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THE POTENTIAL USE OF GRASS GROWTH RETARDANTS AT SULLOM VOE TERMINAL, SHETLAND

A report prepared for W J Cairns and Partners, 16 Randolph Crescent, Edinburgh, Environmental Consultants to BP Petroleum Development Ltd as Operators of Sullom Voe Terminal

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SUMMARY

Three plot trials of available grass growth retardants were set out within the Sullom Voe Terminal, Shetland, in April 1984. The objectives of the trials were to examine the possibility of reducing the numbers of grass cuts, the possibility of spraying instead of cutting grass in high fire risk areas, and to assess any difficulties of spraying by hand on slopes. Three compounds were used: maleic hydrazide, mefluidide and paclobutrazol (in a mixture with mefluidide). In the first experiment (Trial 1) the retardants were applied on three occasions to assess the effect of time of application. In the second experiment (Trial 2) different rates of chemical were used and applications were made either by an hydraulic Oxford Precision Sprayer or a controlled droplet application Micron Herbi sprayer. The effects of subsequent cutting and fertiliser application were also examined. An assessment of the likely difficulties of spraying on slopes was made in an observation trial. The trial sites were on reclaimed areas of gravel substrate. The lack of soil structure and the dry conditions, spring and summer were exceptionally dry in Shetland, meant the swards were prone to drought stress. As a result the retardants were expected to show the severest phytotoxic effects.

In Trial 1 the data indicated that earlier applications gave better results. Best effects were recorded on plots treated on 27 April in Trial 1. Applications were made to the main experiment, Trial 2, on 10 May 1984. In Trial 2 the effect of a cut two weeks after spraying was similar to a retardant spray on uncut swards, particularly on sward height. However, there were benefits in the retardants in suppressing grass flowering. Application of fertiliser did not affect sward height or grass panicle densities, but improved appearance of sprayed plots. Overall the experiments indicated that the retardants can check the sown swards; the suppression of flowering in grasses produced by mefluidide and maleic hydrazide was of particular value. The grass heads are the untidy component of the sown areas and form the greatest fire risk in late season.

Differences between the retardants were not great. Mefluidide gave slightly better height control and panicle suppression when used at 1.0 kg/ha than maleic hydrazide. The mixture with paclobutrazol was more persistent in its growth control than the others, but effects were rather too vigorous. A mixture with less paclobutrazol and more mefluidide deserves investigation. Maleic hydrazide reduced clover cover and frequency; this would be deleterious to the sown swards in the long term. Mefluidide was safe to clover as judged in the first year; paclobutrazol retarded clover growth but may not affect its persistence in the sward. On balance mefluidide at 0.4 or 1.0 kg/ha applied in early to mid-April would give adequate sward control. The mixture of paclobutrazol + mefluidide requires further examination, but under less testing seasonal weather conditions its longevity of action would be advantageous in those areas where cutting cannot be allowed.

INTRODUCTION

With increasing financial pressure on managers of amenity grass (local authorities spend in excess of £100 million per annum on mowing), there is interest in alternatives to cutting. New chemicals are being screened by agrochemical companies for growth regulatory properties and several compounds have been tested by the Weed Research Organization (Marshall, 1983). Chemical growth retardants may reduce the need to mow grass; maintenance costs may be lower as a result and labour can be released to other duties. As well as reducing leaf growth for a period, some compounds may inhibit flowering in grasses.

Two compounds are available commercially; they are Cleared by the Pesticide Safety Precaution Scheme (PSPS) and Approved by the Agricultural Chemicals Approval Scheme (ACAS) for use as stated on the product labels. The retardants are maleic hydrazide and mefluidide. The products containing these active ingredients are given in Table 1.

Table 1. Products containing grass growth retardants

Active ingredients	Product name	Content (% active)	Company
maleic hydrazide	Regulox K	25	Diamond Shamrock
	Mazide A	25	Synchemicals
	Mazide 36A	36	"
	Mazide 3600	36	"
	Royal Slogro	16.7	Uniroyal
maleic hydrazide + 2,4-D	BH43	20+18.5	Diamond Shamrock
	Mazide Selective	20+10	Synchemicals
mefluidide	Mowchem	24	May & Baker

Trials carried out at the Weed Research Organization and experiences of several local authorities indicate that these materials can save mowing. In lower maintenance areas a single application and an end-of-season cut may be sufficient. In areas requiring higher standards, several applications 8 to 10 weeks apart are made during the growing season.

The suitability of these compounds, together with paclobutrazol which is likely to be marketed in 1985, for grass retardation at Sullom Voe Terminal have been examined in two experiments and one trial. Landscaped areas within the Terminal have been sown with grass and clover seed mixtures. The substrates are poor, mostly rock or peat. An area of 15 ha in the centre of the Terminal cannot be grazed by sheep. The grass, which is growing on rocky substrates, is cut two or three times a year with strimmers (it takes c. 4 weeks for the first cut). In one high fire risk area cutting is not allowed. Fertilizer is applied to the grass in May to encourage establishment. The aims of the experiments have been to find treatments which either obviate the need to mow (for high risk areas) or which reduce the current maintenance programme. Factors which have been considered are as follows:

chemical
type of spray applicator
timing of application
fertilizer
mowing, associated with spraying.

METHODS

Two experiments and an observation trial were laid out in April 1984 on an area adjacent to the Offsites Control Building. The area was on a stony substrate with almost no organic matter and no soil structure. In 1981 the area had been sown with seed mixture B:-

42%	Creeping red fescue
15	Chewings fescue
15	Brown Top Bent
15	Smooth stalked meadowgrass
10	Westerwolds ryegrass
1.5	New Zealand Huia White Clover
1.5	Kent Wild White Clover

In Trial 1 (code NC384) three retardants were applied on three dates to examine the timing of spraying. On the second date of Trial 1, applications were made on Trial 2 (code NC284) and Trial 3. In Trial 2 effects of different rates of chemical, spray applicators, fertilizer and mowing were examined. In Trial 3, retardants were applied to banks in an attempt to assess difficulties of spraying on slopes.

Chemicals were applied through an Oxford Precision sprayer (OPS) or a Micron Herbi controlled droplet applicator (CDA). The OPS is pressurised by liquid CO_2 and operated at a boom pressure of 30 p.s.i. (2 bars). The 2m boom used had four nozzles with 8002 Teejets producing a flat fan spray pattern. At a forward speed of 1 m/s the sprayer gave a volume rate of 198.5 l/ha. The CDA sprayer has a battery operated rotary disk atomiser producing droplets of uniform size (c. 250 u). At a forward speed of 1 m/s the red nozzle gave a volume rate of 22.4 l/ha. While the CDA technique is attractive from the point of view of carrying considerably less water during spraying, CDA application of retardants is not yet cleared by the Pesticides Safety Precaution Scheme. Refinements of the application method might be suggested, e.g. low pressure hydraulic spray nozzles. However, the techniques used represent the two main application methods available.

Assessments of the Trials 1 and 2 were carried out by S Duggan and included sward composition in May and July, composite sward heights, numbers of grass panicles, a score of plot appearance and an estimate of clover cover. Sward composition was estimated by recording species present in ten random throws of a 20 cm by 20 cm quadrat (0.04 m^2) per plot. Sward heights were measured with a simple sward stick, consisting of a pierced plastic plate (305 cm^2) which was lowered to rest down a metre ruler (Marshall, 1983). Five readings were taken in each plot every fortnight. Grass panicles were estimated for each species each month (fortnightly initially).

Plot appearance was assessed using a subjective "brownness" score. All assessments were made by S. Duggan and can be compared. The scores are on a 0-9 scale with 0 = all green and 9 = all brown. The percentage cover of clover in each plot was estimated by eye each month.

Assessments on Trial 3 were limited to comments on appearance.

Data were analysed using analysis of variance with the GENSTAT package at the Agricultural Research Computer Centre, Rothamsted.

TRIAL 1. NC384.
THE EFFECT OF THREE RETARDANTS APPLIED ON THREE DATES.

EXPERIMENT DETAILS

Three retardants were applied by OPS to 2m by 2m plots on three dates. Treatments were replicated three times and randomised within blocks. The treatments were as follows:

Code	Retardant	Rate (kg a.i./ha)
C1	maleic hydrazide	5.6
C2	mefluidide	0.4
C3	paclobutrazol + mefluidide	1.0 + 0.13
CONTROL		

Applications were made on the following dates:

T1	27/4/84
T2	10/5/84
T3	23/5/84

The plot layout was as follows

III	T3 C2	T3 C1	T1 C3	T3 C3	T3 CON	T2 C2	T2 C1	T2 CON	T1 C2	T2 C3	T1 C1	T1 CON	2m
II	T2 C3	T2 C2	T1 C2	T3 C3	T2 CON	T2 C1	T1 C1	T3 C2	T1 C3	T1 CON	T3 C1	T3 CON	
I	T1 C1	T3 C1	T2 C2	T1 CON	T1 C3	T3 C2	T2 C1	T3 CON	T1 C2	T2 C3	T2 CON	T3 C3	

T1 application details:

Chemicals were measured out on 25/4/84 and made up to 0.5l final spray volume (56.45 ml of 'Regulox K'; 1.01 ml of 'Embark'; 13.3 ml of paclobutrazol + mefluidide mixture provided by ICI). Unfortunately C2 plots at time T1 were treated at 0.1 kg/ha, a quarter of the dose required.

Plots were sprayed by S. Duggan on the afternoon of 27 April starting at 16.30. Weather conditions were cool, misty with a light wind increasing. There was some risk of drift. Weather records from Lerwick indicate no rain for the succeeding five days.

T2 application details:

Chemicals were measured out on 4/5/84 as part of the Trial 2 applications in a spray volume of 3.0 l (338.5 ml of 'Regulox K'; 25.2 ml of 'Embark'; 80.8 ml of paclobutrazol + mefluidide mixture). Spraying was carried out on 10/5/84 by E J P Marshall starting at 20.45 and ending at 22.30. The sward was damp to dry and the weather was calm to a light breeze with 1/10 cloud cover. Air temperatures were 4.4^{o}C at 21.00, dropping to 2.6^{o}C at 24.00. There was no rainfall for two days after application at Lerwick.

T3 application details:

Spraying was carried out by S. Duggan on 27 May 1984. A light breeze was blowing but negligible drift observed. Gusts up to 11 knots were recorded. Treatment T3 C2 in the second replicate had uneven spray cover with insufficient chemical.

RESULTS

Sward heights

Sward heights are given in Table 2. and illustrated in Fig. 1. Statistical analyses indicated that significant differences between treatments began at the beginning of June. All sprayed plots were significantly shorter than control plots from mid-July. The earlier application dates, T1 and T2, gave generally better height suppression. Differences between the three chemicals were not significant.

Table 2. Mean plate heights (cm) on plots treated with three retardants applied on three dates (T1 = 27/4/84; T2 = 10.5/84; T3 = 23/5/84). * = significantly different to controls.

Treatment	Time	Date							
		8/5	21/5	4/6	18/6	2/7	16/7	30/7	13/7
Control		5.5	8.0	10.0	13.4	13.9	16.3	16.0	17.5
Maleic hydrazide	T1	7.0	8.6	8.3	9.3*	9.7*	9.3*	10.0*	9.4*
	T2	6.0	9.4	8.2	10.4	9.5*	10.8*	10.8*	10.2*
	T3	5.6	6.3	7.7*	9.3*	9.8*	8.5*	9.3*	9.3*
Mefluidide	T1	6.2	6.8	6.6*	7.5*	6.4*	9.2*	8.3*	7.2*
	T2	6.2	7.1	6.8*	7.5*	6.9*	8.0*	8.0*	8.6*
	T3	7.6	10.0	11.6	12.2	13.0	12.8*	14.9	13.7*
Paclobutrazol & mefluidide	T1	5.8	5.7	5.5*	7.1*	7.4*	7.2*	8.4*	6.7*
	T2	5.7	7.8	8.1	8.6*	7.0*	9.4*	7.6*	6.8*
	T3	5.4	8.0	8.2	12.4	11.4	10.7*	10.9*	11.7*
Standard error (against controls)		N.S.	N.S.	0.76	1.08	1.23	1.18	1.23	1.23
(between treatments)				1.32	1.87	2.13	2.05	2.13	2.13

Sward height data can be corrected so that all plots start at the same point. While a simple addition and subtraction of a constant may give an accurate picture of changes initially, it is not realistic later in the season. However the corrected data are given in Table 3. below. T1 and T2 applications of mefluidide and paclobutrazol + mefluidide appear to give good results.

Table 3. Average sward heights (cm) corrected to control height on 8/5/84

Treatment	Time	8/5	21/5	4/6	18/6	2/7	16/7	30/7	13/8
CONTROL		5.5	8.0	10.0	13.4	13.9	16.3	16.0	17.5
Maleic hydrazide	T1		7.5	6.8	7.8	8.2	7.8	8.5	7.9
	T2		8.9	7.7	9.9	9.0	10.3	10.3	9.7
	T3		6.2	7.6	9.2	9.7	8.4	9.2	9.2
Mefluidide	T1		6.1	5.9	6.8	5.7	8.5	7.6	6.5
	T2		6.4	6.1	6.8	6.2	7.3	7.3	7.9
	T3		7.9	9.5	10.0	10.9	10.7	12.8	11.6
Paclobutrazol + mefluidide	T1		5.4	5.2	6.8	7.1	6.9	8.1	6.4
	T2		7.6	7.9	8.4	6.8	9.2	7.4	6.6
	T3		8.1	8.3	12.5	11.5	10.8	11.0	11.8

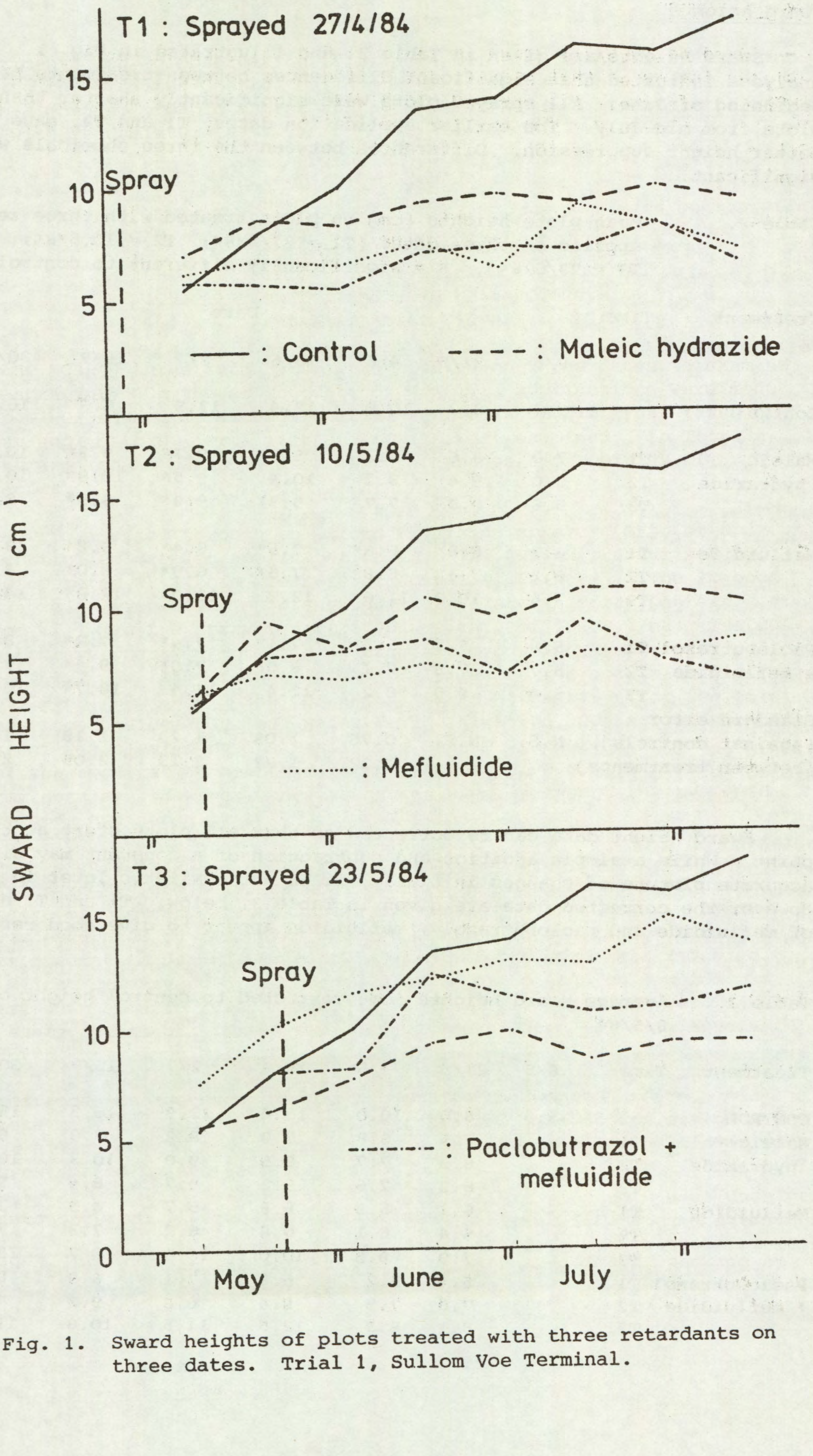

Fig. 1. Sward heights of plots treated with three retardants on three dates. Trial 1, Sullom Voe Terminal.

Panicle numbers

The three retardant treatments caused significant panicle suppression in comparison to controls (Table 4.). T3 applications gave poorest results, while the best grass flower suppression was shown by maleic hydrazide applied at the earliest time (Fig. 2.). At T2 there were no differences between mefluidide and maleic hydrazide. As mefluidide was applied at only 0.1 kg/ha at T1, instead of 0.4 kg/ha the T2 data indicate that mefluidide should have performed as well as maleic hydrazide at the earlier application.

Table 4. Grass panicle densities (No/m^2) on plots treated on three dates with three retardants. (T1=27/4/84; T2=10/5/84; T3=23/5/84)

Treatment	Application Time	Date 21/5	4/6	18/6	28/6	17/7	1/8	13/8
Control		8	97	167	200	215	239	128
Maleic hydrazide	T1	1*	2*	2*	4*	7*	9*	11*
	T2	6	35*	34*	46*	53*	37*	22*
	T3	5	60*	82*	109*	92*	81*	52*
Mefluidide	T1	3*	38*	57*	99*	94*	54*	53*
	T2	2*	13*	33*	49*	39*	36*	26*
	T3	10	76	103*	124*	126*	118*	102*
Paclobutrazol + mefluidide	T1	5*	40*	59*	93*	67*	53*	63*
	T2	4*	33*	64*	99*	79*	78*	56*
	T3	7	68*	108*	156*	151*	151*	102*
Standard error (against control)		1.2	8.3	11.9	11.1	18.7	24.3	11.8
(between treatments)		2.0	14.4	20.6	19.3	32.4	42.0	20.5

* = significantly different from control

The total panicle densities were made up of three grass genera: fescues, ryegrass and meadowgrasses. Fescues provided the greatest number of heads, followed by meadowgrass species and ryegrass. Fescue and meadowgrass flowering was suppressed by the T1 and T2 applications, with maleic hydrazide T1 treatments giving good results. At T2 application mefluidide gave consistently better meadowgrass suppression than other retardants. Ryegrass heads were not recorded before late June. Best suppression was given by maleic hydrazide applied at all dates. Mefluidide gave significant suppression with the T2 application, perhaps indicating better effects should have been achieved at T1 with the correct dose.

Appearance scores

Brownness scores (0-9) on treated plots are given in Table 5. In June and July all sprayed plots were significantly poorer than controls in appearance. Maleic hydrazide T1 and T2-sprayed plots had the highest brownness scores. In August maleic hydrazide and mefluidide plots improved, while paclobutrazol + mefluidide plots had higher scores than controls.

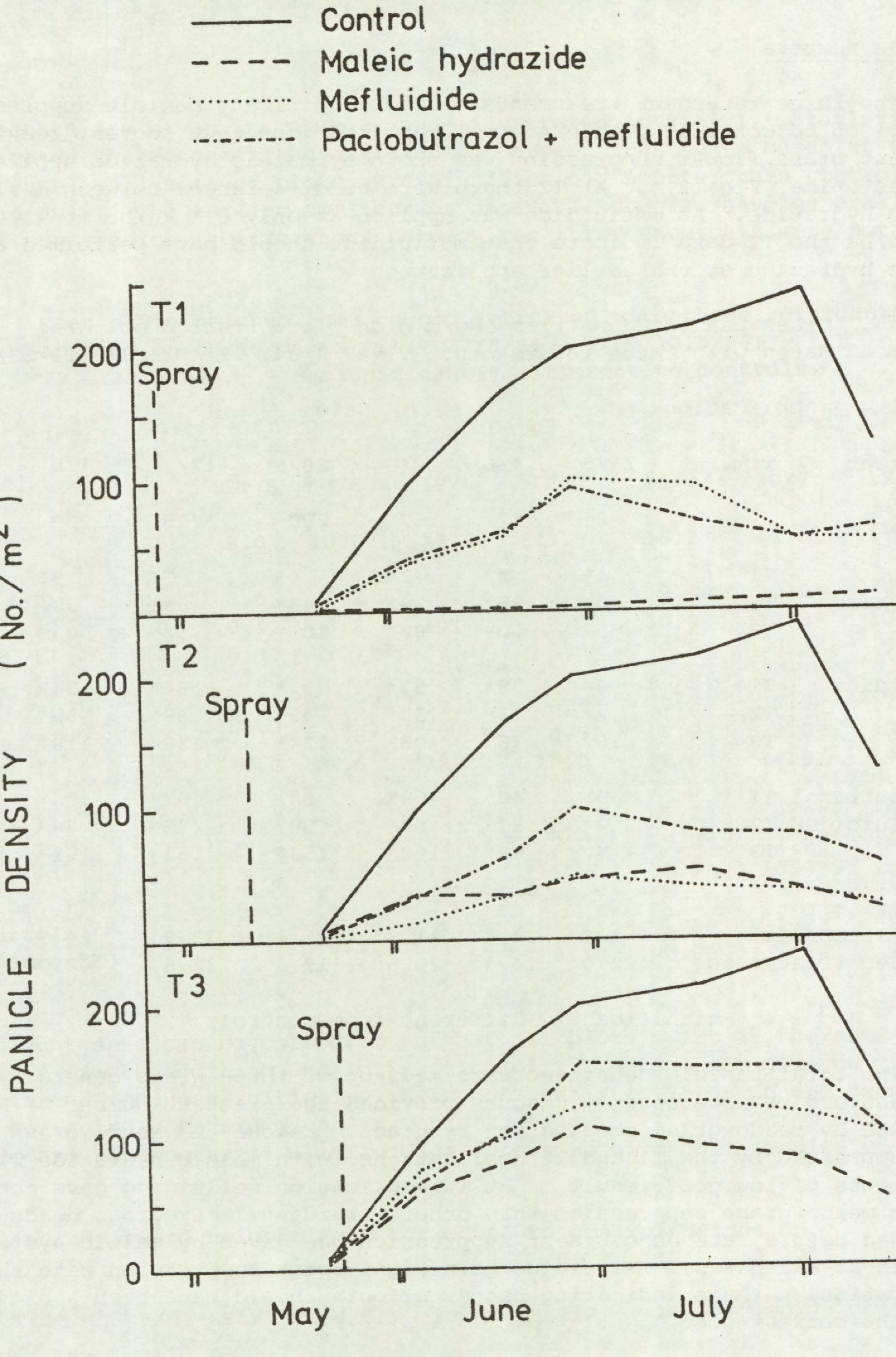

Fig. 2. Grass panicle densities on plots treated with retardants on three different dates (T1 = 27/4/84; T2 = 10/5/84; T3 = 23/5/84). Trial 1, Sullom Voe Terminal.

Table 5. Brownness scores (0-9) on plots treated with retardants on three different dates (T1=27/4/84; T2=10/5/84; T3=23/5/84).

Treatment	Time	Date 21/5	4/6	18/6	28/6	17/7	1/8	13/8
CONTROL		4.1	3.6	3.3	3.3	3.8	4.3	4.7
Maleic hydrazide	T1	4.7	7.7*	7.7*	6.3*	5.3*	5.0	4.3
	T2	4.0	4.0	7.0*	7.0*	6.0*	4.0	4.3
	T3	5.7	4.7	5.3*	5.3*	6.0*	5.7*	4.7
Mefluidide	T1	4.7	5.3*	5.3*	4.0*	4.0*	3.3	3.7
	T2	4.7	4.7	5.0*	4.7*	5.0*	3.3	3.7
	T3	3.0	3.0	3.7	3.7	4.3*	3.3	4.0
Paclobutrazol + mefluidide	T1	5.3	5.7*	5.7*	5.3*	5.7*	4.7	4.7
	T2	4.7	5.0*	5.7*	5.7*	6.7*	6.0*	6.3*
	T3	3.3	4.3	4.0	4.7*	5.3*	5.3	6.3*
S.E. (v. control)		NS	0.38	0.33	0.22	0.28	0.41	0.35
(between treatments)			0.65	0.57	0.39	0.48	0.70	0.61

* = significantly different from control

Clover cover

Visual estimates of clover cover were made on four occasions (Table 6.). Control plots maintained a cover of 30% from April to July; cover increased to 60% in August. In June, maleic hydrazide plots had significantly lower cover values than controls, as did T2 applications of the other retardants. By August it was evident that clover cover on mefluidide plots was similar to unsprayed areas, while it was significantly lower on maleic hydrazide and paclobutrazol mixture plots.

Table 6. Clover cover (%) assessed by eye on plots treated with retardants on three dates (T1 = 27/4/84; T2 = 10/5/84; T3 = 23/5/84).

Treatment	Time	Date 21/5	18/6	17/7	13/8
CONTROL		35.0	33.9	37.8	63.3
Maleic hydrazide	T1	21.7	8.3*	38.3	48.3
	T2	36.7	15.0*	13.3*	36.7*
	T3	30.0	21.7*	28.3	41.7*
Mefluidide	T1	20.0	31.7	46.7	66.7
	T2	40.0	21.7*	48.3	80.0
	T3	46.7	26.7	38.3	76.7
Paclobutrazol + mefluidide	T1	28.3	23.3	30.0	53.3
	T2	26.7	16.7*	25.0	30.0*
	T3	41.7	25.0	35.0	46.7
S.E. (v. control)		NS	3.8	6.1	6.4
(between treatments)			6.5	10.5	11.0

* = significantly different from controls

Sward composition

Sward composition was assessed in early May and again in July using a simple presence/absence record in 0.04 m^2 quadrats. Rooted plants were recorded. In May the sward composition was as follows:

Fescues (Festuca spp.)	97.5%
Bent (Agrostis capillaris)	11.3
Smooth stalked meadowgrass (Poa pratensis)	99.2
Ryegrass (Lolium perenne)	58.9
Annual meadowgrass (Poa annua)	19.9
White clover (Trifolium repens)	91.0

By July significant differences were only found for ryegrass (L.perenne). There was some indication of lower frequencies on maleic hydrazide-treated plots (Table 7.), though no treatments were different from controls.

Table 7. Frequencies (%) of ryegrass (L.perenne) on retardant-treated plots in May and July.

	May	July
Control	56.7	55.6
Maleic hydrazide	55.6	43.3
Mefluidide	65.6	76.7
Paclobutrazol + mefluidide	57.8	62.2
S.E.	NS	8.1

The results may reflect better growth suppression of ryegrass by maleic hydrazide, but it may also indicate a selection pressure. Repeated applications may reduce the amounts of ryegrass in the sward, though this requires verification.

DISCUSSION

In terms of sward height the trial showed that earlier applications gave better results. Applications in early May gave reasonable results, but it is recommended that spraying takes place in April. Differences between the three retardant treatments were small.

Larger differences were recorded with numbers of grass panicles; the earliest application of maleic hydrazide gave best suppression. Experience elsewhere (Marshall, 1983) indicates that mefluidide should have performed well at the earlier application if the dose of 0.4 kg/ha had been applied. Differences in flower suppression between grasses were perhaps evident for ryegrass; maleic hydrazide gave better suppression than mefluidide. Trials of retardants in England have shown that maleic hydrazide and mefluidide affect most grass species. Growth suppression lasts for a period of about 8 weeks on most species. The exception with mefluidide is ryegrass, when retardation lasts only about 4 weeks. In this trial the data show a mefluidide dose response on ryegrass flowering. Mefluidide at 0.1 kg/ha gave poor suppression, while 0.4 kg/ha (T2) gave better results.

Subjective assessments of plot appearance showed that all retardants discoloured the sward. The growing conditions at Sullom Voe were stressed, with shallow rooting depth in ths stony substrates. During 1984 Shetland also had a drier than average year and some drought stress was probably present. The effect of the retardants is an added stress on the plants. Plot appearance improved in August on maleic hydrazide and mefluidide plots, but not on the paclobutrazol + mefluidide plots. This probably reflected the cessation of growth suppression by the foliar-uptake retardants, while the soil-uptake paclobutrazol continued to be active.

Clover is an important component of vegetation on nutrient-poor soils as it is capable of fixing atmospheric nitrogen. In turn, some nitrogen is made available to grasses so sward establishment and growth is encouraged. Cover assessments of clover on treated plots indicated some reductions on maleic hydrazide and paclobutrazol mixture plots. Whether continued applications would reduce clover content needs investigation, but these results indicate that mefluidide is unlikely to reduce clover.

Sward composition assessments in July did not show the clover cover effect recorded in August and only one grass species showed significant effects of retardants. Ryegrass frequencies were lower on maleic hydrazide plots than on mefluidide plots, though neither were significantly different from controls.

It is possible to rank the effects of the retardants on a subjective basis as follows:

	Sward height	Grass flower suppression	Appearance	Period of activity	Clover content	Grass effects
Maleic hydrazide	xxx	xxx	x	xx	x	?
Mefluidide	xxx	xxx	xx	xx	xxx	?
Paclobutrazol + mefluidide	xxx	xx	x	xxx	x	?

None of the retardants gave ideal results, though mefluidide perhaps came closest. The mixture will not give such good head suppression, but may suppress growth longer. It is possible that a formulation that contains more mefluidide and less paclobutrazol would give best results for the Sullom Voe Terminal situation.

TRIAL 2. NC284.
THE EFFECTS OF THREE RETARDANTS APPLIED AT DIFFERENT RATES WITH TWO TYPES OF SPRAYER, WITH THEIR INTERACTIONS WITH CUTTING AND FERTILIZER TREATMENTS.

EXPERIMENT DETAILS

Three chemical retardants were applied by OPS or CDA sprayer; plots were subsequently cut or left uncut and fertilised or unfertilised. The experiment was designed as a plaid with retardants and mowing treatments arranged at 90^o for ease of implementation. Plots were then split in two receiving (+) or not receiving (-) fertiliser at random. Retardant treatments made on 10 May 1984 were as follows:

Code	Retardant	Dose (kg (a.i.)/ha)	Applicator
CONTROL			
C1	Maleic hydrazide (MH)	5.6	OPS
C2	Mefluidide (Mef)	0.4	OPS
C3	Mefluidide	1.0	OPS
C4	Paclobutrazol + mefluidide (Pac+)	1.0 + 0.13	OPS
C5	Paclobutrazol + mefluidide	2.0 + 0.26	OPS
C6	Maleic hydrazide	5.6	CDA
C7	Mefluidide	0.4	CDA
C8	Paclobutrazol + mefluidide	1.0 + 0.13	CDA

Mowing treatments (M1= mown to 5cm; M2= uncut) were carried out with a rotary mower on 24 May 1984, a fortnight after spraying.

Fertiliser (+ and -) was applied by hand on 3 June 1984. The fertiliser was 15:15:15 N,P,K and was applied at a rate of 30 g/m^2, except for plots 1 to 18 which received 300 g/m^2.

Plot layout is given in Fig. 3. Plots were 2m by 4m divided into 2m by 2m subplots for fertiliser. Treatments were replicated three times.

Application details:

Spraying was carried out on 10 May 1984 by E J P Marshall. Chemicals for OPS applications were measured on 4 May in either 1.5l or 3.0l; CDA solutions were made up on 9 May:

	ml concentrate	Final volume (l)
OPS solutions		
Maleic hydrazide	338.5	3.0
Mefluidide	25.2	3.0
Mefluidide	34.2	1.5
Paclobutrazol + mefluidide	80.8	3.0
Paclobutrazol + mefluidide	80.8	1.5
CDA solutions		
Maleic hydrazide	400.0	0.5
Mefluidide	23.0	0.386
Paclobutrazol + mefluidide	95.6	0.5

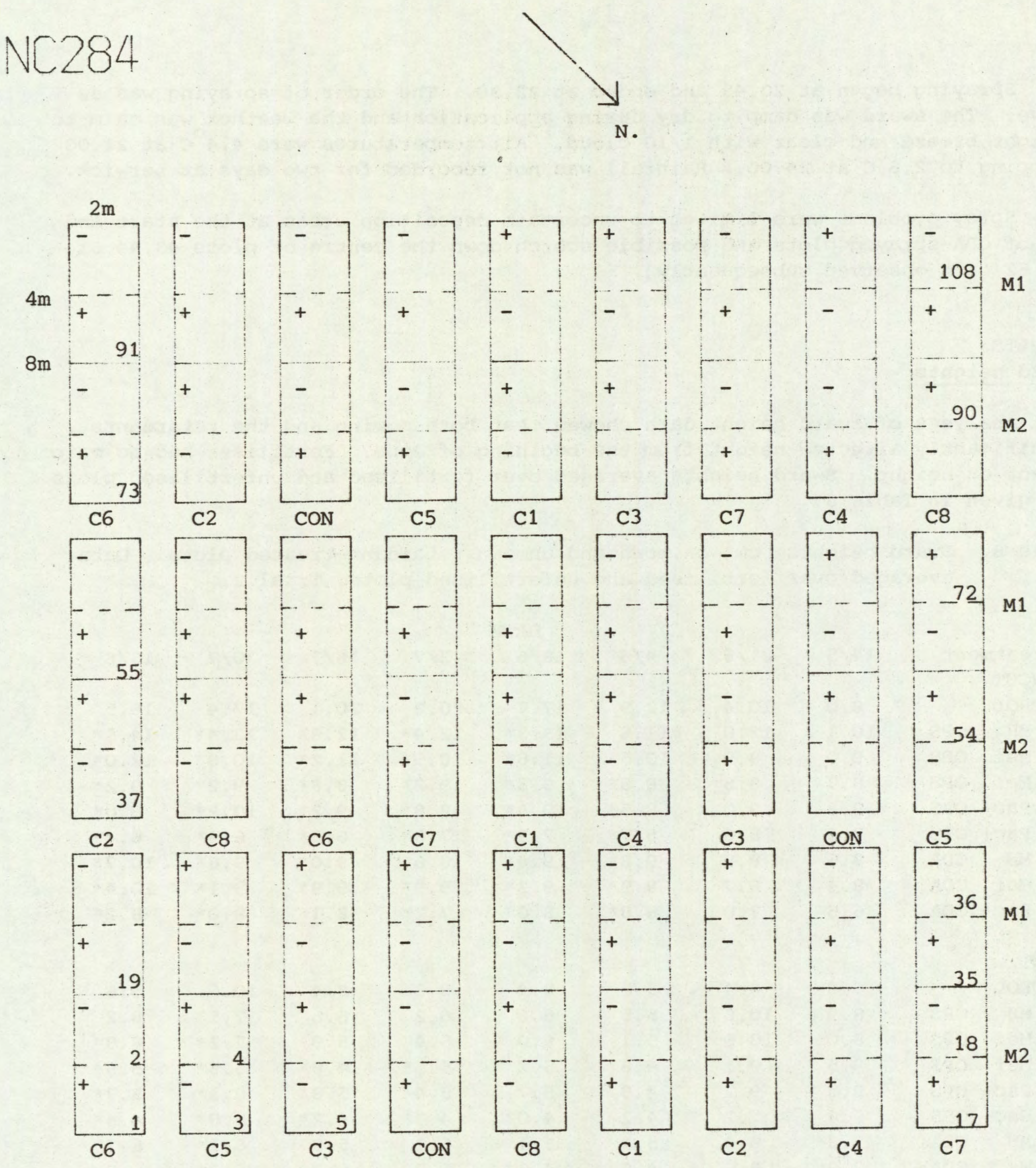

Fig. 3. Trial 2 plot layout, showing plot numbers, chemical treatments (C1 to C8), mowing treatments (M1, M2) and fertilizer application (+, -).

Spraying began at 20.45 and ended at 22.30. The order of spraying was as above. The sward was damp to dry during application and the weather was calm to a light breeze and clear with 1/10 cloud. Air temperatures were 4.4°C at 21.00 dropping to 2.6°C at 24.00. Rainfall was not recorded for two days at Lerwick.

Spray problems were limited to uncertain deposition areas at the start and end of CDA-sprayed plots and possible scorch down the centre of plots 43,44,61 and 62 (not observed subsequently).

RESULTS

Sward heights

Analyses of sward height data showed that both mowing and the retardants significantly affected height from the begining of June. Fertiliser had no main effect on height. Sward heights averaged over fertilised and unfertilised plots are given in Table 8.

Table 8. Sward heights (cm) on mown and unmown retardant-treated plots. Data averaged over fertilised and unfertilised plots. Trial 2.

			DATE							
Treatment			14/5	21/5	4/6	18/6	2/7	16/7	30/7	13/8
UNCUT										
CONTROL			8.0	10.4	12.9	17.7	20.2	20.1	17.4	16.5
C1	MH	OPS	10.1	12.0	11.8	13.3*	12.4*	12.8*	13.4*	14.1*
C2	Mef	OPS	9.0	9.9	10.5	11.8*	10.9*	11.2*	10.8*	12.0*
C3	Mef	OPS	8.7	8.8	8.5*	9.3*	9.2*	8.8*	9.2*	9.2*
C4	Pac+	OPS	8.3	9.0	8.5*	10.4*	8.8*	9.2*	10.2*	9.0*
C5	Pac+	OPS	7.3	8.6	5.7*	7.8*	7.0*	6.5*	6.4*	6.4*
C6	MH	CDA	8.6	8.9	9.8*	9.4*	8.6*	9.0*	9.6*	10.7*
C7	Mef	CDA	8.4	8.7	8.9*	9.3*	9.9*	9.9*	9.1*	10.4*
C8	Pac+	CDA	6.5	7.0	6.8*	8.0*	7.2*	8.1*	8.0*	8.2*
CUT										
CONTROL			6.8	8.4	5.7	8.4	9.3	8.4	10.6	9.6
C1	MH	OPS	8.9	10.6	5.5	6.8	6.2	6.6	7.5*	8.2
C2	Mef	OPS	8.0	10.6	5.1	6.0	6.4	5.9	7.2*	6.9*
C3	Mef	OPS	8.5	9.1	4.8	5.2	5.5*	4.8*	5.6*	5.8*
C4	Pac+	OPS	8.3	9.7	4.9	5.7	5.4*	5.3*	6.1*	5.7*
C5	Pac+	OPS	6.8	7.2	4.2	4.0*	4.3*	4.2*	5.0*	4.4*
C6	MH	CDA	7.3	9.8	5.1	5.1	6.1	5.8	6.1*	6.7*
C7	Mef	CDA	7.9	8.9	4.9	4.6*	6.2	5.7	6.3*	6.8*
C8	Pac+	CDA	7.1	8.2	4.9	5.1	5.4*	4.6*	5.7*	5.1*
S.E.			NS	NS	1.00	1.21	1.15	1.09	0.99	0.99

* = significantly different from controls

On unmown plots all retardant treatments gave swards shorter than controls from mid-June. Differences between retardants were not marked. Maleic hydrazide showed some delay in activity, particularly when applied by OPS. High doses of mefluidide and the paclobutrazol mixture gave good height control. There were some indications of longer activity with paclobutrazol.

The effect of a single cut had a dramatic effect on sward height, mainly by removing many developing flowering heads (see on). Further shortening was achieved by the high dose of mefluidide applied by OPS and the paclobutrazol mixtures by the begining of July. In late July and August all retardants except MH gave shorter swards than controls after a single cut.

Differences between OPS and CDA applications were minimal, with the possible exception of enhanced activity of MH applied by CDA sprayer.

Panicle numbers

Total grass panicle numbers were unaffected by fertiliser application but were significantly affected by mowing and the retardants. Panicle densities averaged over fertilised and unfertilised plots are given in Table 9. and illustrated in Fig. 4. The mowing treatment markedly reduced panicle densities and certain retardants further suppressed grasses from flowering.

Table 9. Grass panicle densities (No/m^2) on cut and uncut plots treated with grass retardants. Data averaged over fertilised and unfertilised plots. Trial 2.

				DATE			
Treatment	21/5	4/6	18/6	28/6	17/7	30/7	13/8
UNCUT							
CONTROL	63	441	356	599	246	129	97
C1 MH OPS	51	109*	102*	149*	96*	41*	44*
C2 Mef OPS	49	79*	64*	107*	89*	36*	54*
C3 Mef OPS	34*	71*	60*	76*	62*	27*	28*
C4 Pac+ OPS	39*	90*	70*	111*	103*	60*	53*
C5 Pac+ OPS	40*	76*	60*	95*	59*	31*	35*
C6 MH CDA	56	86*	64*	103*	84*	42*	54*
C7 Mef CDA	37*	74*	59*	101*	84*	38*	45*
C8 Pac+ CDA	34*	115*	62*	114*	84*	55*	48*
CUT							
CONTROL	46	51	69	103	90	47	41
C1 MH OPS	50	29	21	22	20*	14*	17*
C2 Mef OPS	48	11	15	33	37*	25	24
C3 Mef OPS	35	16	9	14	9*	9*	10*
C4 Pac+ OPS	43	23	24	49	43*	30	30
C5 Pac+ OPS	33	15	17	27	24*	17	15*
C6 MH CDA	50	21	21	19	18*	21	23
C7 Mef CDA	40	19	19	30	33*	19	23
C8 Pac+ CDA	36	23	23	35	29*	25	21
S.E.	5.8	25.0	35.2	37.1	14.7	12.2	8.7

* = significantly different from control

On uncut plots differences between retardant treatments were not significant. On cut plots only OPS applications of MH and higher doses of mefluidide and the paclobutrazol mixture significantly reduced panicle densities compared to controls. CDA applications, which were at the lower doses, gave similar results to OPS spraying.

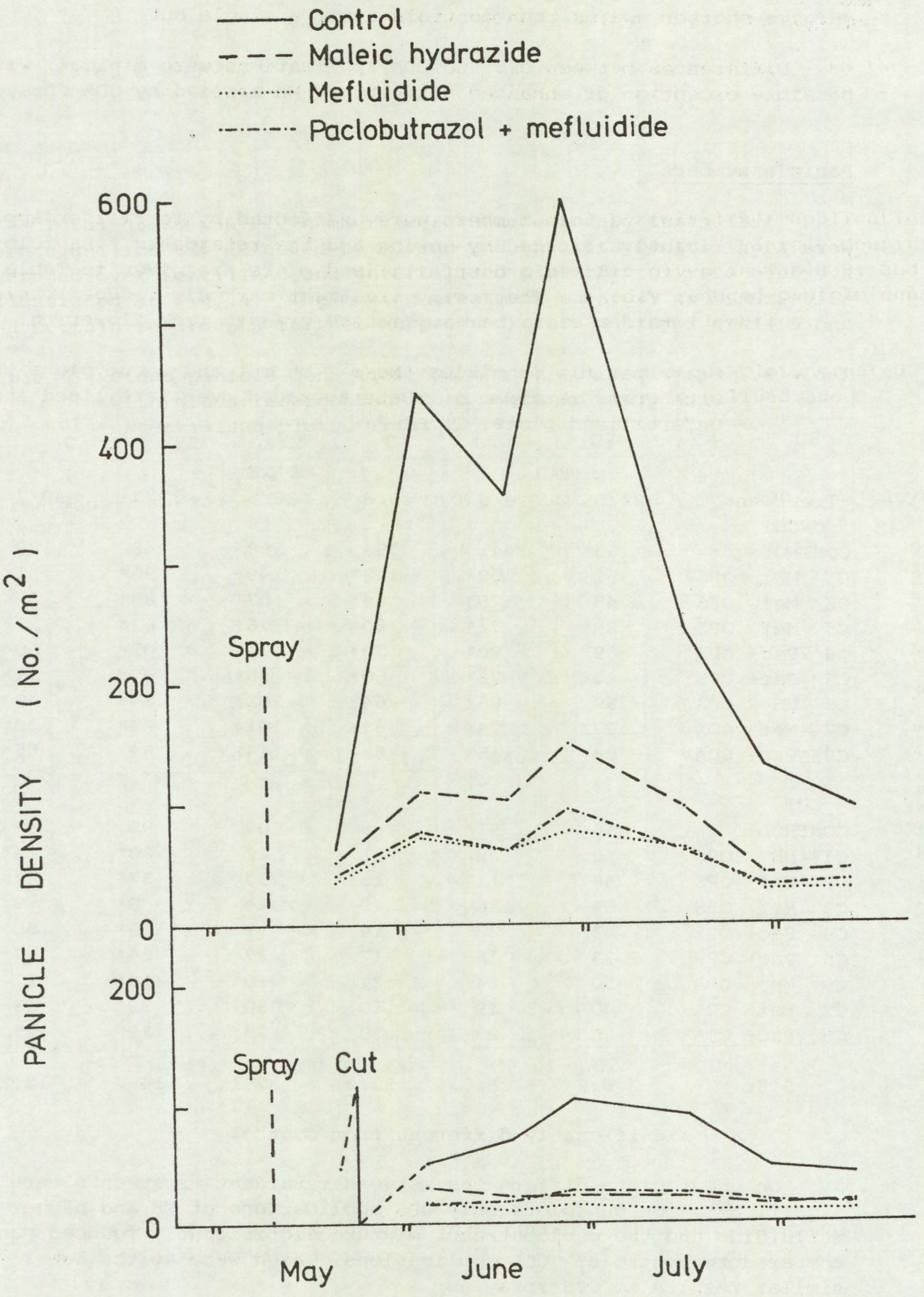

Fig. 4. Grass panicle densities on unmown and mown retardant-treated plots. Trial 2, Sullom Voe Terminal. Data averaged over fertilised and unfertilised plots.

Fescue, ryegrass and meadowgrass were the main components of the swards. The flower head densities of these species on unsprayed control plots during the season are given in Table 10.

Table 10. Panicle densities (No/m^2) of three grass genera on unsprayed control plots at different dates. Trial 2.

	DATE						
	21/5	4/6	18/6	28/6	17/7	30/7	13/8
UNCUT							
Fescue	52	269	210	314	104	96	65
Ryegrass	0	0	0	70	62	21	14
Meadowgrass	11	173	146	215	80	13	18
CUT							
Fescue	43	22	30	29	16	13	9
Ryegrass	0	0	0	34	49	30	25
Meadowgrass	3	29	39	40	24	5	7

The later-emerging ryegrass (L.perenne) was less affected by the cut than fescues and meadowgrasses: differences between cutting treatments were not significant for ryegrass. Fescue panicle densities were significantly reduced by retardants until the end of June, though there were no differences between chemicals. Meadowgrasses were significantly affected until August, with the retardants significantly improving flower suppression over a single cut. Differences between chemicals were not marked, though treatments containing mefluidide were consistently the best.

Appearance scores

"Brownness" scores (0 to 9) on plots were largely unaffected by mowing but were significantly affected by fertiliser and the retardants. There was no evidence of an interaction between these factors. Fertilised plots had a better appearance (lower score) than unfertilised plots (Table 11.).

Table 11. Brownness scores on unfertilised and fertilised plots. Trial 2.

	DATE						
	21/5	4/6	18/6	28/6	17/7	1/8	13/8
Unfertilised	3.96	5.32	5.67	5.65	6.50	5.28	4.69
Fertilised	4.06	5.46	5.00	4.78	5.59	4.20	3.69
S.E.	0.09	0.08	0.08	0.08	0.09	0.14	0.09

The control plots had moderate scores (Table 12) during the trial which increased in July as flowering heads turned brown. All plots had scores reflecting the stressed growing conditions; the amount of bare ground in the plot contributed to the score. Particularly high scores were found on plots treated with paclobutrazol; these plots were probably unacceptable. In June all plots had a significantly higher score than controls. From July, plots treated with MH and mefluidide improved, while paclobutrazol plots remained discoloured. This almost certainly reflected the severity of and the continuation of the paclobutrazol activity.

Table 12. Brownness scores on Trial 2 plots treated with different retardants.

Treatment	21/5	4/6	18/6	28/6	17/7	1/8	13/8
CONTROL	4.1	3.8	2.4	3.3	5.2	4.4	3.8
C1 MH OPS	3.0	4.7	5.8*	4.5	5.3	3.8	3.0
C2 Mef OPS	3.4	5.2	5.0*	4.2	5.5	3.6	2.8
C3 Mef OPS	4.1	5.9*	6.4*	5.8*	5.9	3.6	3.2
C4 Pac+ OPS	3.8	5.8*	5.3*	6.0*	7.3*	6.6*	5.9*
C5 Pac+ OPS	5.2	6.8*	7.0*	6.9*	7.4*	7.3*	6.8*
C6 MH CDA	3.7	5.2	5.2*	5.8*	5.6	4.0	3.5
C7 Mef CDA	4.2	5.3	5.3*	4.3	5.3	3.2	2.8
C8 Pac+ CDA	4.7	5.9*	5.5*	6.3*	6.9*	6.3*	5.9*
S.E.	0.67	0.50	0.43	0.41	0.36	0.40	0.29

* = significantly different from control

Clover cover

Analyses of clover cover showed no significant effects in May or August and weak retardant effects in June and July. Mean cover values were considerably less than those for Trial 1. Fertiliser affected clover cover in June and July. Average clover cover values are given below in Table 13. Cover decreased during the dry weather of June and July and increased in August. There were indications that clover was unaffected by mefluidide (C2,C3,C7) but adversely affected by maleic hydrazide (C1,C6). Reductions in cover were also noted on paclobutrazol plots. Clover plants on maleic hydrazide plots showed some leaf kill. Interestingly, clover leaf size was noticeably smaller on paclobutrazol plots. A retardant effect was occurring, confirming an effect observed in the laboratory on other dicotyledon species (Pers.comm. T West).

The implications for continued annual applications are that clover would be reduced by maleic hydrazide but unaffected by mefluidide. Further investigations with paclobutrazol are required to examine longer term effects on clover populations.

Table 13. Percentage cover of clover on four dates. Data averaged for retardants and for fertiliser treatment. Trial 2.

Retardants	21/5	18/6	17/7	13/8
CONTROL	19.2	13.3	10.8	35.8
C1 MH OPS	19.6	2.5	5.0	15.8
C2 Mef OPS	16.3	7.1	9.2	28.3
C3 Mef OPS	20.0	6.3	10.8	29.6
C4 Pac+ OPS	6.7	5.0	3.8	10.4
C5 Pac+ OPS	10.4	3.8	6.3	8.8
C6 MH CDA	19.6	2.1	5.8	13.8
C7 Mef CDA	17.9	9.2	10.0	27.5
C8 Pac+ CDA	17.1	9.6	9.6	21.3
Fertiliser				
+ N	16.0	7.7	8.9	22.4
- N	16.6	5.4	6.9	20.1

Sward composition

Sward composition in May, estimated by presence or absence in 0.04 m^2 quadrats, was as follows:

	% frequency
Fescue (Festuca spp.)	96.8
Bent (Agrostis capillaris)	21.9
Smooth stalked meadowgrass (Poa pratensis)	88.1
Ryegrass (Lolium perenne)	74.0
Annual meadowgrass (Poa annua)	80.1
White clover (Trifolium repens)	97.1

Analyses showed no initial differences associated with treatments, with the exception of fertiliser and Poa spp. It appeared that on average plots that were to receive fertiliser had more Poa annua and less Poa pratensis than the unfertilised. These differences had disappeared by the July assessment.

In July there were significant chemical effects on P.pratensis, L.perenne and T.repens. Fertiliser had increased L.perenne frequency, notably on the plots receiving 300 g/m^2. There were reductions of P.pratensis on high dose mefluidide and paclobutrazol mixture plots sprayed by OPS (C3,C4,C5) and on mefluidide CDA plots (C7) (Table 14.). Maleic hydrazide significantly reduced frequencies of L.perenne, and frequencies of T.repens when applied by OPS.

Table 14. Average frequencies of three species in May and July on retardant-treated plots at Sullom Voe Terminal. Trial 2.

Treatment	P.pratensis May	P.pratensis July	L.perenne May	L.perenne July	T.repens May	T.repens July
CONTROL	9.4	9.3	6.3	8.8	9.3	8.4
C1 MH OPS	8.1	8.4	7.8	7.0*	9.3	6.6*
C2 Mef OPS	9.7	7.8	7.7	9.6	10.0	9.3
C3 Mef OPS	8.9	6.8*	6.8	8.4	9.8	8.4
C4 Pac+ OPS	8.8	6.1*	6.9	9.5	9.8	7.5
C5 Pac+ OPS	7.8	6.1*	7.7	8.4	9.8	8.8
C6 MH CDA	8.7	8.3	8.3	5.8*	9.8	8.5
C7 Mef CDA	8.8	7.2*	8.0	8.8	9.8	9.3
C8 Pac+ CDA	9.2	8.0	7.3	7.8	9.9	9.2
S.E.		0.59		0.37		0.54

* = significantly different from controls

DISCUSSION

Sward heights and densities of grass heads were markedly reduced by cutting in May. A single spray of certain retardants gave swards that were similar to or shorter than those which only had a cut. Plots which were cut and sprayed were shortest, with mefluidide at 1.0 kg/ha (C3) and paclobutrazol (C4,C5,C8) giving the shortest. Maleic hydrazide showed some delay in activity whereas mefluidide stopped height increases almost immediately.

Panicle densities were affected by the cut. A retardant application in early May gave similar results to a single cut in mid-May. In combination with a cut best flower suppression was shown by maleic hydrazide and high doses of mefluidide and paclobutrazol. Among individual grass species, fescues and meadowgrasses were affected by cutting. Ryegrass flower heads emerged in July and were unaffected by the cut in May. Mefluidide gave good flower suppression in Poa spp.; maleic hydrazide was best at suppressing ryegrass. Both compounds gave some suppression of fescues but earlier application (See Trial 1) would have improved effects. Paclobutrazol alone does not inhibit grasses flowering; the inhibition that was observed was a result of the mefluidide in the mixture. Fertiliser had no effect on sward height or panicle density. In lowland Britain the use of fertiliser on swards that are to be treated with a retardant is not recommended. Indeed it may be counterproductive in encouraging growth. Under the conditions at Sullom Voe the present data indicate that fertiliser use on reclaimed areas could continue with a retardant regime.

Brownness scores, in contrast to height and head number, were affected by fertiliser but not by the cut in May. The stressed growing conditions gave generaly high scores, which fertiliser ameliorated. All retardant treatments caused significantly greater discolouration than controls in June. By July the shorter-lasting foliar retardant treatments of mefluidide and maleic hydrazide allowed improvements in appearance. Highest scores (up to 8.0) were recorded on paclobutrazol mixture plots and scores remained high until August. The higher dose of the mixture would probably be unacceptable in terms of appearance. The soil-uptake compound continued to be active up to August, indicating that any late season flush of growth, if it occurred, would be controlled. The foliar retardants would not control such a flush of vegetative growth, though flower inhibition would continue, judging from experience in the lowlands.

Clover cover on this trial was low averaging 13%. Nevertheless, some trends were noted; in particular clover was adversely affected by maleic hydrazide and a growth suppression effect was caused by paclobutrazol. Mefluidide did not obviously affect clover cover. Nitrogen fixation by clover is important for sward survival in such stressed environments. The implications of an annual growth retardant regime need to be considered. These data indicate that maleic hydrazide is likely to reduce clover; mefluidide would be "clover-safe". The continued use of a paclobutrazol mixture requires further investigation.

Analyses of sward composition in July reinforced the picture of the effect of maleic hydrazide on clover. Frequencies declined significantly from 9.3% to 6.6% in July on OPS sprayed plots. Other declines in grass frequencies, noted for ryegrass with maleic hydrazide and meadowgrass with mefluidide, would probably not be of significance, as other species would take advantage of any declines in populations.

In the light of the deleterious effects of maleic hydrazide on clover, the two other retardants would be more appropriate for use at Sullom Voe. Mefluidide is good at suppressing flowering, whereas paclobutrazol has a longer period of growth inhibition. The high dose of mefluidide gave good results, while the mixture with paclobutrazol was too effective at a rate of 2.0 + 0.26 kg/ha. At the lower rate, the mixture was less effective at inhibiting grass flowering. As the grass heads provide the most unsightly part of the sward and constitute the greatest fire risk later in the year, their suppression is important. On balance the trial results indicate that a high rate of mefluidide would be effective. An alternative which deserves investigation would be a paclobutrazol mixture with less paclobutrazol and more mefluidide, perhaps at doses of 0.7 + 0.4 kg/ha. The implications of continued use of paclobutrazol on clover would need to be looked at.

TRIAL 3. NC484.
OBSERVATION TRIAL ON SPRAYING BANKS.

TRIAL DETAILS

Three retardant treatments were applied by OPS and CDA sprayers on selected areas of bank adjacent to Trials 1 and 2. Sections of bank 5m long were selected in two replicate areas. Treatments were as follows:

Code	Retardant	Rate (kg (a.i.)/ha)	Applicator
CONTROL			
C1	Maleic hydrazide	5.6	OPS
C2	Mefluidide	0.4	OPS
C3	Paclobutrazol + mefluidide	1.0 + 0.13	OPS
C4	Maleic hydrazide	5.6	CDA
C5	Mefluidide	0.4	CDA
C6	Paclobutrazol + mefluidide	1.0 + 0.13	CDA

Spraying was carried out on 10 May 1984 by E J P Marshall, as part of the routine spraying out following Trial 2 applications. In the first replicate the height of bank required two passes of the sprayer. In the second replicate, three passes were needed. The banks were mown on 28 May.

OBSERVATIONS

Spraying on slopes presents certain difficulties. Walking along a contour made accurate application difficult, as walking speed was not easy to control. The more severe the slope, the less accurate the application. Avoidance of spray overlap was also more difficult on slopes, though treated areas were acceptable indicating this would be a minor problem. Under a commercial spray regime, spray lengths would be marked to minimise overlap. It was easier to spray with the lighter CDA sprayer than the OPS, though the OPS gave slightly more even coverage on the slopes.

The swards on the slopes were variable; some areas had large amounts of clover and little grass, others were patchy with bare areas. Nevertheless retardation was observed on all plots with obvious differences from controls at the begining of June. Some scorching at the top of the bank on the first replicate was noted in mid-June, the reasons for which are unclear.

CONCLUSIONS

1. Early applications of retardants gave significant control of sward growth and inhibition of flowering. Applications should be applied in mid-April.

2. A single cut in late May gave reasonable sward height and grass panicle suppression. Retardants applied in mid-May gave similar results to the single cut, though panicle suppression by mefluidide at 1.0 kg/ha was consistently better.

3. The combination of a cut with maleic hydrazide, mefluidide or paclobutrazol at high dose gave good grass flower suppression.

4. Sward height was adequately controlled by mefluidide and paclobutrazol + mefluidide mixtures and to a slightly lesser extent by maleic hydrazide.

5. Suppression of flowering of grasses was best with an early application of maleic hydrazide. The data indicate an early application of mefluidide would have been as effective. Later applications showed that doses of 1.0 kg/ha of mefluidide and the higher dose of the paclobutrazol mixture were effective.

6. Flowering in ryegrass was best suppressed by maleic hydrazide. Flowering in meadowgrasses was largely inhibited by mefluidide.

7. Growth suppression (but not flower inhibition) by maleic hydrazide and mefluidide ceased after about 8 weeks. Paclobutrazol activity lasted at least 14 weeks.

8. High doses of paclobutrazol gave unacceptable appearance.

9. Maleic hydrazide reduced cover and frequency of clover. Mefluidide was "clover-safe". Paclobutrazol retarded clover growth; its effect on clover frequency requires further investigation.

10. Fertiliser applications on the poor substrates could be continued without affecting growth retardant activity.

On balance it is recommended that mefluidide applied by mid-April at doses of 0.4 or 1.0 kg/ha, with or without a subsequent cut, would give adequate sward control. In areas where appearance is of lower importance than fire risk and height control, a mixture of paclobutrazol + mefluidide may be more suitable, giving longer sward control.

Re-application of the retardants in mid-April 1985 would allow an assessment of the favoured treatments; the implications of long-term use could be better assessed, particularly for clover content. In addition, a re-examination of the treatments would allow an insight into retardant effects under different seasonal conditions.

ACKNOWLEDGEMENTS

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ABBREVIATIONS

ångström	Å
Abstract	Abs.
acid equivalent*	a.e.
acre	ac
active ingredient*	a.i.
approximately equal to*	$\simeq$
aqueous concentrate	a.c.
bibliography	bibl.
boiling point	b.p.
bushel	bu
centigrade	C
centimetre*	cm
concentrated	concd
concentration	concn
concentration x time product	ct
concentration required to kill 50% test animals	LC50
cubic centimetre*	cm^3
cubic foot*	ft^3
cubic inch*	in^3
cubic metre*	m^3
cubic yard*	yd^3
cultivar(s)	cv.
curie*	Ci
degree Celsius*	^oC
degree centigrade	^oC
degree Fahrenheit*	^oF
diameter	diam.
diameter at breast height	d.b.h.
divided by*	÷ or /
dry matter	d.m.
emulsifiable concentrate	e.c.
equal to*	=
fluid	fl.
foot	ft
freezing point	f.p.
from summary	F.s.
gallon	gal
gallons per hour	gal/h
gallons per acre	gal/ac
gas liquid chromatography	GLC
gramme	g
hectare	ha
hectokilogram	hkg
high volume	HV
horse power	hp
hour	h
hundredweight*	cwt
hydrogen ion concentration*	pH
inch	in.
infra red	i.r.
kilogramme	kg
kilo ($x10^3$)	k
less than	<
litre	l.
low volume	LV
maximum	max.
median lethal dose	LD50
medium volume	MV
melting point	m.p.
metre	m
micro ($x10^{-6}$)	µ
microgramme*	µg
micromicro (pico: $x10^{-12}$)*	µµ
micrometre (micron)*	µm (or µ)
micron (micrometre)*†	µm (or µ)
miles per hour*	mile/h
milli ($x10^{-3}$)	m
milliequivalent*	m.equiv.
milligramme	mg
millilitre	ml

† The name micrometre is preferred to micron and µm is preferred to µ.

millimetre*	mm
millimicro* (nano: x10^{-9})	n or mμ
minimum	min.
minus	-
minute	min
molar concentration*	M (small cap)
molecule, molecular	mol.
more than	>
multiplied by*	x
normal concentration*	N (small cap)
not dated	n.d.
oil miscible concentrate	o.m.c. (tables only)
organic matter	o.m.
ounce	oz
ounces per gallon	oz/gal
page	p.
pages	pp.
parts per million	ppm
parts per million by volume	ppmv
parts per million by weight	ppmw
percent(age)	%
pico (micromicro: x10^{-12})	p or μμ
pint	pint
pints per acre	pints/ac
plus or minus*	±
post-emergence	post-em
pound	lb
pound per acre*	lb/ac
pounds per minute	lb/min
pound per square inch*	lb/in^2
powder for dry application	p. (tables only)
power take off	p.t.o.
precipitate (noun)	ppt.
pre-emergence	pre-em.
quart	quart
relative humidity	r.h.
revolution per minute*	rev/min
second	s
soluble concentrate	s.c.
soluble powder	s.p.
solution	soln
species (singular)	sp.
species (plural)	spp.
specific gravity	sp. gr.
square foot*	ft^2
square inch	in^2
square metre*	m^2
square root of*	$\sqrt{\ }$
sub-species*	ssp.
summary	s.
temperature	temp.
ton	ton
tonne	t
ultra-low volume	ULV
ultra violet	u.v.
vapour density	v.d.
vapour pressure	v.p.
varietas	var.
volt	V
volume	vol.
volume per volume	v/v
water soluble powder	w.s.p. (tables only)
watt	W
weight	wt
weight per volume*	w/v
weight per weight*	w/w
wettable powder	w.p.
yard	yd
yards per minute	yd/min

* Those marked * should normally be used in the text as well as in tables etc.

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