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USE OF DINITRAMINE IN SWEDES AND TURNIPS

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Summary Dinitramine, 2.5 - 10 oz a.i./ac, was applied pre planting with and without soil incorporation in a number of trials on swedes and turnips in Scotland and England. The result showed that rates of 3.75 - 5 oz a.i./ac with incorporation gave satisfactory weed control. On soils with higher organic matter weed control was less satisfactory at these rates. Although these rates caused some initial check to the crop, yields were increased.
Trials on 10 varieties of swedes and turnips showed no variation in varietal susceptability to the herbicide.

INTRODUCTION

Dinitramine the common name for N^3 N^3 diethyl 2, 4-dinitro-6-trifluoromethyl-m-phenylenediamine was discovered in the U.S.A. (1) and developed primarily for control of annual grasses and broad leaved weeds in cotton and soya bean. Initial screening at Jealotts Hill in 1971 (2) showed promise of useful effect in certain brassicae crops, carrots, legumes and strawberries. The work reported in this paper is confined to its use on field swedes and turnips.

There has been a revival of interest in the swede and turnip crop in the past few years due to its great potential for producing high yields of starch equivalent per acre. Combined with the rising prices of other feeding stuffs, the decreasing labour force means that chemical weed control is becoming increasingly accepted for this crop.

METHOD AND MATERIALS

Dinitramine (25% e.c.) was applied through standard low volume farm sprayers in a series of trials during 1972 and 1973 in Scotland and England. The trials were in four series as follows:

SERIES I	- (9 Trials)	1972	Dinitramine at 2.5,5.0,7.5 and 10 oz a.i./ac incorporated and non-incorporated.
SERIES II	- (4 Trials)	1973	Dinitramine on mineral soils at 3.75, 5.0 and 10 oz a.i./ac all incorporated.
SERIES III	- (4 Trials)	1973	Dinitramine on higher organic matter soils (6 - 10%) 3.75, 5.0, 7.5 and 10 oz a.i./ac all incorporated.
SERIES IV	- (2 Trials)	1972/73	Dinitramine at 5 or 7.5 oz a.i./ac applied across a range of turnip and swede varieties.

TABLE 1.

TRIAL SITE DETAILS

Trial No		County	Crop	Variety	%	Flat/ Ridge	Row Space	Drilling Date	Spraying Date	Incorp Implement	Depth
SERIES I											
Renner	1	Northumb	Swedes	Magnificent		Ridge	28"	14.5.72	24.5.72	Discs	4"
Sutherland	2	Northumb	Swedes	Angus		Ridge	26"	8.6.72	7.6.72	Rotavator	4"
Whitty	3	Yorks	Turnip	Green Globe		Flat	20"	18.7.72	18.7.72	Harrows	2"
Miller	4	Lothians	Swedes	Victory	3.7	Flat	24"	3.5.72	1.5.72	Harrows	3"
Adamson	5	Fife	Swedes	Doon Major	3.7	Flat	26"	3.5.72	2.5.72	Rotavator	2½"
Milne	6	Berwick	Swedes	Benefactor	2.7	Ridge	26"	19.5.72	16.5.72	Rotavator	4"
Foot	7	Dorset	Swedes	Champion		Flat	18"	21.6.72	20.6.72	Harrows	1-2"
Manning	8	Hereford	Swedes	Doon Spartan	4.9	Flat	20"	26.6.72	22.6.72	Turb/till	6"
Rigby	9	Hereford	Swedes	Warrington	3.7	Flat	20"	13.7.72	11.7.72	Harrows	4"
SERIES II											
Teasdale	10	N. Yorks	Turnip	Green Globe		Flat	22"	19.6.73	18.6.73	Turb/till	2"
Ducker	11	E. Yorks	Swedes	Brittania		Flat	24"	2.6.73	1.6.73	Turb/till	2"
Rigby	12	Hereford	Swedes	Tipperary		Flat	21"	16.6.73	13.6.73	Harrows	2"
Allright	13	Worcester	Swedes	Eclipse		Flat	21"	23.6.73	18.6.73	Harrows	2"
SERIES III											
Scott	14	Northumb	Turnip	Bruce	6.6	Flat	18"	16.5.73	16.5.73	Discs	3-4"
Thornton	15	Northumb	Turnip	Wallace	7.8	Flat	18"	8.6.73	6.6.73	Discs	4-6"
Scott-Harden	16	Dumfries	Turnip	Bruce	8.5	Ridge	28"	28.5.73	24.5.73	Discs	6"
Manson	17	Lanark	Swedes	Wilheims berger	10.8	Flat	Broad cast	16.6.73	8.6.73	Rotavator	3-4"

Duplicate plots of each treatment were laid down and all trials included an unsprayed control plot and/or trifluralin at the standard rate (16 oz a.i./ac).

Incorporation of herbicides, where required, was by means of standard farm equipment and ranged from harrows to rotovators (for details Table 1.) Incorporation was carried out as soon as possible after application usually within 2 hours.

Control plots generally had some measure of mechanical weed control during the season.

Plant counts - 10 random counts of 5 yard lengths of row were recorded at emergence and at singling and expressed as % of untreated controls.

Yields - number and total weight of roots were recorded by taking 10 random samples of 5 yards of row per plot and the result expressed as a % control.

Weed control:- Weed cover was assessed on the score of 0 = complete control 5 = no control in 1972 and on basis of % ground cover in 1973.

Full details of the sites in both years are given in Table 1.

RESULTS

SERIES I

Plant counts showed some reduction at all rates above 2.5 oz a.i./ac decreasing on average to 84% of control at 10 oz a.i./ac (Table 2)

Crop vigour assessments showed that by approximately 8 weeks after sowing the crop has outgrown this check except at the 10 oz rate where in certain trials the effects continued to show until harvest.

Non- incorporation whilst marginally reducing phytotoxicity reduced weed control drastically and to an unacceptable level. No yields or further assessments were made on these treatments.

TABLE 2.

SERIES I - Plant count, crop vigour and weed cover assessments

Material	Dinitramine								Control	Trifluralin
Rate (oz a.i./ac)	2.5		5		7.5		10		Nil	16
No. Trials	(2)		(9)		(2)		(9)		(9)	(9)
Incorporation Method *	A	B	A	B	A	B	A	B	-	A
Plant counts										
at Emergence	109	104	96	94	104	101	86	92	100(20.1)	94
at Singling	103	104	97	97	93	97	84	88	100(19.8)	92
Crop Vigour										
at Singling	5.0	5.0	4.3	4.3	4.0	5.0	3.4	4.0	4.7	4.3
9 - 12 weeks	4.5	5.0	4.1	4.3	4.0	5.0	4.1	3.7	4.0	4.3
Weed Cover (6 Trials only)										
at Singling	3.4	4.2	2.1	2.7	1.3	3.7	1.2	2.0	5.0	2.0

* A = Herbicide incorporated immediately after spraying
B = Herbicide not incorporated.

Yield figures were obtained from 7 trials (Table 3.) and these clearly showed the effect of weed control in increasing yield and the ability of the crop to compensate for small losses in plants by increasing average root size.

TABLE 3.

SERIES I - Average Yield and Root Size

Material Rate oz a.i./ac	Dinitramine 2.5	5.0	7.5	10	Control Nil
(a) On 5 Trials					
Yields	-	127	-	138	100 (19.0)
Root size(lbs)		1.9		2.4	1.5
(b) On 2 Trials					
Yields	120	112	118	115	100 (13.5)
Root size(lbs)	1.4	1.4	1.5	1.6	1.1

( ) Control yield tons/ac.

SERIES II

The 1973 trials on mineral soils (Table 4.) confirmed that rates of 3.75 - 5 oz a.i./ac gave satisfactory weed control and equivalent to trifluralin at the standard rate.

Plant counts and crop vigour also confirmed that whilst these rates caused some initial check to the crop it outgrew this after 6 to 8 weeks and final yields were well above those of untreated controls. At 10 oz a.i./ac the check was more permanent and was visible up to harvest although yields were less affected and equivalent to the untreated controls. Damage was more serious where prolonged dry conditions followed drilling (i.e. Site 12).

TABLE 4.

SERIES II - 1973 Dinitramine on mineral soil

Material Rate - oz a.i./ac	Dinitramine 3.75	5	10	Control Nil	Trifluralin 16
Plant Count at singling					
Site No					
10	126	122	119	100(10.2)	135
11	83	93	103	100(58.1)	100
12	66	69	59	100(16.4)	66
13	95	94	84	100(20.5)	91
mean	93	95	91	100(26.3)	98
Crop Vigour at 8 weeks					
10	4.0	4.0	2.0	4.0	3.0
11	4.0	4.0	3.0	4.0	4.0
12	4.0	4.0	3.0	5.0	4.0
13	4.0	4.0	3.0	5.0	4.0
mean	4.0	4.0	2.7	4.5	3.7
Weed Cover at 8 weeks					
10	5.1	3.6	6.7	9.8	6.1
11	35.0	17.0	15.0	50.0	25.0
12	20.0	7.5	4.0	82.0	20.0
13	32.5	22.5	7.5	72.5	42.5
mean	23.0	13.0	8.0	54.0	23.0
Yields % of control/ av root weight lbs					
10	109/3.3	127/3.6	98/2.9	100/2.9 (26.3)	106/3.4
	-	-	-		
12	146/2.6	162/3.1	114/4.1	100/1.3 (14.3)	143/2.4
13	97/1.0	104/1.2	97/1.3	100/1.0 (12.1)	112/1.0

( ) Control yield tons/ac

SERIES III

On higher organic matter soil (average 8.2%) weed control was generally inferior to that on mineral soils (see Table 5) and at the lower rates *Chenopodium album* and *Polygonum persicaria* in particular being poorly controlled (Site 16).

Plant counts showed a similar trend to that on mineral soils but crop vigour was only affected at rates above 5 oz and disappeared more quickly so that final yields are not expected to be affected.

TABLE 5.

SERIES III - Dinitramine on higher organic matter soils (6 - 10%)

Material Rate - oz a.i./ac	Dinitramine 3.75	 5.0	 7.5	 10	Control Nil	Trifluralin 16
Plant Count at singling **						
Site No						
14 *	-	-	-	-	-	-
15	100(17.8)	88	108	74	-	91
16	100(19.2)	91	93	93	100	88
17	100(10.2)	91	74	114	120	82
mean	100(16.3)	89	96	89	110	88
Crop Vigour at 8 weeks						
14	3.0	3.0	3.0	2.0	2.0	3.0
15	4.5	4.5	4.5	3.0	5.0	4.5
16	5.0	5.0	4.5	4.0	5.0	5.0
17	3.0	2.5	2.5	2.5	3.5	2.5
mean	3.9	3.8	3.5	3.0	3.9	3.8
Weed Cover at 8 weeks						
14	50	40	35	35	75	35
15	5	5	5	5	25	5
16	60	50	40	30	65	50
17	20	9	10	9	10	12
mean	67	26	22	20	44	25

* Field redrilled due to severe flea beetle attack
** Expressed as % of lowest rate of dinitramine

SERIES IV

In each year a range of swede and turnip varieties were sown in plots and treated with dinitramine at 5 and 7.5oz a.i./ac in 1973 and 72 respectively. Plant counts were compared with untreated controls. Slight loss of plants around 5 - 10% as in other trials were found but no significant differences occurred between varieties. Varieties treated were swedes - Wilheimsberger, Doon Major, Smith's Prize, Magnificent, Best of All; turnips - Aberdeen, Bruce, Wallace, Invincible and Bortfelder.

DISCUSSION

These trials have shown that satisfactory weed control was obtained with dinitramine at rates of 3.75 - 5 oz a.i./ac on most soils when this was incorporated. Control persisted right to harvest and in these two years there was no significant late germination of weeds. The weeds present at the harvest were, in the main, those surviving from the initial spring flush, i.e. The resistant species and the few weeds of other species which did survive. Although these weeds tended, by mid season, to mask the benefits of earlier weed control, a considerable yield advantage was given from having obtained early weed control even where inter-row mechanical weed control was given.

From the farmers point of view it also made the date of singling less critical. On soils with organic matter content approaching 10% the weed control was unsatisfactory at 3.75 oz a.i./ac and only just acceptable at 5 oz a.i./ac. From these and other farmer trials the following provisional weed susceptability table is given:

TABLE 6.

Weed Susceptability Table (5 oz a.i./ac)

Weed	No of observations	Category *
Capsella bursa-pastoris	8	MR
Chenopodium album	10	MS-S
Fumaria officinalis	6	MS-MR
Galeopsis tetrahit	3	S
Poa annua	7	S
Polygonum aviculare	10	MS
" convolvus	7	MS
" lapathifolium	2	MS
" persicaria	6	MS-MR
Senecio vulgaris	2	R
Sinapis spp	7	MR
Stellaria media	14	S-MS
Spergula arvensis	2	MS
Tripleurospermum maritimum	8	MS
Veronica spp	4	S

* S = Susceptable   MR = Moderately resistant
MS = Moderately susceptable   R = resistant

These trials clearly showed the necessity for incorporation of the herbicide after application. From other trials and work in the U.S.A. (1 & 2) it appears that incorporation should be within 24 hours. Some check to the crop as with most currently available herbicides seems unavoidable but is outweighed by the improved yields obtained by satisfactory weed control.

One aspect of weed control in the swede and turnip crop which is not adequately covered by these trials and requires further work is the effect of ridging and consequent depth of incorporation required. It would seem logical that the rate of chemical should be increased in these situations.

Acknowledgements

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References

1. Borax Consolidated (1972) - Product Information Sheet SH1 U.S.B. 3584 Herbicide

2. Plant Protection Ltd (1973) - Product Information Sheet - Cobex Herbicide.

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EVALUATION OF FLUOFENPROP ISOPROPYL*

FOR THE CONTROL OF AVENA FATUA IN SPRING BARLEY

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Summary In 1973 Fluofenprop isopropyl was evaluated in four replicated trials on spring barley at five dosage rates ranging from 0.6 to 2.0 kg a.i./ha with application covering crop growth stages from early tillering through to the second node stage (Feekes Scale E to J/K). There were two application times at each site.

Fluofenprop isopropyl gave effective control of *Avena fatua* under Scottish conditions. Optimum weed control and crop response resulted from the application of 1.0 kg a.i./ha in 337 l./ha of water from late tillering to the 1st node stage of crop development. In these trials crop yields showed a 21% increase over the untreated control plots where timing of application was optimal.

INTRODUCTION

Work conducted by Shell Research Ltd. prior to 1973; A. Sampson (1973) had shown fluofenprop isopropyl to be a very promising herbicide for the control of *Avena fatua* with a good crop selectivity to barley. The optimum dosage rate appeared to be about 1.0 kg a.i./ha when applied during crop growth stages F to J.

The 1973 trials were designed to test this result under Scottish conditions.

METHODS AND MATERIALS

Four trials were laid down in 1973, one in each of the counties Berwickshire, East Lothian, Morayshire and Inverness-shire. The soils were all in the range of loam to sandy loam with o.m. contents of between 2.8 and 5.6%. The experimental design was randomized block with 4 replicates and plot size was 31.1 m x 3.2 m.

Application was by Land Rover mounted sprayer at 337 l./ha and 2.1 kg/cm^2 pressure through fan jets.

Fluofenprop isopropyl (20% e.c.) was applied at five dosage rates, 0.6, 0.8, 1.0, 1.6 and 2.0 kg a.i./ha.

*Chemical name = isopropyl N - benzoyl - N - (3 - chloro - 4 - fluorophenyl) - 2 - aminopropionate
also known as W.L.29762

There were two application times early and late, which varied at each site giving applications throughout the whole range of crop growth from early tillering through to the second node stage (E to J/K). There were two untreated controls in each block at each site, one of which was 'tracked' at each application time.

Treatment Details:-

Site No.	Variety	Early Application Date	Early Application Crop stage	Late Application Date	Late Application Crop stage	Assessment Date	Harvest Date
1	Golden Promise	16/5/73	F - G	24/5/73	H	18/7/73	15/8/73
2	Clermont	28/5/73	F - G	7/6/73	I	24/7/73	8/9/73
3	Golden Promise	16/5/73	G - H	29/5/73	J - L	19/7/73	7/8/73
4	Clermont	28/5/73	G - H	7/6/73	I	24/7/73	13/8/73

Three types of assessment were undertaken:-

a) Avena fatua panicles were counted in five quadrats (0.5m x 0.5m) per plot at the flowering stage close to harvest. There were two separate counts, one of the panicles above and level with the crop (i.e. visible) and the other of panicles below crop level, the sum of the two counts giving the 'total' referred to in the results.

b) Crop effects were assessed on the E.W.R.C. scale 1 - 9 (1 = no damage, 9 = complete crop kill), recorded on the same dates as the counts were taken. Immediately prior to harvest six measurements of crop straw length were completed per plot.

c) Finally all plots were harvested and plot yields and moisture contents recorded. (Harvested area = 31.1m x 2.0m/plot).

All results were statistically analysed.

RESULTS

a) Wild Oat Control (See Table 1)

All treatments at all sites significantly controlled both the visible and total infestations.

Table 1

Number of Avena fatua panicles as a % of control*

Site		1		2		3		4		Mean	
Treatment	Rate (kg a.i./ha)	Visible	Total	Visible	Total	Visible	Total	Visible	Total	Visible	Total
Fluofenprop isopropyl Early application	0.6	21.0	22.0	4.8	19.0	7.9	23.0	(3.3)	24.0	9.3	22.0
	0.8	15.0	16.0	3.2	12.0	2.4	15.0	(3.4)	16.0	6.0	14.7
	1.0	15.0	18.0	6.8	21.0	2.4	6.2	(0)	3.7	6.1	12.2
	1.6	12.0	15.0	3.8	15.0	2.7	9.9	(0)	5.1	4.6	11.3
	2.0	5.6	8.3	1.8	8.4	2.9	7.2	(1.9)	3.1	3.1	6.8
Fluofenprop isopropyl Late application	0.6	40.0	41.0	1.4	12.0	15.0	25.0	(0)	22.0	14.1	25.0
	0.8	16.0	23.0	(0)	11.0	9.3	24.0	(0)	11.0	6.3	17.3
	1.0	14.0	18.0	1.7	11.0	5.6	27.0	(0)	4.0	5.3	15.0
	1.6	2.0	4.5	(0)	9.0	3.2	33.0	(0)	2.6	1.3	12.3
	2.0	1.0	1.8	1.1	2.5	2.4	25.0	(0)	1.6	1.1	7.7
Mean no. of wild oats/m^2 in untreated controls		162	164	125	135	39	42	50	58	94	100
L.S.D. between:-											
2 Means at same rate		2.55	2.66	4.01	2.01	2.39	2.32	-	3.09		
2 Means at same time		3.77	4.00	7.16	2.62	3.44	3.30	-	4.94		
Greatest value signif. lower than control		51	49	37	60	53	54	-	44		

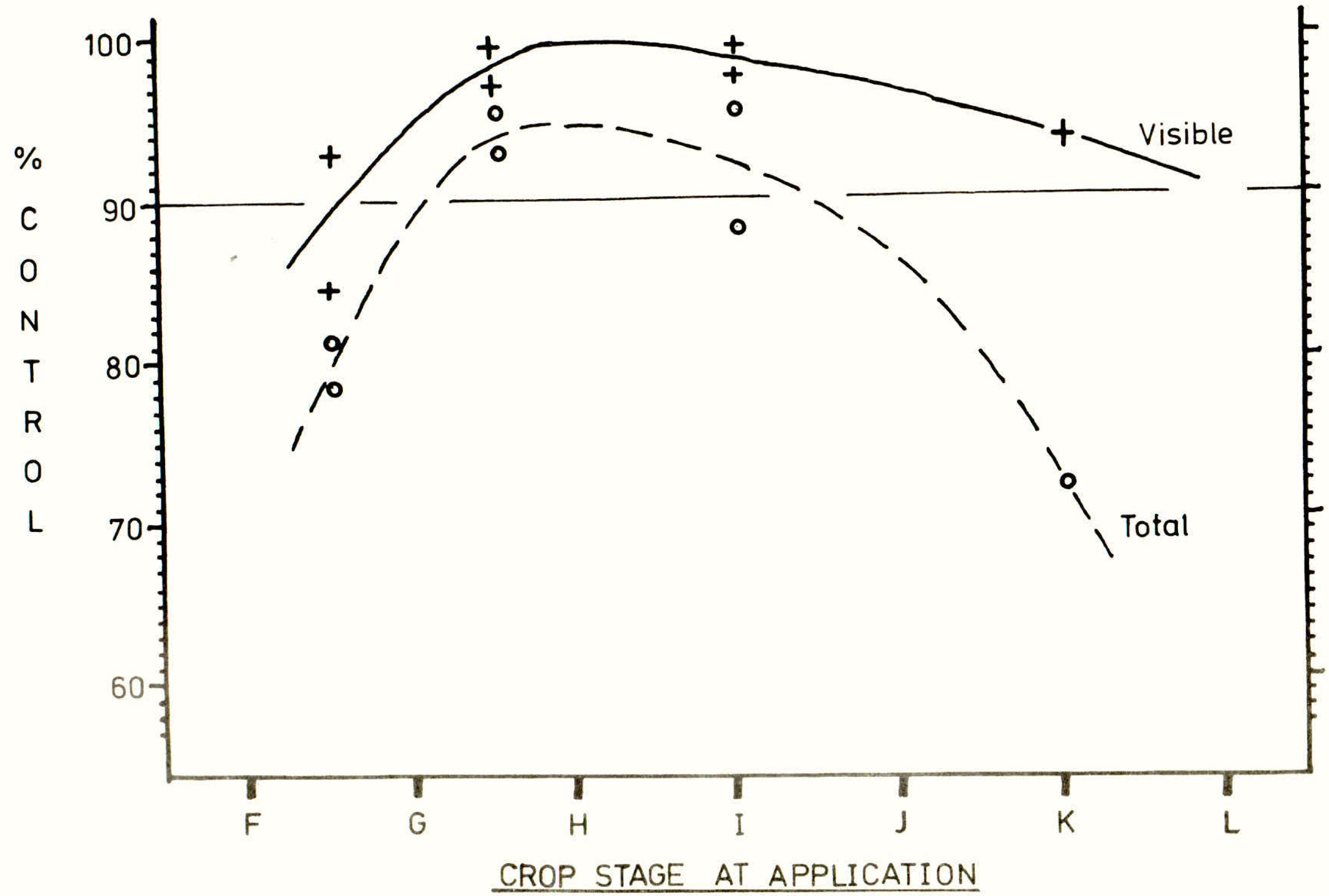
* = Detransformed logarithm of plant numbers as a % of the untreated control.

()= Excluded from analysis.

Fig. 1.

CONTROL OF WILD OATS WITH FLUOFENPROP ISOPROPYL

1·0 kg a.i./ha



Excellent control of visible panicles (i.e. those at or above crop level) was achieved by fluofenprop isopropyl at rates of 0.8 kg a.i./ha and above. The 1.0 kg a.i./ha rate gave 94% control of visible panicles and in excess of 85% control of total panicles.

Those Avena fatua plants remaining below crop level were generally less than half as tall as the crop and were suffering from crop competition. At three of the sites the later application was the more effective even though at one of these (Site 1) heavy rain fell within 30 min of the late application, causing some chemical "wash off" which was reflected in poor weed control at the two lower rates. At site 3, where the early application was the most effective, the late application had been applied at a more advanced crop growth stage than at any of the other sites. Even so, all but the 0.6 kg a.i./ha rate of fluofenprop isopropyl gave better than 90% control of visible infestation but left an unacceptable number of stunted wild oats below crop level.

Fig 1 shows % wild oat control plotted against crop growth stage following application at the 1.0 kg a.i./ha rate of fluofenprop isopropyl. It was apparent that visible panicles i.e. those at and above crop level, were acceptably controlled (over 90% control) by application at all crop stages in the range F to K. However the most effective control was from application at crop stages G to I when up to 98% eradication of visible panicles was achieved. Over 90% control of total panicles resulted from application in this same period; from late tillering to 1st node of the crop.

b) Crop Effects (See table 2)

Table 2

Mean crop straw lengths to base of ear (cms)

Treatment	Rate (kg a.i./ha)	Site Number 1	2	3	4	Mean
Fluofenprop isopropyl	0.6	65.3	85.0	63.2	83.6	74.3
Early application	0.8	64.2	85.0	62.0	84.0	73.8
	1.0	64.3	80.0	62.1	82.5	72.2
	1.6	64.0	83.0	59.4	85.0	72.8
	2.0	62.1	84.0	60.3	84.5	72.7
Fluofenprop isopropyl	0.6	65.3	81.0	59.2	82.8	72.0
Late application	0.8	63.5	81.0	60.0	82.0	71.6
	1.0	62.0	80.0	62.2	83.0	71.5
	1.6	62.4	78.0	60.4	78.4	69.8
	2.0	64.2	74.0	60.2	79.1	69.3
Control		65.4	85.0	60.8	82.3	73.3
L.s.d. Between:-						
2 means at same rate		3.0	4.0	3.5	4.2	
2 means at same time		4.3	6.0	5.0	6.0	
Treatment and Control		2.6	3.0	3.0	3.7	

Some straw shortening occured after treatment with fluofenprop isopropyl, particularly at the higher rates. At sites 3 and 4 there were few significant differences from the control in straw lengths although there was a tendency for the crop in plots treated at the late application to be shorter than those treated earlier. However, at site 1 (Golden Promise) significant reduction in straw length occurred in the plots treated at growth stages F and G at 2.0 kg a.i./ha and at growth stage H at 1.0 and 1.6 kg a.i./ha, although there were no significant reductions with time of application.

The Clermont at site 2 had shown visible shortening earlier at the two highest rates, apparently due to site conditions since the same variety at site 4 had shown no such symptoms. The mean straw length at site 2 was significantly reduced compared with the untreated control by all the late application treatments and by the early application at 1.0 kg a.i./ha, the reductions being greater at the later application.

c) <u>Crop Yield</u> (See Table 3)

Significant yield increases of up to 45% above the unsprayed control were achieved following treatment; the increases in general were greater on those sites with the highest infestation of wild oats. In no case did a yield reduction compared with the control follow treatment with fluofenprop isopropyl

Table 3

Mean crop yields, corrected to 15% moisture, as a % of untreated control

Treatment	Rate (kg ai/ha)	Site Number 1	2	3	4	Mean
Fluofenprop isopropyl Early application	0.6	136	120	115	114	121.3
	0.8	138	125	113	114	122.5
	1.0	145	114	111	104	118.5
	1.6	144	118	113	110	121.3
	2.0	143	114	113	116	121.5
Fluofenprop isopropyl Late application	0.6	139	121	101	107	117.5
	0.8	136	111	103	101	112.8
	1.0	141	109	111	102	115.8
	1.6	125	105	114	110	113.5
	2.0	143	100	108	107	114.5
Control		100 (3491)	100 (3933)	100 (3739)	100 (3710)	100 (3718)
L.s.d. between:-						
2 means at same rate		19	11	8	10	10
2 means at same time		27	16	11	14	
Treatment and control		16	10	7	9	9

( ) = Mean control yield in kg/ha.

The early applications generally gave greater yield increases than the later, the 1.0kg a.i./ha rate of flucfenprop isopropyl at site 4 being the only early treatment which did not give a significant increase over the untreated control.

Analysis of the mean figures for the 4 sites showed that the early applications gave 6.5% higher yields than the later, this difference being significant, but that there were no significant differences in yield between the different rates of flucfenprop isopropyl applied. At site 2 the only increases which were not significant were from the late application at the three higher rates, two of these treatments being those where visible shortening had been apparent earlier.

DISCUSSION

The trials reported showed fluofenprop isopropyl to be an effective herbicide for the control of *Avena fatua* in spring barley. 90% control of visible panicles and 85% control of total panicles were taken as being commercially acceptable. A statistically significant reduction of panicles did not necessarily imply that the reduction was commercially acceptable.

1.0kg a.i./ha of fluofenprop isopropyl gave acceptable wild oat control and the optimum time for application was from late tillering to 1st. node stage of the crop (G to I), when over 90% control of total panicles was achieved. The stage of growth of the wild oat was not critical. Maximum yield increases followed the early applications, all of which were applied during crop stages F to H, which tied in well with maximum wild oat control following application during stages G to I.

The straw shortening which occurred was more apparent following the later application, averaging at most 4 cm at the highest rate but only 2 cms at the 1.0kg a.i./ha rate of fluofenprop isopropyl. However, following the early application (F to H) it was not significant at the 1.0 kg a.i./ha rate and was less than 1cm at the highest rate.

Fluofenprop isopropyl therefore had good crop tolerance at rates of up to 2.0kg a.i./ha and provided useful yield increases at all application rates, in spite of the relatively late removal of weed competition. This was because major yield depressions occur when the wild oat overtops the barley crop, shielding the flag leaf and glumes. Porter, Pal and Martin (1950) concluded that 45% of the dry matter to fill the ear is derived from the flag leaf after ear emergence and 30% from the ear itself. Fluofenprop isopropyl removed the wild oat competition before shading of the upper leaves could occur.

The excellent wild oat control achieved by fluofenprop isopropyl could also be partly attributed to a relatively late timing of application since the majority of wild oats would have germinated by the time application took place.

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ASULAM - FURTHER ASPECTS OF ITS USE ON BRACKEN

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Summary Aerial application of asulam at 4.5 kg/ha, applied to the green expanded fronds during mid-July to late August has given excellent control of bracken *Pteridium aquilinum* in upland grazing situations.

Comparative spray retention studies have shown the greater relative efficiency of applications made by aircraft spraying systems compared with conventional ground spraying equipment.

Observations from small plot experiments and large-scale trials suggest that widespread application of asulam to bracken situations in upland areas is unlikely to have any serious long-term effects on indigenous flora, forest trees etc.

As an aid to management, further investigations show that treated fronds may be cut 2 weeks after treatment without affecting the degree of control achieved.

INTRODUCTION

Since the publication of the last review of bracken control experiments with asulam (Soper, 1972). results of further investigations which could affect both the field performance of the compound and its acceptability to the hill farmer and forester are now available.

METHODS AND MATERIALS

The need to confirm earlier but limited indications of the effectiveness of aerial application of asulam to bracken was recognised in 1971. As a result, 4 experimental sites were sprayed in Scotland, in collaboration with local advisers, in July 1972. These consisted of large, unreplicated plots of at least 4 acres in size, sprayed by means of an 'Alouette' II helicopter fitted with conventional boom equipment. A standard application rate of 4.5 kg asulam in 45 l of water per ha was used throughout. Lower, supplementary doses of asulam were, however, employed at two of the sites.

At one of the experimental sites in Scotland, asulam was also applied at 2.2 and 4.5 kg in 340 l of water per ha through a conventional, tractor-mounted crop sprayer. At this site only, a dye was added to the spray fluid. The dye was quantitatively recovered from samples of treated fronds by washing with a 0.01% w/v aqueous solution of Ethylan CP. A colorimetric method was used to determine the quantity of dye recovered from each sample. It was, thus, possible to calculate the amount of asulam retained following each type of treatment.

During the same period, extensive commercial application of asulam was being made, by both helicopter and fixed-wing aircraft, to several hundred acres of bracken-infested hill-land in both Northern England and Scotland. Farmers were subsequently asked to give their opinion of the degree of control achieved.

Some initial information on forest tree-tolerance was already to hand from earlier activity experiments laid down in forestry situations in 1971. Subsequent work, in collaboration with the Forestry Commission, has been aimed at examining the tolerance of a range of conifers of economic importance to applications of asulam ranging from 1.5-6.0 kg/ha. Replicated plots containing 3 year-old plants of *Larix leptolepis*, *Picea abies*, *P. sitchensis*, *Pinus nigra*, *P. sylvestris*, *Pseudotsuga menziesii* and *Tsuga heterophylla* were treated, without the protection of a bracken canopy, in July and early September. Pot experiments were also undertaken in 1972 to determine the tolerance of selected hill flora to 2.2 to 9.0 kg asulam per ha. The grasses, *Agrostis tenuis*, *Anthoxanthum odoratum*, *Deschampsia* and *Festuca* spp., *Molinia caerulea* and *Nardus stricta* were in flower when sprayed. The shrubs *Calluna vulgaris* and *Vaccinium myrtillus* were also included. This aspect was reinforced by observations from larger trials on a wide range of species occurring in or near bracken habitats.

Since management procedures in both agriculture and forestry may necessitate the removal of the bracken canopy soon after spraying, two replicated trials were laid down to determine the effect of post-spray cutting on the efficacy of asulam. A split, split-plot layout was employed using 2.2, 3.4 and 4.5 kg of asulam in 336 l of water per ha in June and July. These were subjected to three management regimes - cutting 1, 2 and 4 weeks after spraying.

In all this work 'Asulox', the 40% aqueous concentrate of asulam, as alkali metal salt, was used. All bracken assessments have been made using random quadrats ($0.5m^2$) counting frond (i.e. stem) numbers.

RESULTS

The results of both experimental and commercial application of asulam by aircraft are presented in tables 1 and 2. Table 3 shows the results of the comparative spray retention studies and relative effectiveness of the application methods and rates of use under review. In all cases bracken counts were made some 12-13 months after spraying.

The results of the conifer tolerance experiments are shown in table 6, whilst those from pot experiments and observations in larger scale trials on a range of species occurring in or near bracken habitats are shown in table 5.

The influence of post-spray cutting on the effectiveness of asulam is detailed in table 4.

Table 1

Effect of aerial application of asulam on bracken, 12-13 months post-spraying

Location	Acreage treated	Spray date	Type of aircraft	Asulam kg/ha	Assessed July-August 1973: Mean fronds/m^2 Treated area	Adjacent unsprayed control	% Control
Parton, Kirkcudbright	4 5	20.7.72	Helicopter	3.4 4.5	0.7 0.6	18.9 21.9	96 97
Dunscore, Dumfries	20	20.7.72	Helicopter	4.5	1.6	25.2	94
Island of Seil, Argyll	20	21.7.72	Helicopter	4.5	0.3	28.0	99
Inverfarigaig, Inverness	15 15	21.7.72	Helicopter	2.2 4.5	2.7 0.8	No suitable control area	- -
Harkerside, Yorkshire	50	30.8.72	Helicopter	4.5	1.4	20.8	93
Winster, Westmorland	105	24.8.72	Fixed-wing	4.5	1.1	29.6	96
Burneside, Westmorland	50	24.8.72	Fixed-wing	4.5	1.1	22.2	95

Spray volume = 45 l/ha throughout.
Mean frond numbers determined from 30 x $0.5m^2$ random quadrats.

Table 2

Asulam - Bracken control - Aerial application 1972
Commercial users opinion of results
12 months post-spraying (Northern England/Scotland)

Questionnaire sent to: No. of Farmers	Total Acreage Sprayed	Replies received at 2.1.74: No. of Farmers	Total Acreage Sprayed	Degree of control (from replies): Excellent	Good	Poor
39	1,423	30	1,089	17	11	2*

* These have been further described as "patchy control" due to poor application on difficult sites.

Table 3

The effect of spray volume/application method on the retention of 3.4 kg/ha of asulam applied to a natural stand of bracken (90-135 cm high)

Location: Parton, Kirkcudbright
Date of spraying: 20.7.72

Application method	Volume rate (l/ha)	Retention µl spray/g	Retention µg asulam/g	% control of frond Nos.** (12 months post spray)
Helicopter	45	5	376	96
Ground sprayer	330	13	136*	97*

* calculated from application of 4.5 kg asulam per ha.
** determined from 30 x $0.5m^2$ random quadrats.

Table 4

Asulam - Control of bracken, effect of post-spray cutting of fronds on activity, assessed 12 months after spraying

Date of spraying	Asulam kg/ha	Frond Nos./$3m^2$ (Mean of 3 replicates) No Cutting	Time of cutting (Weeks after spraying) 1	2	4	% Control of Frond Numbers No Cutting	Time of cutting (Weeks after spraying) 1	2	4
SITE A									
27.7.72	2.2	13.0	49.7	29.3	23.3	88	51	74	80
	3.4	13.7	23.7	15.3	15.7	88	77	87	86
	4.5	11.3	13.7	19.0	14.3	90	87	83	87
	0	113.0	102.3	114.0	116.7				
	S.E. of a single treatment mean (asulam treatments only) = ± 4.48								
SITE B									
18.7.72	2.2	7.0	31.7	14.0	8.7	95	84	93	95
	3.4	11.3	12.7	11.0	12.7	92	93	94	93
	4.5	9.7	10.7	5.0	4.0	93	94	98	98
	0	142.7	195.3	213.0	183.0				
	S.E. of a single treatment mean (asulam treatments only) = ± 3.72								

Table 5

Reaction of grasses and herbaceous species to direct sprays of asulam at 4.5 kg/ha

Species	Tolerance
Upland grasses:	
Agrostis gigantea	MS-S
Agrostis stolonifera	S
Agrostis tenuis	MS
Anthoxanthum odoratum	MR
Bromus spp.	MS
Cynosurus cristatus	MS
Dactylis glomerata	MS
Deschampsia flexuosa	MR
Deschampsia caespitosa	MR
Festuca ovina	MR-MS
Festuca pratensis	MR-MS
Festuca rubra rubra	MR
Festuca tenuifolia	MR
Holcus lanatus	S
Holcus mollis	S
Lolium perenne	MR
Molinia caerulea	MR
Nardus stricta	MR
Phleum pratense	MS
Poa annua	S
Poa pratensis	MS
Poa trivialis	S
Upland herbs and shrubs:	
Achillea millefolium	R
Anagallis arvensis	R
Bellis perennis	S
Calluna vulgaris	MR
Cirsium arvense	MS
Cirsium vulgare	MS
Digitalis purpurea	R
Endymion non-scriptus	R
Equisetum spp.	MS-S
Erica tetralix	R
Euphrasia anglica	(MS)
Juncus effusus	MR
Juncus inflexus	R
Leontodon officinalis	MR
Lotus corniculatus	MS-S
Luzula spp.	R
Plantago spp.	MS
Polygonum spp.	S
Potentilla reptans	R
Prunella vulgaris	(R)
Ranunculus repens	MR-MS
Rubus spp.	MS
Rumex acetosa	MR-MS
Rumex acetosella	MS
Rumex crispus	S
Rumex obtusifolius	S
Saxifraga spp.	(S)
Sedum spp.	(MS)
Senecio jacobaea	MS
Stellaria graminea	R
Stellaria media	MR
Taraxacum officinale	MR
Trifolium pratense	MS
Trifolium repens	MR
Tussilago farfara	MS
Ulex europaeus	MR
Ulex gallii	MR-MS
Vaccinium myrtillus	R
Vaccinium vitis-ideae	R
Veronica chamaedrys	R
Marsh and aquatic plants:	
Anagallis tenella	R
Callitriche stagnalis	(R)
Cirsium palustre	(MS)
Glyceria fluitans	MS
Hypericum elodes	(MS)
Juncus bufonius	(MS)
Lotus pedunculatus	MS
Melampyrum pratense	(R)
Pedicularis palustris	(R)
Potamogeton polygonifolius	(S)
Ranunculus omiophyllus	R
Ranunculus flammula	MS
Scirpus fluitans	(R)
Mosses and lichens:	
Cladonia spp.	R
Fontinalis antipyretica	(R)
Polytrichum commune	R
Sphagnum spp.	R

R = good tolerance
MR = slight check
MS = severe check
S = very severe check
( ) = categories given on limited information only

Table 6

Tolerance of young trees to direct sprays of asulam at 4.5 kg/ha (in active growth)

		Species	Tolerance
Conifers:	Corsican pine	(Pinus nigra var. maritima)	MR
	Douglas fir	(Pseudotsuga menziesii)	MR
	Grand fir	(Abies grandis)	(R)
	Japanese larch	(Larix leptolepis)	(MR)
	Norway spruce	(Picea abies)	MR
	Scots pine	(Pinus sylvestris)	(R)
	Sitka spruce	(Picea sitchensis)	(MR)
	Western hemlock	(Tsuga heterophylla)	S
Non conifers:	Beech	(Fagus sylvatica)	(R)
	Birch	(Betula pendula)	MR
	Elder	(Sambucus nigra)	(R)
	Elm	(Ulmus sp.)	(R)
	Hawthorn	(Crataegus monogyna)	R
	Holly	(Ilex aquifolium)	(R)
	Poplar	(Populus sp.)	MR
	Privet	(Ligustrum vulgare)	MR
	Willow	(Salix sp.)	MS

R = good tolerance
MR = slight check
MS = severe check
S = very severe check
( ) = categories given on limited information only

DISCUSSION

The effectiveness of aerial application of asulam on bracken has been verified by detailed counts and by a large number of farmer observations.

The associated spray retention studies have confirmed the expected greater efficiency of aerial application in depositing asulam sprays on bracken. Not only is the overall amount of asulam retained by the fronds much greater than that retained by the ground sprayed bracken, distribution over the plant is more uniform.

Earlier work had given an indication of relative deposit levels necessary to effect control of bracken. For example, almost 100% control of frond numbers was consistently obtained in 1972 from bracken which had retained deposits ranging from 20-80 ug/g of plant when sprayed 12 months earlier. Since the deposit levels in this latest work were well in excess of these earlier figures, the excellent control obtained from all treatments was not unexpected (table 3).

Of the conifers treated, Tsuga heterophylla was susceptible to asulam but other species were more resistant and showed no significant damage. In the hill-flora tolerance experiments, damage to Agrostis tenuis was invariably severe at the higher rates, but the other grass species were much more tolerant; Calluna and Vaccinium were unharmed. Limited observations have indicated that lichens, and some mosses (e.g. Polytrichum commune, Sphagnum spp.) are unaffected by direct sprays of asulam at 4.5 kg/ha. On the other hand, the tolerance of indigenous ferns appears doubtful. It must be emphasised that the categories against each species indicate the reaction to direct applications of asulam at 4.5 kg/ha, applied to plants in active growth in July and August. When growing under the protection of a dense bracken canopy, plants will be substantially shielded and in such conditions, little or no effect has often been noted even on sensitive species.

In forestry situations, asulam has safely 'released' young conifers from bracken competition, although the lack of effect in the season of treatment may not obviate the need for some hand-weeding within the tree-lines. It is now clear, however, that where either the situation or subsequent management procedures necessitate post-spray cutting, this may be effected 14 days after spraying without detracting from the degree of control ultimately achieved. Because of the protection afforded by the bracken canopy, the damage to grasses seen in both small-plot and pot experiments has rarely proved a problem in either experimental or commercially sprayed situations. Good swards have often been revealed the season after treatment especially where approved after-care procedures (e.g. liming, fertilising) have been instituted.

CONCLUSIONS

1. Application of asulam from 3.4 - 4.5 kg/ha provides a reliable means of selectively controlling bracken in many agricultural and forestry situations. As such, its widespread use in upland areas is unlikely to have any serious long-term effects on indigenous flora, forest trees etc.

2. The greater efficiency of aircraft spraying systems makes them an invaluable tool for applying asulam to otherwise inaccessible upland situations.

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THE USE OF GLYPHOSATE IN THE CONTROL OF BRACKEN

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Summary Treatment of bracken with glyphosate at 1.1, 2.2, 4.5 and 6.7 kg/ha a.e. during August 1972 gave reductions in frond numbers of up to 97% in 1973. Especially at the higher rates and in late August applications there was much grass kill, *Agrostis tenuis*, *Anthoxanthum odoratum* and *Poa* spp. being severely affected, but *Festuca* spp. less so.

INTRODUCTION

Glyphosate shows herbicidal activity against a wide range of plants, and is particularly promising for the control of rhizomatous weeds (Monsanto, 1971). A small quantity became available for experimental use during August 1972, and its effect on bracken and on the underlying herbage was investigated.

METHOD AND MATERIALS

Dense bracken (approx. 8 fronds/m^2) at Glespin, Lanarkshire (map ref. NS 775296) was sprayed with glyphosate at rates of 1.1, 2.2, 4.5 and 6.7 kg/ha a.e. on 3rd and 28th August, 1972, using a knapsack sprayer. The plots were 5 x 5 m with 1 m discards between, and the water carry was 400 l/ha. Assessments of reductions in frond numbers and visual estimates of sward composition were made in August 1973, and the results compared with those obtained from plots treated with asulam at 4.5 kg/ha a.i. on the same dates as a standard. Treatments were not replicated.

RESULTS

Table 1

Effect of asulam and glyphosate on frond numbers (% reduction)

Herbicide	Rate (Kg/ha)	Spraying date: August 3	Spraying date: August 28
Asulam	4.5	91.6	89.1
Glyphosate	1.1	79.0	78.6
	2.2	75.2	94.7
	4.5	94.7	97.0
	6.7	95.7	97.0

Table 1 shows that glyphosate at 1.1 kg/ha did not give satisfactory control of frond numbers, while at 4.5 and 6.7 kg/ha, the reduction in numbers was marginally better than that obtained with asulam at 4.5 kg/ha. At 2.2 kg/ha, glyphosate showed greater effectiveness when applied at the end rather than at the beginning of August.

While asulam had little effect on the underlying vegetation (Table 2), glyphosate in most cases markedly changed sward composition. The application of glyphosate in early August when there was still a dense frond cover gave no marked change in the vegetation at 1.1 and 2.2 kg/ha, but at higher rates, *Agrostis tenuis* and *Anthoxanthum odoratum* were severely affected. *Festuca ovina* and *F. rubra* appeared much more resistant however, and were able to colonize bare ground left by the death of other grasses. Glyphosate applications at all rates at the end of August, by which time fronds at this site were starting to die back, killed almost all grasses with a resulting increase in the spread of moss. *Poa annua* and *Poa pratensis*, although present in only small amounts in the original sward, were very susceptible to glyphosate application, and disappeared entirely at all rates except 1.1 kg/ha in early August.

Table 2

Effect of asulam and glyphosate on underlying vegetation (% ground cover)

Date of treatment	3.8.72					28.8.72					Untreated
Herbicide	asulam	glyphosate				asulam	glyphosate				
Rate (kg/ha)	4.5	1.1	2.2	4.5	6.7	4.5	1.1	2.2	4.5	6.7	
Agrostis tenuis	20	30	25	0	0	5	2	0	0	0	15
Anthoxanthum odoratum	15	15	20	5	5	40	5	5	1	2	20
Deschampsia flexuosa	1	3	0	5	0	2	0	0	0	0	1
Festuca spp.	25	10	5	40	30	5	1	5	5	5	15
Poa spp.	5	3	0	0	0	2	0	0	0	0	10
Carex + Luzula spp.	3	2	0	5	2	5	5	2	0	0	3
Galium hercynicum	10	5	5	3	1	3	2	1	2	5	5
Potentilla erecta	3	2	5	2	2	5	5	2	2	0	3
Mosses	3	5	5	0	5	1	20	10	10	10	3
Bare ground	15	25	35	40	55	30	60	75	80	78	25

DISCUSSION

From the results obtained, it appears likely that effective control of bracken frond numbers by glyphosate will be accompanied by the death of almost all the valuable grazing components of the underlying sward, although further experiments are being carried out to determine this point. Any selective effects promoting the spread of fescues will result in small improvements in sward quality, but the use of glyphosate in practice probably depends on its incorporation into a joint programme of bracken clearance and reseeding. This will not necessarily be a disadvantage under West of Scotland conditions where the stock-carrying potential of much hill land is determined largely by its over-wintering capacity, and ploughing as a means of improvement is impossible in most cases.

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