

The field selected in the Carse of Stirling had been pure-sown with Scots timothy in 1968. Since then it has been cut each year for hay followed by aftermath and winter grazing. Annual fertiliser input was 80 kg N/ha applied in the spring. The soil pH, typical of Carse clay was 5.1. The plot area was in a 'dirty' part of the field, although the *Holcus* was not entirely uniform throughout the experimental area. Other grass weeds present included *Agrostis*, *Poa* and *Bromus* species.

The plots, each 26.8 m^2, were sprayed on 6 March 1974 with an Oxford Precision Sprayer with '0' size nozzles. Five herbicides were sprayed at each of three levels in 450 l/ha water:

Herbicide (kg ai/ha)	Low (LR)	Medium (MR)	High (HR)
Asulam	0.56	1.12	2.24
Dalapon	0.47	0.95	1.90
Glyphosate	0.14	0.28	0.56
Linuron	0.56	1.12	2.24
Paraquat	0.09	0.18	0.36

The 15 treatments, plus three controls, were replicated three times in a randomised block design.

The data recorded include the effects on crop growth 8 weeks after spraying, a scoring on Holcus presence 15 weeks after spraying, dry matter yields and botanical composition when the crop was cut for hay on 12 July 1974 and an assessment of treatment on the weight and size of timothy seed heads.

RESULTS

Following spraying in March there was a prolonged dry spell in April and May and timothy growth was particularly slow. Eight weeks from spraying the degree of herbage scorching due to the treatments was recorded (Table 1). Linuron plots were unaffected and asulam only showed scorch at HR. The HR of paraquat and dalapon

Table 1

Visual assessment of effect on herbage growth and of Holcus content

	Effect on growth 8 weeks after spraying				Holcus presence 15 weeks after spraying			
Rate	LR	MR	HR	Mean	LR	MR	HR	Mean
Control				0				4
Asulam	0	0	1	0	4	3	1	3
Dalapon	0	1	2	1	3	2	1	2
Glyphosate	1	3	3	2	4	3	1	3
Linuron	0	0	0	0	3	1	1	2
Paraquat	0	1	2	1	3	3	2	3

Scale: 0 = no scorch; 3 = severe scorch. 0 = no Holcus; 5 = heavy infestation

showed considerable effect whilst MR and HR of glyphosate were particularly severe. After 15 weeks (28 June) plots were scored for Holcus content (Table 1). At this time timothy growth was still poor. Data illustrate that the HR of glyphosate, asulam, linuron and dalapon and the MR of linuron all appeared to be controlling the Holcus reasonably well.

Due to the high incidence of grass weeds the field was not kept for seed production and on 12 July, plots were cut at the hay stage. The total mean dry matter yield from the control plots was 8.26 t/ha. Glyphosate at the HR had the greatest effect on total dry matter production producing only 4.74 t/ha. Botanical separation of the harvested material showed that the yields of timothy dry matter, (Table 2), were severely affected by glyphosate averaging 1.73 t/ha over the three rates compared with the control of 4.17 t/ha. Linuron and asulam had least effect on timothy yield.

Table 2
Timothy yield and Holcus content of the hay cut

	Timothy yield (DM t/ha)				Holcus (% fresh wt)			
	LR	MR	HR	Mean	LR	MR	HR	Mean
Control				4.17				7.9
Asulam	3.34	4.05	5.17	4.19	10.8	6.9	2.3	6.5
Dalapon	3.53	4.05	2.97	3.52	21.6	7.2	5.4	11.4
Glyphosate	2.84	1.01	1.33	1.73	10.6	6.8	3.1	6.8
Linuron	4.79	5.19	5.28	5.09	0.7	1.8	0.0	0.8
Paraquat	3.20	3.28	2.92	3.13	11.6	10.5	6.6	9.6

	Timothy yield	Holcus
S.E. (diff) treatments	±1.028	±4.65
S.E. (diff sprays	±0.594	±2.69
S.E. (diff) control v treatments	±0.840	±3.80

Table 2 also shows the percentage Holcus of the harvested herbage. The marked effect of linuron on Holcus content is noteworthy and is in keeping with earlier experiments (Harkess, 1973). Glyphosate gave a useful degree of control but also brought about a serious reduction in the yield of timothy.

The large seed heads in the linuron plots were particularly noticeable. In order to define the physical appearance of the crop and the potential timothy seed yields, the mean weight and length of seed heads are recorded in Table 3. Linuron treatment produced heads weighing on average 114 mg and of 503 mm in length. Data

Table 3
Mean weight and length of timothy seed heads

	Weight per seed head (mg)				Length of seed heads (mm)			
	LR	MR	HR	Mean	LR	MR	HR	Mean
Control				88				409
Asulam	96	73	107	92	423	413	424	420
Dalapon	100	91	70	87	433	378	320	377
Glyphosate	83	77	70	77	342	286	292	306
Linuron	110	108	124	114	523	461	525	503
Paraquat	97	107	119	108	463	494	452	469

	Weight	Length
S.E. (diff) treatments	±11.8	±41.3
S.E. (diff) sprays	± 6.8	±23.8
S.E. (diff) control v. treatments	± 9.6	±33.7

for glyphosate treatments were 77 mg and 306 mm respectively. The average number of seed heads in the botanical sample (150-220 gm) for glyphosate was 16 compared with 37 for linuron and the control.

DISCUSSION

The variation in the botanical content of the site and the varying density of the timothy were factors not unexpected in a farm sward. The use of swards with known varying weed contents would be of value in overcoming these variability factors and aid the interpretation of results (Wells and Haggar, 1974). Nevertheless the data suggest a valuable role for linuron and a need for further work on dalapon and asulam. The choice of the latter material followed observations that the spot spraying of Rumex in timothy swards by asulam also appeared to control Holcus and certainly at the MR and HR this was the case. The effects of paraquat and dalapon were disappointing possibly due to the poor spring growth rate of timothy. Field spraying of these chemicals on commercial farms over the December to February period in 1971/72 and 1972/73 had shown considerable control of Holcus, so spring application may be less suitable. Field sprayings with linuron in October have proved very beneficial in controlling Holcus (Harkess, 1973).

The cost benefit factor has always loomed high in seed growers thoughts and the longevity of effect will be important. However, with the improvement in seed prices and recent EEC incentives for seed production there will be an increasing interest in the use of herbicides for the control of Holcus in timothy seed crops.

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THE USE OF DALAPON FOR SWARD RENOVATION IN NORTH-EAST SCOTLAND

W. F. Cormack* and R. E. L. Naylor
School of Agriculture, Aberdeen, AB9 1UD

Summary Dalapon was applied in mid July to a seven-year-old grass sward at 0, 2.5, 5.0 and 7.5 lb a.i./ac. A nitrogen treatment (0 or 56 lb N/ac) was superimposed but the effect was negligible. A dose rate of 2.5 lb dalapon/ac gave the most promising results, with an increase in the proportion of valuable species from 50 to 80 per cent in four months. Poa trivialis, Holcus lanatus, and Agrostis stolonifera were more susceptible to dalapon than were Lolium perenne and Festuca pratensis.

When equivalent rates of application were used in a growth cabinet experiment, the observations on speed of kill and on survival broadly agreed with those of the field trial. There was an indication that meadow fescue was more resistant to dalapon than perennial ryegrass.

INTRODUCTION

Little interest in dalapon was shown in this country until Elliot and Fryer (1958) suggested that the most likely uses of this chemical in the UK would be for chemical ploughing, couch, bracken and aquatic plant control. After using dalapon at 10-20 lb a.i./ac for sward destruction on difficult upland areas prior to reseeding, Ormrod (1958, 1960) concluded that chemical renovation was more likely to be of value on more productive grassland. Gardner (1960) found an improved sward after the application of fertiliser and 3.75 lb a.i./ac of dalapon in spite of oversown seed failing to grow. The recognition of the potential of paraquat for sward destruction led to this compound replacing dalapon as a chemical plough, but interest in using low rates of dalapon as a sward renovator have continued. Most experiments have confirmed an optimum dose of about 2.5 lb a.i./ac for maximum grass weed control with minimum crop damage, application being mid July in 20-30 gal/ac (Allen 1965; Allen and Oswald 1968; Oswald, Haggar and Elliot 1972).

Few investigations on the selective use of dalapon have been performed north of the English Midlands. The north-east of Scotland is an important stock rearing and fattening area with a large proportion of land under grass, and this investigation aimed to assess the suitability of using dalapon selectively for sward renovation in this area.

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* now at Brooms Barn Experimental Station, Bury St Edmunds, Suffolk

METHOD AND MATERIALS

(a) THE FIELD EXPERIMENT

Site

The trial was performed at Waterside Farm, Newburgh, Aberdeenshire OS grid ref 011283. The composition of the seven-year-old sward measured is given in Table 1. The soil was a freely-drained sandy loam of the Cairnrobin series, of the Collieston association. The site was on a moderately steep slope from 25-75 ft above sea level with a northerly aspect. Ploughing and reseeding is very unreliable in a dry year. Annual rainfall is about 30 inches.

Treatments

Dalapon was applied on 18 July 1973 at 0, 2.5, 5.0 and 7.5 lb a.i./ac, to plots 2 m wide x 50 m long. The herbicide was applied in 25 gal/ac by knapsack sprayer with a wide angle nozzle, thus covering the whole width of each plot at one pass. The design was an unreplicated split plot, subplots receiving either 0 or 56 lb N/ac as "nitram", hand spread.

Observations

Sward composition was assessed before spraying, by botanical separation of a number of turves cut at random intervals up the slope. Assessments made after spraying used a less time-consuming method of random clip sampling (GRI Staff, 1961).

(b) THE POT EXPERIMENT

Eight six-inch diameter pots, filled with John Innes Potting Compost No. 1, each containing five plants were prepared for each of *Lolium perenne*, *L. multiflorum*, *Festuca pratensis*, *Poa trivialis* and *Holcus lanatus*. Four months after sowing, the grasses were acclimatised in a growth cabinet for a fortnight. The conditions were a 13 hour day at 13,000 lux at 16°C, with the night temperature at 11°C. The grasses were then cut to a uniform height of six inches and treatment applied a week later. Dalapon was applied at rates equivalent to the field rates with a laboratory sprayer. Two nitrogen levels of 0 and 112 lb N/ac were used. The design was a non-replicated factorial with 5 species, four doses and two nitrogen rates.

Visual observations were made of all treatments and pots were cut at almost two week intervals after treatment over a six-week period. Before the final cut a survival score on a scale from 0 (completely dead) to 5 (fully alive) was given.

RESULTS

In the field, only at the top of the slope did perennial ryegrass (*Lolium perenne*) contribute much less than one quarter of the sward before spraying. Smooth stalked meadow grass (*Poa pratensis*) and creeping bent (*Agrostis stolonifera*) comprised the majority of the sward at the top of the site.

Table 1

Percentage species composition of a series of turfs 1 - 4 taken up the slope

Turf No.	1	2	3	4
Lolium perenne	26.8	21.1	23.7	5.9
Festuca pratensis	29.6	37.0	0.0	0.0
Poa pratensis	22.7	15.2	52.2	50.1
Holcus lanatus	19.2	3.9	15.3	1.0
Agrostis stolonifera	0.0	0.0	5.5	34.3
Festuca rubra	0.7	21.0	0.0	0.4
Others	1.0	1.8	3.3	8.3

For the purpose of sward evaluation the species present were classified as either valuable or weedy. Perennial ryegrass and meadow fescue were arbitrarily taken as being the only valuable species present.

The botanical composition of the four main plots was assessed two months after spraying (September). Samples were taken from the lower end of each of the main plots except for the plot that had received 5.0 lb dalapon/ac which was taken almost three-quarters of the way up the slope. This probably accounts for the startlingly high percentage increase in valuable species compared to other dose rates. Changes in the botanical composition of the plots are given in Table 2. The subplots were cut with an Allen-scythe in September and fresh weights were recorded. The yield of sprayed plots, compared to the unsprayed control is given as the percentage yield reduction in Table 2.

Table 2

Changes in the sward after two months

Dalapon lb a.i./ac	Percentage valuable species originally	after 2 months	% increase	% Yield reduction	% Dead Material
0.0	56.4	66.4	17.7	0.0	42.1
2.5	56.4	79.6	41.1	47.0	62.8
5.0	25.0	58.8	135.2	79.0	61.4
7.5	56.4	88.0	56.0	76.0	85.7

Despite the increase in percentage of valuable species at the higher rates of application, the rates of 5.0 and 7.5 lb a.i./ac were considered unsuitable for sward renovation due to gappiness and large yield reductions. Further study was concentrated on the lower rate of dalapon. Final botanical analysis was carried out in November, four months after spraying. Individual subplots that had received or had not received application of nitrogen were assessed and the results given in Table 3.

Table 3

Changes in the sward after four months

Dalapon lb a.i./ac	Nitrogen 56 lb N/ac	Percentage valuable species originally	after 4 months	% increase	% Dead Material
0.0	+	23.7	30.4	28.3	56.9
	-	56.4	69.4	23.1	43.3
2.5	+	56.4	80.6	42.9	42.7
	-	25.0	70.5	182.0	49.1

A seasonal increase in the percentage of valuable species was observed on the control plots; there was a larger increase on plots that had received 2.5 lb dalapon/ac. Nitrogen application appeared to have no consistent effect.

When plants in the growth cabinet were sprayed with dalapon, damage showed within a few days of spraying, with leaves rolling, becoming chlorotic and dying from the tip downwards. Table 4 gives survival data of the species seven weeks after spraying with dalapon.

Table 4

Survival of grass species after spraying with dalapon seven weeks previously

Nitrogen (lb N/ac)	112				0			
Dalapon (lb a.i./ac)	0	2.5	5.0	7.5	0	2.5	5.0	7.5
L. perenne	5	0	0	2	5	3	0	1
L. multiflorum	2	0	0	0	4	2	0	0
F. pratensis	5	2	0	0	3	4	1	0
P. trivialis	4	0	2	0	3	0	0	0
H. lanatus	5	0	0	0	3	1	0	0

Scale: 0 - completely dead 5 - fully alive

The order in which the species showed symptoms of dalapon damage was Poa trivialis first, then Lolium multiflorum, Holcus lanatus, Lolium perenne and Festuca pratensis last. Poa trivialis developed symptoms after five days at the highest rate of application of dalapon, and all rates of application caused almost complete death of this species after twelve days. In contrast after twelve days all meadow fescue looked healthy. The addition of nitrogen appeared to enhance the herbicidal effect of dalapon in this experiment.

DISCUSSION

The selectivity of dalapon was less marked in the growth cabinet experiment than in the field trial. More actively growing plants, with greater meristematic activity may be more susceptible to dalapon (Ashton and Crafts 1973) and this may account for the lower selectivity of dalapon in the growth cabinet experiment than in the field trial. In contrast to the field trial, where perennial ryegrass showed the greatest recovery, meadow fescue survived best in the growth cabinet.

The two higher dose rates of dalapon (5.0, 7.5 lb a.i./ac) resulted in the largest increase in the proportion of valuable species in the sward but yield was severely affected. Thus an optimum rate of about 2.5 lb a.i./ac is confirmed. Application dates were not tested but in north-east Scotland it is possible that the optimum date of application may be later than mid July.

Allen (1969) found a larger improvement as a result of spraying with dalapon when nitrogen was applied as well. Because the whole area had been fertilised before spraying it was difficult to assess whether nitrogen had aided the herbicidal effect of dalapon on the field plots as it did in the growth cabinet experiment, but plots with added nitrogen appeared to have a much closer sward, nitrogen thus seeming to aid recovery.

Improvements to the sward were consistently due to an increased proportion of perennial ryegrass. For the first two months this was only an apparent increase, because of death of the susceptible species. During the second two months perennial ryegrass was able to vegetatively colonise the bare areas left by dying plants. Allen (1969) found many plants of Poa species growing from seed in bare patches, but no evidence of this was seen in this investigation.

In the north of Scotland a number of coastal areas have sandy soil, and this combined with exposure and low rainfall makes wind blow not uncommon. The field adjacent to the site at Newburgh was ploughed and reseeded in August 1973 and had a very poor take of seed because of dry weather. In contrast the dalapon renovated sward looked healthy, some level of production was maintained and erosion was eliminated.

Little information about the commercial application of sward renovation using dalapon is available. However, Haggar (1973) reported an extra output of 72 lb beef/ac after three years, from plots treated annually with dalapon at 2.5 lb a.i./ac and 40 lb N in July. This represented a useful economic return over the cost of the herbicide treatment.

It thus seems likely that there is considerable scope for the use of dalapon as a sward renovator on sites on which it is difficult to cultivate and re-establish grassland. Further comparisons of costs and benefits of reseeded and dalapon-improved swards are desirable, if only to confirm the apparent benefits. There may be long-term effects on production consequent upon the absence of soil cultivation and conservation of soil structure, and the prevention of erosion.

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SPRAYING AND CUTTING EXPERIMENTS ON RAGWORT (SENECIO JACOBAEA L. AND S. AQUATICUS HILL)

J. C. Forbes
School of Agriculture, 581 King Street, Aberdeen AB9 1UD

Summary On the basis of experiments conducted in Aberdeenshire and Orkney it is concluded that:

1. MCPA at 1.4 kg a.i./ha is equally effective in preventing flowering in the year of spraying of both Senecio jacobaea and S. aquaticus if it is applied at the rosette stage in mid May;
2. 2,4-D ester at 1.68 kg a.i./ha has given significantly better control of both flowering plants and first year plants of S. jacobaea in the year of spraying than MCPA at 2.24 kg a.i./ha;
3. for prevention of flowering in the year of spraying, a mid April application has given best results;
4. indications are that control in the year following spraying will be equally good with an April or May as with a June application;
5. cutting at the flowering stage gives no reduction in population of either S. jacobaea or S. aquaticus.

Current official recommendations regarding the best time of spraying of MCPA or 2,4-D are questioned, at least for conditions in northern Scotland.

INTRODUCTION

Some of the earliest experimental work on control of ragwort (Senecio jacobaea L.) in grassland by spraying with the growth-regulator herbicides MCPA and 2,4-D took place in New Zealand (Lynch 1949, Ward 1949). In the United Kingdom, a programme of joint NAAS and ARC experiments (Holly, Woodford and Blackman 1952, Fryer 1953, Fryer and Chancellor 1956) demonstrated the efficacy of these materials under British conditions, and led to recommendations which are still operative (Fryer and Makepeace ed. 1972, Anon. 1973). There is no record of British work on control of Senecio aquaticus Hill by spraying with MCPA or 2,4-D, although locally it can be a very serious grassland pest (Davies 1953, Forbes 1974).

Two spraying experiments are described in this paper, having three main objectives:

1. The response of Senecio aquaticus to MCPA was compared with that of S. jacobaea.
2. A comparison of the degree of control of S. jacobaea obtainable by spraying at various times of the year was made.
3. MCPA and 2,4-D were compared in their effectiveness.

In addition, some results showing the effect on populations of S. jacobaea and S. aquaticus of cutting the flowering stems are presented.

The normally biennial life-cycle of ragwort means that to control the weed a herbicide must do two things: it must kill second-year plants, giving control in the year of spraying; and it must kill first-year plants, giving control in the following year. Much of the experimental work with MCPA and 2,4-D has revolved around finding the best time and rate of application for both aspects of control.

Holly et al (1952) stated, on the basis of the results of eighteen experiments (of which no details were given), that "the best time to spray appears to be in June when the flowering shoot is developing rapidly but before the buds are showing signs of opening: some equally good results have been obtained in the spring but June is preferable."

Fryer (1953) showed that spraying with 2,4-D at any time from the early bud stage onwards gave extremely variable control of flowering plants in the year of spraying, but gave between 87 and 100% control* of flowering plants in the following year. No plots were sprayed before the early bud stage, at the end of June.

Fryer and Chancellor (1956) found that in four out of five sites in central and southern England spraying during stem elongation but before bud emergence gave better control in the first year than did later spraying, thus confirming the results of Holly et al (1952).

The MAFF advisory leaflet on ragwort (Anon. 1973), however, recommends that MCPA or 2,4-D be applied "when the first flower buds are just visible, in late June or early July". Recommendations in the Weed Control Handbook (Fryer and Makepeace ed. 1972) are more in accordance with experimental findings: "The best time for treatment is in June in southern counties, when the flowering shoot is developing rapidly and ... before the flower buds are well formed."

Of British authors, then, only Holly et al (1952) have compared June spraying with earlier treatment, but there is no convincing published evidence that April or May spraying might not be more effective. Hjelle (1972) recommends for Norway that ragwort should be sprayed at the rosette stage. A preliminary experiment performed by the North of Scotland College of Agriculture suggested that control in the year of spraying was better with an application of MCPA or 2,4-D in May, when the ragwort was still in the rosette stage, than with any later treatment, and that control in the following year was at least as good as with later treatments (Anon. 1974).

In most experiments where both chemicals have been used, 2,4-D has proved slightly but not significantly superior to MCPA for control of Senecio jacobaea (Ward 1949, Holly et al 1952, Hjelle 1972, Anon. 1974).

It has long been realised (M'Alpine and Wright 1894) that cutting the flowering stems of ragwort prevents seeding, but does not destroy the plant. Indeed it can increase the vigour of the ragwort and induce perennation (Poole 1938). After the weed has begun flowering and therefore become conspicuous, however, cutting and carting off the flowering stems may be the only feasible method of preventing seeding, and accordingly it is a very common practice, all the more so because it is a scheduled injurious weed under the Weeds Act 1959. A spraying treatment which gave good and reliable control in the same year would make cutting unnecessary.

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* Calculated by the method used in this paper - see Results section

METHODS AND MATERIALS

Experiment 1: Control of Senecio jacobaea and S. aquaticus by spraying, cutting and fertiliser application.

At each of two sites in Orkney, part of a severely ragwort-infested field in long ley grass was fenced off for this experiment. A split-plot design was used, with two blocks each being divided into two main plots, each of which was in turn divided into five sub-plots. In each block one main plot received 375 kg/ha of a 20 : 10 : 10 compound fertiliser in April 1973; the others received no fertiliser. Within each main plot, the five sub-plots, each 30 m by 6 m, received the following treatments, allocated at random:

A control (no treatment);

B MCPA 1.4 kg a.i./ha, mid May 1973;

C MCPA 1.4 kg a.i./ha, mid May 1974;

D MCPA 1.4 kg a.i./ha, mid May 1973, repeated mid May 1974;

E flowering stems cut, August 1973.

All spraying was done with a knapsack sprayer delivering 220 litres/ha of water.

Four assessments were performed in each plot. In each case the whole plot was counted.

1. rosettes in April 1973 (pre-treatment);
2. flowering stems in July 1973;
3. rosettes in April 1974;
4. flowering stems in August 1974.

The earlier post treatment assessments allowed more replication since fewer treatments had up till then been applied to the twenty sub-plots at each site.

One site, on Burray, carried an infestation mainly of Senecio jacobaea, while the other, at Stenness on Mainland Orkney, had an infestation of S. aquaticus. Unfortunately all the ragwort in the S. jacobaea site disappeared for no known reason between assessments 3 and 4, and consequently no results can be presented for treatments C and D on S. jacobaea.

Experiment 2: Comparison of two chemicals applied on four different dates for control of Senecio jacobaea.

Part of a hill grassland severely infested with Senecio jacobaea at Midmar, Aberdeenshire, was fenced off and divided into twenty plots, each 25 m by 10 m, and these were arranged in two blocks of ten. There were two chemical treatments:

MCPA (potassium salt) 2.24 kg a.i./ha;

2,4-D ester 1.68 kg a.i./ha;

superimposed on four dates of application:

17 April 1974 (rosette stage);

16 May 1974 (rosette stage);

13 June 1974 (flowering stem elongation, no flower buds visible);

15 July 1974 (flower bud stage).

All spraying was done with a knapsack sprayer delivering 270 litres/ha of water. Cattle were excluded from the site only during the two weeks after each spraying. The eight treatment combinations and two untreated controls were assigned at random to each block of ten plots.

So far, the following counts have been performed in each plot:

1. rosettes in March 1974 (pre-treatment);
2. flowering stems in August 1974;
3. first-year plants in August 1974.

Assessments 1 and 2 took in the whole plot, and assessment 3 involved counting a 2 m strip up the middle of the plot and multiplying by five. Further assessments will be carried out in 1975.

Experiment 3: Effect of cutting flowering stems on a Senecio jacobaea population.

Six plots, each 20 m square, were marked off on the Senecio jacobaea infested hill at Midmar, Aberdeenshire, where the plants had been cut annually in the flowering stage until 1971. Three plots were untreated, and three were cut in August 1973, the treatments being assigned at random to the plots.

So far, two assessments have been performed in each plot:

1. flowering stems in August 1973 (pre-treatment);
2. flowering stems in August 1974.

RESULTS

Calculation of Per Cent Control

For every plot receiving a particular treatment, the post-treatment count was divided by the pre-treatment count. These ratios were used for statistical analysis, but for calculation of per cent control, the ratios were averaged for each treatment. The average ratio was then divided by the average ratio for control plots and multiplied by 100. This figure subtracted from 100 gave per cent control. This method of calculation takes into account background changes in weed density as well as plot-to-plot variation.

Experiment 1

Per cent control of Senecio jacobaea and S. aquaticus obtained by spraying with MCPA, cutting and fertiliser application is shown in Table 1. It will be seen that neither cutting nor fertiliser application caused any statistically significant change in the populations of either species. The mid May application of MCPA in 1973 gave an excellent suppression of flowering in that year in both species, and the number of rosettes remaining in April 1974 suggested a good control of flowering later that year. The rather indifferent (and, due to insufficient replication, statistically non-significant) figure of 71% control of flowering stems of S. aquaticus in August 1974 largely results from a spectacular background decline in ragwort population between April and August, against which herbicide control looks less impressive. Similar sudden changes in population density of ragwort for no apparent reason have been recorded by previous authors (Holly et al 1952, Fryer 1953, Harper and Wood 1957). The effect of the 1974 MCPA application in the year of spraying on S. aquaticus was similar to that of the 1973 application. Spraying in two consecutive years apparently gives improved control, but in this experiment there were no statistically significant differences between spraying treatments.

Table 1

Per cent control of Senecio jacobaea and S. aquaticus

	Treatment				
	MCPA 1.4 kg a.i./ha, mid May				
	1973	1974	1973 & 1974	Cutting	Fertiliser
Senecio jacobaea					
Flowering stems July 1973	91***				-28 NS
Rosettes April 1974	85***			15 NS	36 NS
Senecio aquaticus					
Flowering stems July 1973	88***				12 NS
Rosettes April 1974	84***			-42 NS	42 NS
Flowering stems August 1974	71 NS	82*	92*	10 NS	-50 NS

NS - not significantly different from control

* - difference from control significant, $P<0.05$

*** - " " " " $P<0.001$

Experiment 2

Table 2 shows per cent control achieved by spraying MCPA and 2,4-D ester on four dates from April to July. Considering first of all the number of flowering stems in August of the year of spraying, analysis of variance showed that variation due to date of application was significant at the 0.1% level, variation due to chemical was significant at the 1% level, and variation due to chemical - date interaction was not significant. From Table 2 it is clear that the best suppression of flowering in the year of treatment was obtained with the earliest spraying, in mid April. The later the chemical was applied after this date, the poorer was the control. At all times of spraying, 2,4-D ester at 1.68 kg a.i./ha gave better control than MCPA at 2.24 kg a.i./ha. Considering now the number of first year plants remaining in August of the year of spraying (giving some idea of the degree of control which might be expected in the following year), analysis of variance showed that variation due to date of application was not significant, variation due to chemical was significant at the 5% level, and variation due to chemical - date interaction was significant at the 1% level. It can be seen in Table 2 that the April, May and June sprayings all had a similar effect. The poor control obtained with the mid July application is probably largely the result of rain immediately after spraying and of the short interval between spraying and assessment rather than of any resistance of the first year plants to the chemicals at this stage. Again at all spraying times 2,4-D gave better control than MCPA.

Table 2

Per cent control of Senecio jacobaea in August of the year of spraying

Spraying date	2,4-D ester 1.68 kg a.i./ha Flowering stems	First year plants	MCPA 2.24 kg a.i./ha Flowering stems	First year plants
17 April 1974	97	85	81	67
16 May 1974	83	85	73	76
13 June 1974	68	91	61	70
15 July 1974	31	44	22	30

Least sig difference (flowering stems): 12 ($P = 0.05$); 18 ($P = 0.01$); 27 ($P = 0.001$)
" " " (first year plants): 27 ($P = 0.05$); 41 ($P = 0.01$); 63 ($P = 0.001$)

Experiment 3

Table 3 gives the average numbers of flowering stems in the cut and uncut plots prior to cutting and one year later. The cut plots have shown a greater per cent increase than the uncut plots, but the difference is not statistically significant.

Table 3

Average number of flowering stems of Senecio jacobaea per 20 m by 20 m plot

	August 1973	August 1974
Not cut	807	1035
Cut August 1973	749	1123

DISCUSSION

The most interesting findings to emerge from these experiments are the results set out in Table 2. It would be unwise to draw hard and fast conclusions from the results of one experiment, even though they confirm indications from a preliminary experiment (Anon. 1974). At the same time, however, these results should not be dismissed as aberrant, or as being caused by unusual local conditions, simply because they are at variance with official recommendations. As can be seen in the introduction to this paper, the author has been unable to trace any published results of experimental spraying of ragwort in the United Kingdom earlier in the year than at flowering stem elongation.

April, May and June spraying gave equally good control of first year plants, suggesting that in the year following spraying suppression of flowering will be equally good. The earlier the application, however, the better was the control of flowering stems in the year of treatment. This experiment suggests, therefore, that for the most effective control of ragwort, taking both aspects into consideration, spraying should be done in April. Clearly before official recommendations could be amended a programme of experiments in a wide range of sites would have to be initiated with the aim of verifying or otherwise the results of this experiment.

The application rates of 2,4-D and MCPA used in the experiment were those recommended in the Weed Control Handbook (Fryer and Makepeace ed. 1972), and the results show that 2,4-D gave significantly better control than MCPA at these rates. This confirms indications from earlier research in Scotland (Anon. 1974), England (Holly et al 1952), Norway (Hjelle 1972) and New Zealand (Ward 1949), although various dose rates and formulations of both chemicals have been involved. Perhaps the time has come to recommend 2,4-D as first choice for ragwort control, with MCPA as a reasonable alternative. In the experiment under discussion clover check was not noticeably more severe with 2,4-D than with MCPA, and all treatments showed considerable regernation of clover by August in the year of spraying.

It seems likely on the basis of the results shown in Table 1 that recommendations for *Senecio jacobaea* will be applicable also to *S. aquaticus*. Hjelle (1972), who recommends 2,4-D in preference to MCPA for control of *S. jacobaea*, says that both chemicals are equally effective against *S. aquaticus* in Norway. It is interesting that Hjelle recommends spraying both species in the rosette stage.

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