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areas. To produce a new equilibrium of species a change in overall management is needed. Continuing but perhaps infrequent applications may be required, and combination with other cultural or mechanical techniques may also be necessary.

1.5 Research

The potential uses of chemicals for weed control in amenity situations are obvious, and most requirements are met by developments in agricultural grassland weed control. Research efforts have therefore not included the control of broad-leaved plants, except for demonstration trials of scrub control using available compounds. The bulk of the work described in this report is on the effects of herbicides and growth regulators on amenity grass swards. By the nature of the project, experiments have been of short duration mostly lasting one season. The aims of herbicide treatments have been to elucidate useful selectivities between grass species, by changing dose and time of year of spraying. A general reduction in grass growth has also been sought. An increase in desirable dicotyledon species has also been an aim of treatment. An important aspect of any treatment is the subsequent effect on appearance; this factor has been included in assessments. Growth regulators have been examined for effect, period of sward retardation and appearance; applications have also been made at different times of year. The effects of repeated annual application of retardants on sward composition have also been investigated in two trials, one sprayed for three years, the second for two years.

Further work has been limited to trials of birch, pine, hawthorn and hazel control, and a single trial examining the potential of wild flower seed introduction into established grassland.

Experiments have been entirely conducted in the field, mostly on amenity sites. Grassland trials have been conducted in two stages. Preliminary investigations of herbicides and growth regulators have employed a logarithmic-sprayer. Doses of applied chemical are halved every 5m along 20m long plots. A large number of chemicals can be examined, and a series of trials in spring, summer and autumn were set up using this technique. Compounds were selected from those currently available for agricultural, horticultural and forestry use. The second stage trials have been sprayed with selected chemicals at finite doses using an Oxford Precision Sprayer (OPS), at a volume rate of 200 $l\ ha^{-1}$. These trials have allowed more detailed assessments of chemical effects.

To arrive at valid recommendations for managers it is necessary to understand the effects of repeated chemical use on sward composition. The results of one trial with herbicides, and two with growth retardants, are useful in this respect. However most of the work reported here is short term, giving information on sward reactions to chemicals over the first season.

2. HERBICIDES IN AMENITY GRASSLAND

2.1. Preliminary trials

2.1.1. Methods

A series of eight trials were conducted with a range of herbicides applied by logarithmic-sprayer, a hand-held machine designed to spray a 20m long, 1m wide plot. The dose of chemical applied was halved every five metres along the plot. The grassland sites ranged from waste ground dominated by couch grass (*Elymus repens*), to country parks with mixed species swards.

Applications were made in spring, summer or autumn. As observational trials the experiments provided experience and insight into the likely effects of a range of doses on a number of swards. The trials were assessed for appearance in terms of "brownness" on a subjective 0-9 scale, and were studied for a general reduction in sward height and bulk, and for selectivity between species. The trials, their location and sward type are listed in Table 7.

Table 7
Logarithmic-sprayed trials with herbicides

Trial code No.	Location	Sward type	Application time (spring, summer, Autumn)
NC-1-78	Draycote Country Park	Mixed - *Holcus lanatus*	A
NC-3-79	Waseley Country Park	Mixed	A
NC-2-80	WRO	Waste ground-*Elymus repens*	Sp.,Su.,A
NC-5-80	Forhill Picnic Area	Mixed	Sp.
NC-7-80	Oxford Airport	*Arrhenatherum-Festuca*	Su.
NC-8-80	Draycote Country Park	Mixed - *H.lanatus*	Su.
NC-9-80	Oxford Airport	*Arrhenatherum-Festuca*	A
NC-11-81	WRO	*E.repens*	A

The herbicides that have been included in the trials are listed in Table 8. The compounds included grass-specific herbicides (alloxydim, dalapon, fluazifop and sethoxydim), and "total" or broad spectrum herbicides (aminotriazole, atrazine, glyphosate, paraquat and propyzamide). The remaining compounds have shown some selectivity between grass species (e.g. Haggar & Squires, 1979).

Table 7

Herbicides used in log-sprayed trials, their uptake and recommended use

Chemical	Uptake & Action	Weed control uses. Dose in kg a.i./ha
Alloxydim	Foliar + soil	Annual + perennial grasses @ 0.75-3.0
Aminotriazole	Foliar; translocated	*A.repens* + other weeds @ 4.5
Asulam	Foliar; translocated	Docks in grass @ 1.7; Bracken @ 4.5
Atrazine	Soil	Total weed control; grass in forestry; in roses @ 1.5-5.0
Carbetamide	Soil (+ foliar)	Annual grasses in winter; *H.lanatus* @ 3.0
Dalapon	Foliar (+ soil); transloc.	Annual + perennial grasses @ 5.0-17.0
Ethofumesate	Soil + translocated	Weeds in grass crops @ 1.0-2.0
Fluazifop	Foliar + soil	Annual + perennial grasses @ 0.25-2.0
Glyphosate	Foliar; translocated	Most annual + perennial plants @ 0.5-2.2
Linuron	Contact + soil	Weeds in potatoes carrots, parsnips @ 0.5-3.4
Paraquat	Contact	Annual weeds; top kill on perennials @ 0.3-1.4
Propyzamide	Soil	Winter use in perennial crops; ornamentals @ 1.4-3.4
Sethoxydim	Foliar + soil	Annual + perennial grasses @ 0.5-2.0

2.1.2. Results

The coarse vegetation of couch grass - dominated waste ground is only representative of the most derelict amenity situations, and the results are of limited application. Where spring and summer applications were effective, they were accompanied by scorching and poor appearance. Asulam, carbetamide and linuron had little effect. Control of couch (*E.repens*) in spring was given by high doses of atrazine (>3.0 kg ha^{-1}), dalapon (>4.5 kg ha^{-1}), ethofumesate (>4.5 kg ha^{-1}) and propyzamide (>2.0 kg ha^{-1}). Summer and autumn applications of aminotriazole (2.0 kg ha^{-1}), dalapon (6.0 kg ha^{-1}), glyphosate (1.0 kg ha^{-1}) and propyzamide (2.0 kg ha^{-1}) were also effective against *E.repens*. Autumn trials of alloxydim (4.0 kg ha^{-1}), fluazifop and sethoxydim (both 1.5 kg ha^{-1}) gave no control. In general, control of grasses resulted in increases in dicotyledons, notably cleavers (*Galium aparine*), creeping thistle (*Cirsium arvense*) and nettles (*Urtica dioica*), none of which are desirable.

On mixed swards useful results were given by the logarithmic-sprayed trials. Patterns of brownness score were variable, depending on compound. Speed of development ranged from paraquat, taking 24 hours for marked scorch symptoms to appear, to 3 weeks for asulam. The changes in score over time are illustrated for experiment NC-2-80 in Fig.1. Applications in spring and summer have in general caused unacceptable discolouration of the sward. Autumn applications provide the most useful treatments, as discolouration while it still occurs is limited to a time of year when visitor numbers are lowest. Of equal importance, coarse grasses are still translocating reserves at this time of year, and are likely to be more affected by herbicides than at other times. Other desirable components of the sward, particularly short-growing flowers, are less likely to be present in the sward canopy at this time, and so will be unaffected by foliar-acting compounds.

Reductions in sward height and bulk have been recorded at several trials, and the results are summarised in Table 9.

Table 9
Dose ranges and times of application of herbicides which have subsequently given reductions in grass bulk. Data from log-sprayed plots on amenity swards.

	Dose range (kg ha^{-1} a.i.)		
Chemical	Spring	Summer	Autumn
Alloxydim	*	*	-
Aminotriazole	2.0-3.5	0.5-1.5	1.1-2.0
Asulam	2.0-4.0	-	1.5-3.5
Atrazine	-	-	-
Carbetamide	-	-	-
Dalapon	1.0-4.5	1.3-2.5	2.2-5.5
Ethofumesate	-	-	4.0-8.0
Fluazifop	*	*	-
Glyphosate	-	0.5-1.5	0.2-0.7
Linuron	1.5-4.0	-	-
Paraquat	-	1.0	0.3-1.0
Propyzamide	1.3-2.0	0.5-1.0	0.8-1.0
Sethoxydim	*	*	-

* Not investigated

Selectivities between grass species were difficult to identify on the log-sprayed plots. Nevertheless, species were resistant to some treatments, and selective control of Yorkshire fog (*H.lanatus*) was demonstrated. A summary of effects on individual grasses is given in Table 10.

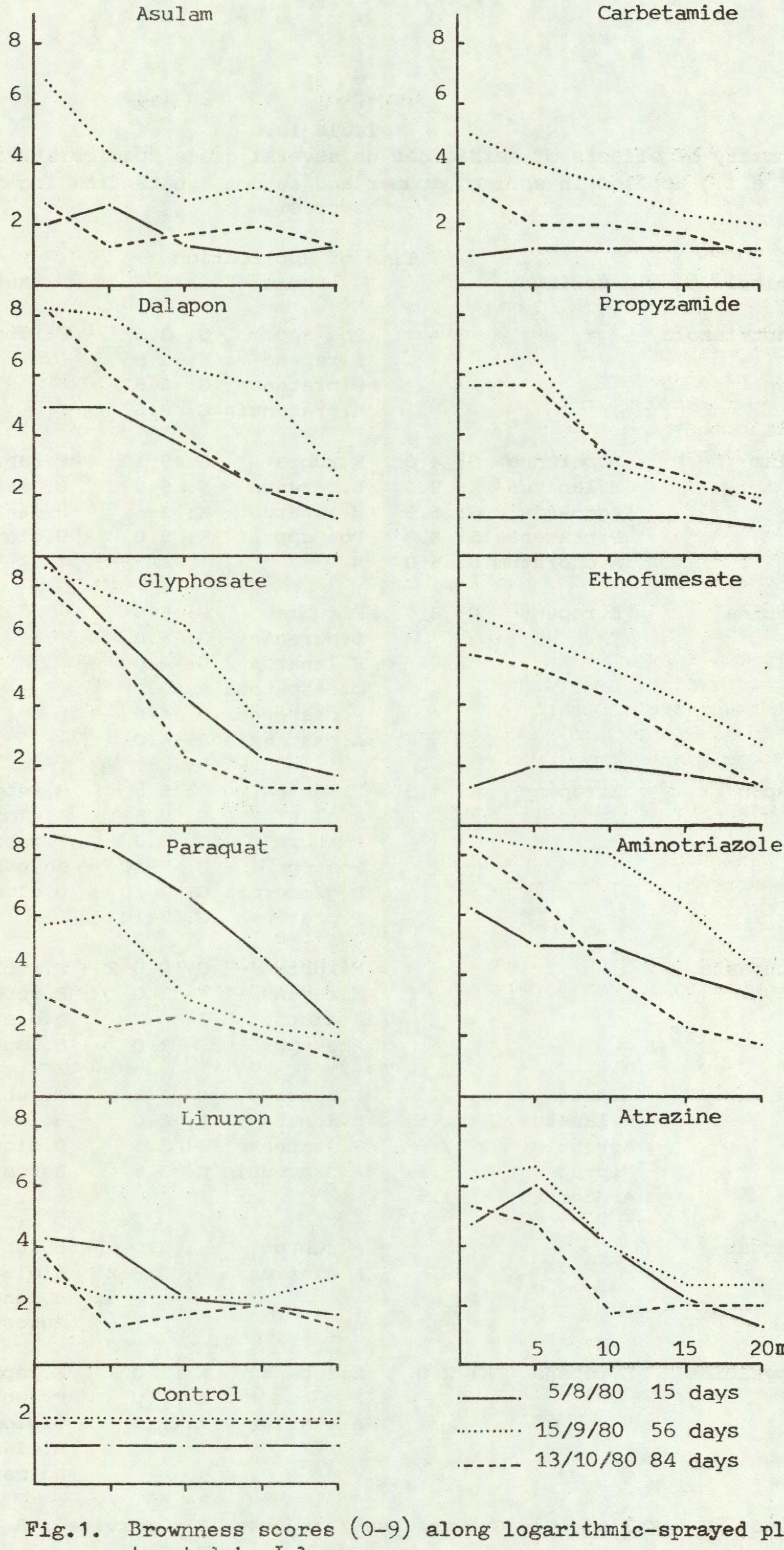

Fig.1. Brownness scores (0-9) along logarithmic-sprayed plots treated in July.
Experiment NC-2-80.

Table 10.

A summary of effects of herbicides on several grass species at various doses (kg ha^{-1} a.i.) applied in spring, summer and autumn. Data from log-sprayed amenity swards.

Chemical	Spring		Summer		Autumn	
Aminotriazole			Poa spp.	G: 3.5	F.rubra	S: 2.0
			E.repens	K: 1.5		
			P.pratense	G: 3.5		
			A.pratensis	G: 3.5		
Asulam	L.perenne	S: 4.0	F.rubra	G: 5-10	F.rubra	S: 4.0
	H.lanatus	K: 2.0	L.perenne	S: 6.0	L.perenne	S: 6.0
	Agrostis	G: 5.0	H.lanatus	K: 3-6	H.lanatus	K: 1.0
	P.pratense	S: 4.0	Poa spp	K: 5.0	D.glomerata	S: 4.0
	A.odoratum	S: 5.0				
Atrazine	E.repens	K: 3.0	F.rubra	G: 5.0		
			L.perenne	G: 5.0		
			H.lanatus	G: 4.0		
			D.cespitosa	R: 3.0		
			P.pratense	S: 4.0		
			A.pratensis	S: 4.0		
Dalapon	E.repens	K: 4.5	E.repens	G: 3.5	E.repens	K: 6.0
			A.elatius	G: 2.5-10	A.elatius	G: 2.5
			F.rubra	G: 5.0	F.rubra	G: 2-10
			Poa spp	G: 7-10	Agrostis	S: 7.5
			D.glomerata	G: 7-10	D.glomerata	G: 2-8
			P.pratense	G: 7-10		
Glyphosate			F.rubra	G: 0.6-2	F.rubra	S: 0.4
			E.repens	K: 1.0	E.repens	K: 1.5
			A.elatius	G: 0.7	A.elatius	K: 0.7-2
			Poa spp	G: 1.0	H.lanatus	S: 0.2
Linuron	L.perenne	S: 3.5	F.rubra	G: 3.5	F.rubra	S: 4.0
	H.lanatus	K: 1.5	H.lanatus	K: 2.0	H.lanatus	K: 1.5
	Agrostis	S: 3.5	P.pratense	S: 3.5	D.glomerata	R: 4.0
	P.pratense	S: 3.5	A.pratensis	G: 3.5	Agrostis	R: 4.0
	A.odoratum	S: 3.5				
Paraquat			F.rubra	K: 1.0	F.rubra	K: 0.5
			A.elatius	G: 0.8-2	A.elatius	G: 0.5-2
					H.lanatus	G: 0.3-1
					Agrostis	G: 0.1-1
Propyzamide	E.repens	K: 2.0	E.repens	K: 2.0	E.repens	K: 2.5
			F.rubra	K: 2.0	F.rubra	K: 0.5
			A.elatius	K: 2.0	D.glomerata	R: 3.0
					A.elatius	G: 0.5-2
					Agrostis	K: 1.0

Legend: K = Killed; G = Growth check/ reduced; S = Survived; R = Resistant.

H.lanatus can be controlled in mixtures of grasses with linuron between 1.5 and 3.0 kg ha^{-1}, or with asulam between 2.0 and 4.0 kg ha^{-1}. This result is in agreement with Harkness & Hope (1974). Established *Dactylis glomerata* was resistant to at least 3.0 kg ha^{-1} of propyzamide. *Deschampsia cespitosa* was resistant to 3.0 kg ha^{-1} of atrazine.

2.2. Main herbicide experiments.

2.2.1. Methods

Five experiments have investigated herbicides on various grasslands in more detail than the log-sprayed trials. The experiments, listed in Table 11 were sprayed with an Oxford Precision Sprayer (OPS) giving a finite dose of herbicide, at a volume rate of 200 l ha^{-1}. Applications were made in the autumn, as preliminary trials indicated better and more appropriate effects would result at this time.

Table 11.
Experiments with herbicides in grassland, applied at finite doses.

Trial code No.	Location	Sward type
NC- 1-79	Fish Hill Picnic Area	A: *Festuca-Agrostis* B: *Arrhenatherum elatius*
NC-15-80	Oxford Airport	*A.elatius*
NC-16-80	A: Forhill; B: Waseley	Mixed swards.
NC-12-81	Waseley	Mixed swards
NC-15-81	Oxford Airport	*A.elatius*

Experiments were assessed for appearance using the brownness score (0-9); sward heights were measured using a sward stick (Castle,1976) with a plate lowered down a ruler onto the sward and a height reading obtained. Sward composition was assessed by species presence or absence in quadrats.

2.2.2. Experiment descriptions

2.2.2.1. NC-1-79 Fish Hill, Hereford and Worcester

Site and treatment details

The experiment was set up on two contrasting grass areas in a picnic area on the top of the Cotswold scarp. The area is based on limestone and the site had been created about 10 years previously as part of a road-widening scheme.

Block A - was initially a mown sward (cut 4-5 times a year) consisting mainly of *Agrostis* and *Festuca* spp. with *Poa* spp., *Dactylis glomerata* and *Elymus repens*. Mowing operations ceased at the start of the experiment.
Block B - was an irregularly cut (<1 a year) rough grass area dominated by *Arrhenatherum elatius*.

Plots - were 2m by 2m, with 1m discard areas between. Five herbicides and two controls constituted one replicate. On Block A there were 6 replicates; on Block B there were 4.

Date of spraying:	29.11.79	17.9.80 (only 1/2 the replicates)	15.10.81
Chemical		Dose (kg ha^{-1} a.i.)	
Asulam	2.5	2.5	2.5
Dalapon	5.0	5.0	5.0
Glyphosate	0.3	0.3	0.5
Linuron	2.5	2.5	2.5
Paraquat	0.4	0.4	0.5

Half the replicates were sprayed annually, half were sprayed in 1979 and 1981.

Results

A subjective assessment of brownness of each plot was made at irregular intervals. Plots were scored from 0 (= all green) to 9 (= all brown and bare ground). The scores of plots sprayed annually are shown in Fig.2 over the period 1979 to 1982. The scores for the control plots have increased each winter, particularly on Block A. During the experiment the plots were not mown, and as a result vegetative litter has accumulated. The unmown Block B plot scores were consistently higher than Block A, reflecting the greater amounts of standing dead plant material.

Most rapid scorch of the plots was shown by paraquat; dalapon and glyphosate effects took longer to develop. Asulam and linuron had only small effects on Block A plot appearances; greater effects were shown on the Block B sward. In general, plot scores returned to values similar to unsprayed controls by May or June. But plots were obviously discoloured in spring.

The heights of the grass in treated plots were measured on three occasions using a sward stick (Castle 1976)(Table 12). The sward heights should not be compared between times. In June 1980 on Block A, no herbicide gave swards significantly shorter than controls. In June 1981, dalapon, glyphosate and paraquat plots which had been treated twice were significantly shorter than controls. In 1982, dalapon and glyphosate gave shortest plots. On Block B no significant differences to controls were recorded, except for dalapon plots in June 1980.

Table 12

Sward heights (cm) on plots sprayed with herbicides annually (A) or biennially (B). Block A, experiment NC-1-79.

	Sward height (cm)					
Date of assessment	26.6.80		26.6.81		21.5.82	
Annual/biennial	A	B	A	B	A	B
No. sprays received	1		2	1	3	2
Chemical						
Asulam	23.7		36.7	34.1	19.1	16.5
Dalapon	18.0		28.8	35.3	12.6	17.4
Glyphosate	23.1		30.7	42.9	13.3	14.0
Linuron	19.7		34.5	31.5	22.5	18.9
Paraquat	19.0		29.1	33.9	20.1	16.5
Control	21.1		42.8		21.8	
S.E.	1.11		3.30			

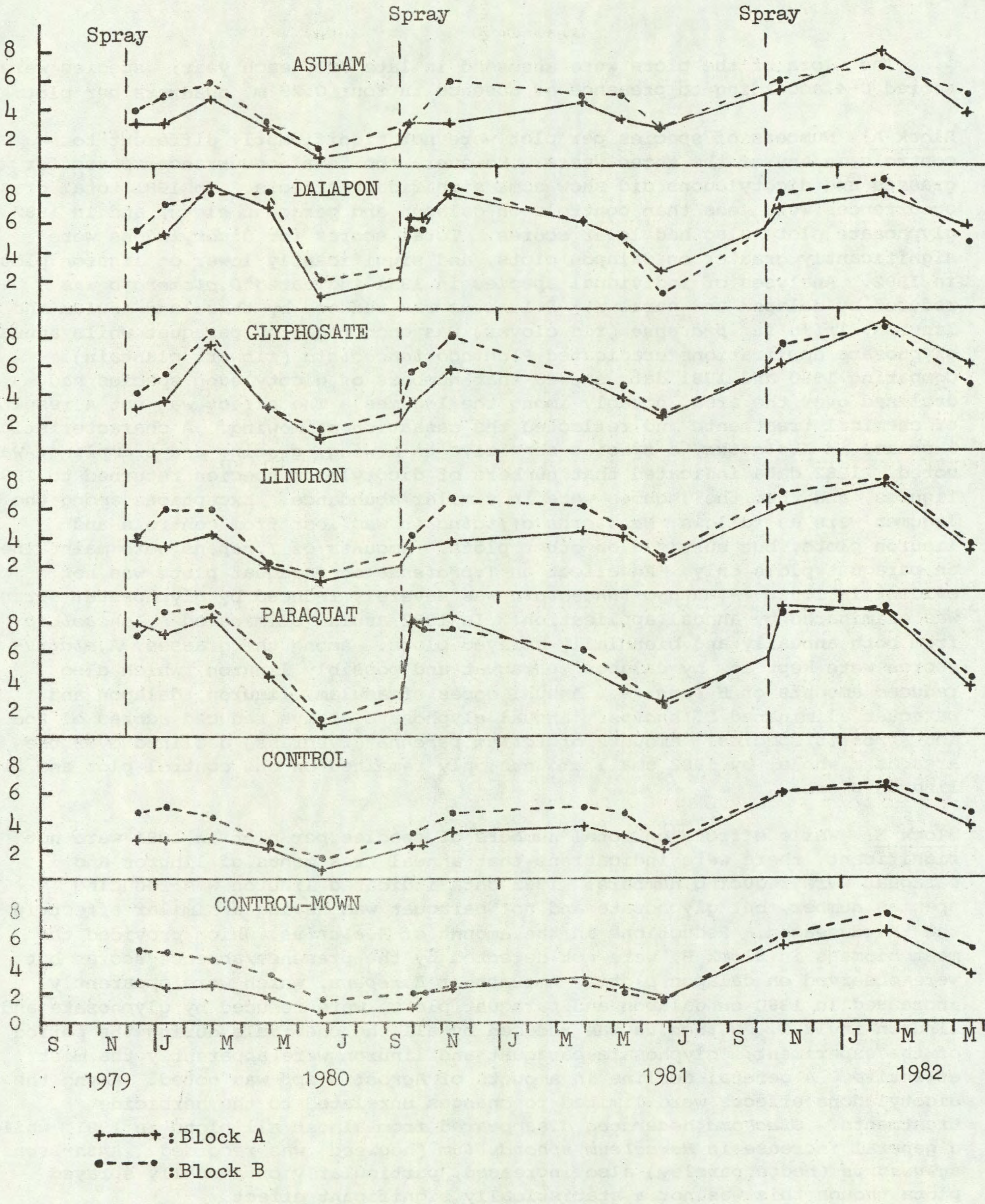

Fig.2. Brownness scores (0-9) of two swards (A & B) treated with herbicides over three seasons. Experiment NC-1-79

The flora of the plots were assessed in late July each year; species were scored 0-4, according to presence or absence in four 0.25 m^2 quadrats per plot.

Block A: Numbers of species per plot were not significantly different to controls in any of the three years. However, the total occurrence scores for grasses and dicotyledons did show some significant effects. In 1981 total grass occurrences were less than controls on dalapon and paraquat plots, and in 1982 glyphosate plots also had lower scores. Total scores for dicotyledons were significantly greater on dalapon plots, and significantly lower on linuron plots in 1982. Analyses of individual species in 1981 indicated *D.glomerata* was reduced by dalapon and paraquat; *H.lanatus* was reduced by these and asulam and linuron; *Trifolium pratense* (red clover) was encouraged by paraquat while annual glyphosate applications eradicated *Plantago lanceolata* (ribwort plantain). Comparing 1980 and 1981 data showed that numbers of dicotyledon species had declined over the area, notably among the legumes. The effect was not a result of chemical treatments and reflected the cessation of mowing. A characteristic increase in *A.elatius*, a species sensitive to mowing, grazing and trampling, was noted. 1982 data indicated that numbers of dicotyledon species returned to 1980 figures, and that the legumes were in similar abundance. Exceptions among the legumes were as follows: *Melilotus officinalis* was lost from controls and linuron plots, but survived on other plots. Amounts of *T.repens* were maintained on paraquat plots only. An effect on *T.pratense* on paraquat plots was not evident in 1982. *Plantago lanceolata* was severely reduced by glyphosate; it was eliminated by annual application. In 1982 asulam eliminated *P.lanceolata* from both annually and biennially-sprayed plots. Among the grasses, *A.elatius* scores were kept low by dalapon, paraquat and possibly linuron, which also reduced amounts of *H.lanatus*. Annual doses of asulam, linuron, dalapon and paraquat eliminated *H.lanatus*. Annual glyphosate sprays reduced scores of *Poa* and *Agrostis* species. Amounts of *Lolium perenne* (ryegrass) declined over the area as a whole; by 1982 small amounts only remained on one control plot and two linuron plots.

Block B: While effects on total numbers of species per plot in 1981 were not significant, there were indications that annual treatments of linuron and paraquat were reducing numbers. 1982 data indicated linuron was reducing species number, but glyphosate and not paraquat was having a similar effect in the third season. Reductions in the amount of *A.elatius*, which provided the most biomass in Block B, were not detected by the presence/absence scores but were observed on dalapon plots. Amounts of *E.repens*, which were apparently increased in 1980 on dalapon and paraquat plots, were reduced by glyphosate and linuron in 1982. *H.lanatus* was reduced by all the chemicals during the period of the experiment; glyphosate paraquat and linuron were apparently the most effective. A general decline in amounts of *Agrostis* spp was noted. Among the dicotyledons effects were limited to changes unrelated to the herbicide treatments. *Glechoma hederacea* disappeared from almost all plots in 1981, while a general increase in *Heracleum sphondylium* (hogweed) was recorded. *Anthriscus sylvestris* (hedge parsley) also increased, particularly on annually sprayed plots though this was not a statistically significant effect.

Discussion

It is apparent that on their own the herbicides at the doses used did not create short swards. Without mowing there was an accumulation of dead vegetation, which gave a poor appearance (Fig.2.) even on controls. Nevertheless, dalapon, glyphosate and possibly paraquat did give a check on grass growth, and some dicotyledons were encouraged. A marked decline in legumes in 1981 was noted on Block A as a result of the changed management. However, by 1982 this decline had been reversed. It appears that a period of equilibration followed the start of the trial. On the rough grass area (Block B), dalapon checked grass growth, giving a reduced sward height in 1980. Otherwise, changes reflected the overall management (or rather the lack of it), and herbicide effects were few. While effects on total numbers of species were not significant, lower numbers of dicotyledons were found on linuron and glyphosate plots (Table 13). Asulam, dalapon and paraquat plots maintained species numbers.

On Block A control plots, *Melilotus officinalis* (common melilot) disappeared together with *Cynosurus cristatus* (crested dogstail). On Block B controls, more species were lost including *Medicago lupulina* (black medick), *M.officinalis*, *Vicia hirsuta* (hairy tare), *Glechoma hederacea* (ground ivy) and *L.perenne* (ryegrass). Recruitments to Block A controls included *Cerastium* sp (chickweed), *Potentilla reptans* (creeping cinqfoil), *Rumex obtusifolius* (broad leaved dock) and *Carex hirta* (hairy sedge). Block B controls gained *Ranunculus acris* (meadow buttercup), *Vicia sativa* (common vetch), *A.sylvestris*, and *Torilis japonica* (upright hedge-parsley).

Among the less common dicotyledons in the plots, several recruitments are noteworthy, though their appearances may be unrelated to herbicide spraying. *M.officinalis*, which disappeared from control plots, either appeared or survived on all but linuron-sprayed plots. *Lathyrus pratensis* grew on asulam and paraquat plots, and *Potentilla reptans* appeared on all but glyphosate and paraquat plots. On Block B, *Geum urbanum* (herb bennet) appeared in all plots, and *Rhinanthus minor* (yellow rattle) was found on asulam, paraquat and linuron plots. *Knautia arvensis* (field scabious) appeared on dalapon and paraquat plots, and *Prunella vulgaris* also grew on paraquat plots. A single plant of *Ophrys apifera* (bee orchid) was found on a biennially-sprayed asulam plot.

To conclude, the trial indicated that the removal or breakdown of vegetative litter is important; this is usually achieved by mowing. The herbicides at low doses could give some check of grass growth, without eradicating desirable species but could not stop the accumulation of litter and, without mowing, some of the taller undesirable dicotyledons were encouraged, e.g. *H.sphondylium*. Dalapon and paraquat were the most promising of the herbicides.

Table 13.

Average numbers of dicotyledon species, and total number of species on herbicide treated plots in July 1982. Experiment NC-1-79

	Treatments											
	Asulam		Dalapon		Glyphosate		Linuron		Paraquat		Control	
Block	A	B	A	B	A	B	A	B	A	B	A	B
Mean No. dicotyledon species	5.67	8.25	7.83	7.75	6.50	6.25	5.50	6.75	8.33	8.25	7.17	7.25
Mean total No. species	11.67	12.50	13.67	12.00	12.33	9.50	12.17	11.00	14.17	12.25	14.00	12.25

2.2.2.2. NC-15-80 Oxford Airport

Site and treatment details

On a piece of irregularly cut rough grassland, an unrandomised trial of the effects of five herbicides applied at seven times from October to December was laid out. The sward was mainly a mixture of *A.elatius* and *F.rubra*. Plots were 2m by 2m with 1m discard strips between, and two replicates were treated. Doses and times of application were as follows:

Dates of spraying	Chemical	Dose (kg ha^{-1})
10.10.80	Aminotriazole	1.5
20.10.80	Dalapon	5.0
30.10.80	Glyphosate	0.5
7.11.80	Paraquat	0.5
18.11.80	Propyzamide	0.75
28.11.80		
8.12.80		

Results

In February 1981 the experimental area, including untreated grass, had poor appearance with much standing dead vegetation, giving a "brownness" score of 8.5. By May plot appearances had improved, but all plots were worse than untreated areas. Propyzamide plots had highest scores, followed by dalapon plots. Trends associated with time of application were limited to dalapon which gave greatest scorch on plots sprayed on the last three dates.

Species compositions of treated plots and adjacent control areas were assessed in July 1981, by noting presence or absence in five 30 cm x 30 cm untreated areas; these data would be expected to only show up large differences between plots. Trends that were noted are as follows:-

Aminotriazole	:	Increases in *Cirsium arvense* with later applications. On the second replicate *E.repens* was reduced, while *H.sphondylium* increased.
Dalapon	:	Reduction in *A.elatius* (one replicate). Slight reduction in *Convolvulus arvensis* (one replicate).
Glyphosate	:	No changes on one replicate. Increased amounts of *Heracleum sphondylium* on the second.
Paraquat	:	Increases in *Glechoma hederacea*, *Lathyrus pratensis* and possibly *E.repens* on one replicate. A slight reduction of *D.glomerata* on the other.
Propyzamide	:	Reductions in *A.elatius* and *F.rubra* were found on both replicates and were accompanied by increases of *G.hederacea* and *Pastinaca sativa* on one replicate, and increases of *Galium aparine* and *H.sphondylium* on the second.

Discussion

Consistent effects associated with time of application were not found. Control of grasses was particularly vigorous with low doses of propyzamide, leaving brown plots in May. More acceptable check on grasses was found with dalapon and paraquat. In general, grass control was accompanied by unpredictable increases in dicotyledons. The tall umbellifers, hogweed (*H.sphondylium*) and wild parsnip (*P.sativa*) increased, though the shorter ground ivy (*G.hederacea*) also did well. Tall herb vegetation may provide a more interesting habitat than grass in rough areas of amenity sites, but it will become impenetrable in time. Species such as cleavers (*G.aparine*) thistles (*Cirsium* spp.) and bramble (*Rubus* spp.) if present, would be expected to increase under such circumstances.

2.2.2.3. NC-16-80 Forhill Picnic Area and Waseley Country Park, Hereford & Worcester.

Site and treatment details

An unreplicated trial was set up in two amenity sites near Birmingham. Five herbicides were applied to grass plots 2m by 5m on 25.11.80, at the following doses:

Aminotriazole	1.5 kg ha^{-1} a.i.
Dalapon	5.0
Glyphosate	0.5
Paraquat	0.5
Propyzamide	0.75

Results

Scores were made in early March, early April and late June (Table 14). Marked vegetation kill was noted on all plots, though some recovery was seen on glyphosate plots in March. *Ranunculus repens* was unaffected on dalapon plots, while at Waseley *Rumex obtusifolius* was sprouting. *Dactylis glomerata* was unaffected on propyzamide plots. In April, glyphosate plots had lowest scores, reflecting the more rapid recovery of grasses. By June all plots had good appearance, but poor appearance was present in earlier months.

Table 14

Brownness scores of herbicide-treated plots in two amenity sites, at three times. Experiment NC-16-80

Forhill	Chemical				
	Aminotriazole	Dalapon	Glyphosate	Paraquat	Propyzamide
March	8	8	7	9	7
April	7	7	5	6	7
June	1	2	1	1	1
Waseley					
March	8	8	5	9	8
April	5	8	3	8	8
June	1	1	1	1	1

When measured in late June significantly lower swards were produced at Forhill on dalapon ($P < 0.01$), glyphosate ($P < 0.05$) and aminotriazole ($P < 0.001$) plots.

Forhill: species compositions

Observations on the plots indicated a change in vegetation across the area, and so plots were compared to adjacent controls. The composition of all the control areas in August 1981, when detailed assessments were made, was as follows:

	% Frequency		% Frequency
Elymus repens	63.6	Rumex obtusifolius	12.1
Holcus lanatus	57.6	Ranunculus repens	12.1
H.mollis	78.8	Cirsium arvense	6.1
Agrostis spp	60.6		
Phleum pratense	30.3		
Poa spp.	48.5		
Lolium perenne	24.2		
Dactylis glomerata	9.1		

Observations of the plots in June indicated little or no effects on glyphosate and aminotriazole plots. *H.lanatus* appeared to have been removed from propyzamide, dalapon and paraquat plots. *D.glomerata* was unaffected on propyzamide plots. Detailed assessments of composition in August indicated the following effects on treated plot.

Dalapon	:	Slight increase in *Agrostis* spp.
Paraquat	:	Increase in *E.repens*; slight increase in *P.pratense*.
Glyphosate	:	Increase in *Agrostis* and *Poa* spp.
Aminotriazole	:	Increase in *Agrostis* spp. and *P.pratense*.
Propyzamide	:	Reduction in *H.lanatus*, *Poa* spp., *P.pratense* and *R.obtusifolius*. Increase in *H.mollis* and *D.glomerata*.

Waseley: species compositions

The composition of control plots in August was as follows:

	% Frequency		% Frequency
H.lanatus	96.7	Rumex obtusifolius	12.1
Agrostis spp.	96.7	Cerastium holosteoides	3.3
Poa spp.	70.0	Achillea millefolium	3.3
Alopecurus pratensis	63.3		
P.pratense	50.0		
L.perenne	43.3		
D.glomerata	20.0		
F.rubra	6.7		
Anthoxanthum odoratum	3.3		

Observations of the plots in June indicated removal of *H.lanatus* by dalapon, paraquat, aminotriazole and propyzamide. *R.obtusifolius* was apparently encouraged on dalapon plots, and was prominent on paraquat plots. This species was limited to the edges of the propyzamide plot. Detailed assessments in August indicated the following:

Dalapon	:	Increase in *P.pratense*, *R.obtusifolius*.
Paraquat	:	Reduced *H.lanatus*, *Poa* spp. and *L.perenne*.
Glyphosate	:	Increase in *Poa* spp., *L.perenne* eliminated.
Aminotriazole	:	Slight reductions in *H.lanatus*, *Agrostis* spp., *Poa* spp., and *A.pratensis*.
Propyzamide	:	Reduction in *H.lanatus*. Slight reduction in *P.pratense*. Elimination of *Poa* spp. Increase in *D.glomerata*.

Discussion

Glyphosate gave less effects than found on other trials, and may have been affected by light rainfall after application. In terms of reducing sward height, only paraquat gave consistent effects at the two sites. Broad-leaved species could be encouraged by dalapon treatments. In situations where undesirable plants such as docks, thistles and nettles are present, dalapon treatments may be unsuitable. Paraquat treatments may be more useful, as *H.lanatus* can be reduced and sward heights are lower. However, *A.repens* was encouraged at Forhill by paraquat, and continued use might allow the species to dominate the sward. Glyphosate gave little obvious effect, but apparently encouraged finer bents and meadow grasses. Aminotriazole had little effect at Forhill, but gave reduced sward height and reduced frequencies of several grasses at Waseley. Propyzamide reduced some coarser grasses, but allowed cocksfoot to increase as found on log-sprayed plots. As this species grows in tussocks, its encouragement may not be suitable for amenity areas.

2.2.2.4. NC-12-81 Waseley Country Park, Hereford & Worcester

Site and treatment details

Plots 2m by 4m were established on grass which had been cut in August. The plots were divided into 2m by 2m subplots, one of which was re-cut at random on 22.9.81. Cuttings were left on the plots. Six herbicides were sprayed onto the main plots on 13.10.81 at the following doses:

Alloxydim	1.0 kg ha^{-1}
Asulam	2.5
Dalapon	5.0
Fluazifop	0.25
Glyphosate	0.5
Paraquat	0.5

The composition of the control plots, in terms of frequency of occurrence in quadrats, was similar to data given in 2.2.2.3. for Waseley swards.

H.lanatus	100%	Rumex acetosa	36.7%
Agrostis spp.	93.3		
A.pratensis	93.3		
Poa spp.	53.3		
F.rubra	16.7		
P.pratense	13.3		
D.glomerata	6.7		
L.perenne	3.3		

Results

Plot scores indicated that September cutting gave poorer appearance over winter. The effect no longer was apparent in spring 1982. By late May 1982 all plots had shown growth, and while only asulam plots were statistically similar to controls, only dalapon and glyphosate plots were obviously poorer in appearance.

Statistical analyses of sward height indicated large differences between blocks and no significant chemical effect. Nettles had dominated one plot treated with alloxydim; shortest plots were those sprayed with dalapon and glyphosate. In July differences were again not significant, though plots treated with alloxydim and fluazifop were on average taller than controls.

Sward compositions were assessed using frequency in quadrats at the end of July 1982. No differences were found to be statistically significant, either for individual species or for total grass or dicotyledon scores.

Discussion

As no significant sward height reductions were produced, none of the treatments would seem to be useful. Shortest swards were given by those chemicals giving poorest appearance (dalapon, glyphosate). No adverse or beneficial effects were recorded amongst the flora, using the quadrat assessments. The activity of alloxydim and fluazifop was probably low at the time of application; recommendations for the use of these compounds advise spraying in spring and summer during active growth. Increases in docks and nettles might have been expected and were indicated on alloxydim, fluazifop and glyphosate plots but these effects were not significant.

The effects of a summer mowing and repeated applications might have created changes in the sward. A single herbicide spray, did not give useful results.

2.2.2.5. NC-15-81 Oxford Airport

Site and treatment details

Two replicate blocks were set out on *A.elatius* - *F.rubra* grassland, with plots 2m by 7m. Paraquat at doses of 0.1, 0.2, 0.3, 0.4 and 0.5 kg ha^{-1} was sprayed on 5.11.81.

Results

Plots which received 0.2 kg ha^{-1} or more were severely discoloured in February 1982, while controls also had poor appearance with the dead vegetation from the previous year. In May, only slight effects on brownness score were found up to doses of 0.3 kg ha^{-1}; more obvious effects were found at higher doses.

Rabbits grazed the plots during the spring, and no statistical differences in sward height were found between treatments in May or July. Shortest average sward height was given by 0.5 kg ha^{-1} in July.

The dicotyledon species present in the plots were counted in May, and species were assessed in more detail in July 1982 using quadrat counts. In May there was an indication that dicotyledon species numbers were reduced at doses of 0.4 and 0.5 kg ha^{-1} (Table 15).

Table 15
Numbers of dicotyledon species in May and July on plots treated with paraquat the previous autumn.
Experiment NC-15-81.

	Dose (kg ha^{-1})					
	Control	0.1	0.2	0.3	0.4	0.5
May	12.0	12.0	10.0	11.5	9.5	8.0
July (quadrats)	8.5	7.5	10.5	6.5	10.0	10.5

The quadrat counts did not show any effects on grass species. Among the dicotyledons *G.hederacea* was significantly ($P<0.05$) more frequent on plots treated at 0.4 and 0.5 kg ha^{-1}. The same trend of increasing frequency with dose, while not statistically significant, was noted for *Cirsium arvense* (creeping thistle) and *Pastinaca sativa* (wild parsnip). However, there was no evidence of reduced numbers of species at higher doses of paraquat, as indicated earlier in the year (Table 15).

2.3. Discussion

2.3.1 Herbicide effects on amenity grassland.

Finite dose experiments for the manipulation of sward floras have concentrated on aminotriazole, asulam, dalapon, glyphosate, paraquat and propyzamide, as these compounds gave promising results in log-sprayed trials. After autumn spraying these herbicides have given a check of spring grass growth, and other changes in the sward flora. Some changes appear useful, others may be detrimental. Autumn applications appear to be most appropriate as grasses dominate the sward at this time of year and are translocating food reserves downwards to storage organs. Therefore, grasses are more likely to be affected by foliar compounds, while most of the dicotyledons have disappeared from the sward. Any discolouration of the sward is largely limited to periods following autumn spraying when few visitors are present. The newer grass-specific herbicides, alloxydim, sethoxydim and fluazifop, gave few useful effects after autumn spraying. In agriculture, such compounds are recommended for use during periods of rapid plant growth. Further investigations of spring applications of these and other compounds is needed.

Aminotriazole produced varying effects; some check on grasses, notably *A.elatius* and *H.lanatus* could be achieved with a resulting reduction in sward height. However, increases in tall dicotyledons such as *C.arvense* could also occur. Asulam did not give sward height reductions at Fish Hill, though some selectivity against *H.lanatus* gave height reductions in log-sprayed trials. The compound causes a temporary check on most grasses. Further work on spring applications of asulam is required. Dalapon does not affect dicotyledons directly, and by affecting grasses, sward heights were consistently reduced following autumn applications. As a result, common dicotyledons present in the sward were encouraged. However, if tall undesirable species such as docks and thistles are present, they may respond to the loss of grasses by dominating the sward. This effect appears less likely on glyphosate and paraquat plots, probably because the herbicides will check any dicotyledons present in the sward at spraying. Glyphosate, being well translocated, appeared to have a greater effect on herbs than paraquat. There were indications of species number declining on glyphosate plots. On paraquat plots herbs were maintained, though in two trials couch grass increased after spraying. On swards dominated by *A.elatius* paraquat was particularly successful at giving shorter swards. Propyzamide at 0.75 kg ha^{-1} was highly active against *A.elatius* and *F.rubra*, leaving a poor appearance. In other mixed swards effects were less dramatic though grasses were reduced. Established *D.glomerata* was unaffected.

Selective control of particular grass species has not been well demonstrated, with the exception of *H.lanatus* control. Linuron and asulam can remove *H.lanatus* in mixtures, and the species is checked by paraquat, aminotriazole and glyphosate. In comparison to asulam, linuron is more selective among grasses against *H.lanatus*, but it may reduce amounts of legumes. Paraquat has given good suppression of *A.elatius* in mixtures with *F.rubra*.

It is apparent that the composition of the sward is one of the factors determining the result of herbicide applications. If nettles, docks or other vigorous species are present initially, most low-dose herbicide treatments simply encourage them. If, however, undesirable species are absent, then herbicides may give useful effects, particularly in rough grass. On the longest-running experiment, the integration of mowing with herbicides has been shown to be necessary for the maintenance of short swards. A single herbicide application will not prevent the accumulation of dead vegetation. The cessation of mowing of short grass has itself caused major changes in the sward.

In rougher areas there appears to be some potential for single doses of paraquat, dalapon or glyphosate for controlling the dominant grasses. However, insuffient work has been done for general recommendations to be made. In shorter swards, at least one cut a year is needed, probably in late summer, but further work is required to ascertain the best mowing time and the best mowing/herbicide combinations. The results indicate that herbicides for sward manipulation will probably be most useful for remedial treatments of amenity areas, as opposed to maintenance operations.

2.3.2. Application and costs

The costs of applying herbicides depend on the application equipment used, and the dose of active material applied. Costs are therefore variable and difficult to predict accurately. Two extremes of application method which could be used are the tractor-mounted wide boom sprayer, as used in agriculture, or the knapsack sprayer. The standard cost of agricultural spraying, using a 12m tactor-mounted boom, is £6.0 ha^{-1}. Using a knapsack sprayer, an operator can cover about 1800 m^2 in an hour; it takes about 5.5 hours to spray a hectare.

Assuming labour and equipment costs of £4 $hour^{-1}$, knapsack spraying can cost £22 ha^{-1}. Application costs can vary considerably from £6 ha^{-1} to £22 ha^{-1}.

Costs of active herbicide depend on dose. The cost of a range of herbicides used at particular doses are given below. The figures are retail prices, without V.A.T., quoted by local agricultural merchants. Cheaper prices might be achieved by bulk ordering or tendering.

Herbicide	Dose (kg ha^{-1})	Cost (£ ha^{-1})
Aminotriazole	2.5	27.30
Asulam	2.0	33.70
Dalapon	5.0	11.50
Glyphosate	0.5	19.40
Linuron	1.5	30.25
Paraquat	0.5	13.60
Propyzamide	0.75	41.05

The doses given are those used in field trials on amenity grassland; the doses did not necessarily produce beneficial results. It should be noted that these figures will soon become out of date, and are presented only as a relative guide. Addition of labour and equipment costs is required to give actual treatment cost, which can then be compared with mowing costs. The cost of cutting grass perhaps averages £90 ha^{-1}, but varies from £7 ha^{-1} to £250 ha^{-1} (Section 3.3.2.) depending on machine. The figures given above indicate that herbicides used for sward manipulation can be relatively inexpensive.

3. GROWTH RETARDANTS IN GRASSLAND

3.1. Preliminary trials

3.1.1. Methods

A series of nine logarithmic-sprayed trials were conducted with growth retarding compounds. Similar sites to those used for herbicide trials were chosen, and applications were made in spring, summer and autumn (Table 16).

Table 16
Logarithmic-sprayed trials with growth retardants

Trial	Location	Sward Type	Application (Spring, Summer, Autumn)
NC-3-79	Waseley Country Park	Mixed	A
NC-1-80	WRO	*E.repens*	Sp (+cutting)
NC-3-80	WRO	Mixed pasture	Sp
NC-5-80	Forhill Picnic Area	Mixed	Sp
NC-6-80	Waseley Country Park	Mixed	Su
NC-10-80	Draycote Country Park	Mixed; *H.lanatus*, *F.rubra*	Su
NC-11-80	WRO	*E.repens*	Su (+volume)
NC-14-80	Forhill Picnic Area	Mixed	A
NC-10-81	WRO	Mixed pasture	Su
NC-1-82	WRO	Mixed pasture	Sp

The compounds used in the trials are listed in Table 17. Only maleic hydrazide (MH) is currently cleared and approved for use as a grass retardant in the UK. Other compounds are either still being developed, or are used for other purposes. Dikegulac is used for hedge retardation, and to promote branching in some ornamental species. The last three retardants in Table 17 were only investigated in trial NC-1-82.

Two trials on waste ground (NC-1-80 and NC-11-80) were set up to investigate other factors, as well as compound. NC-1-80 incorporated three mowing treatments: uncut, cut before spraying, cut after spraying. NC-11-80, using MH only, attempted to investigate the effects of three volume rates of application.

Table 17
Growth retardants used in log-spray trials, and their mode of uptake.

Chemical	Uptake
Maleic hydrazide (MH)	Foliar
Mefluidide	Foliar
Paclobutrazol (PP333)	Soil (+ foliar)
EL 500	Soil
WL 83801	Soil
Dikegulac	Foliar

3.1.2. Results

Experiment NC-1-80 was conducted on *E.repens*-dominated waste ground, which had large amounts of standing dead vegetation. The first three retardants in Table 17. were used, and mixtures of MH and 2,4-D were included. Mowing treatments were part of the trial; plots were either left uncut, cut 4 weeks before spraying or 2 weeks after. On uncut plots MH was ineffective, while mefluidide and PP333 were active. Plots mown two weeks after spraying gave poor results; high doses of mefluidide and MH + 2,4-D had the only noticeable effects. Best retardation was noted on mown plots, with the exception of PP333 which surprisingly had no effect. Mefluidide at 0.5-1.0 kg ha^{-1} gave best plots, and retardation lasted 12 weeks.

Generally better results were given on the shorter sward where standing dead vegetation was absent. Maleic hydrazide gave poorest results on the tall vegetation, where more spray was intercepted by non-target material. Effects on broad-leaved plants were observed with mefluidide and MH + 2,4-D. Sprouts of nettle (*Urtica dioica*) and cleavers (*Galium aparine*) were killed by 0.3-2.0 kg ha^{-1} mefluidide, though plants grew away after 7 weeks. Twisting of flowering plants of hedge garlic (*Alliaria peteolata*), and temporary effe cts on *Cardaria* sp., *Artemisia vulgaris*, *Pentaglottis* sp., and *Rumex obtusifolius* were noted on mefluidide plots. *Potentilla reptans* (creeping cinqfoil) was killed by 3.0 kg ha^{-1} 2,4-D, and *R.obtusifolius* was checked down to 1.0 kg ha^{-1}.

Experiment NC-11-80 was conducted on the same vegetation-type as used for NC-1-80. MH was applied, after mowing, using the logarithmic-sprayer; the initial dose of 8.0 kg ha^{-1} was achieved using either one, two or three sequential passes to simulate volume rates of 300, 600 and 900 l ha^{-1}. The experiment was abandoned after 4 weeks, as the vegetation was highly variable. Nevertheless, the three volume rates gave average sward heights which were all significantly ($P<0.05$) shorter than controls at doses of 4.0 kg ha^{-1} and above. Volume rate under these circumstances appeared to have no effect on MH activity.

Results of the main logarithmic-sprayed trials indicated that the three main compounds investigated could retard swards. Discolouration could occur, and at high doses phytotoxic effects were seen. A summary of the useful dose ranges of the compounds is given in Table 18.

Table 18

Doses of retardants resulting in no suppression, and supression accompanied by marked discolouration

	Dose (kg ha^{-1} a.i.)	
Retardant	No suppression	Suppression with discolouration
MH	3.5	6.5
Mefluidide	0.1	1.2
PP333	0.5	4.5

The narrow dose range of MH can be contrasted with the wider range of activity shown by mefluidide and PP333

Best results have been given by spring applications. Applications in summer (NC-6-80, NC-10-80) gave variable results which were generally poor. Autumn applications (NC-14-80) either gave no significant retardation in spring (MH) or there was marked discolouration followed by sward retardation.

Maleic hydrazide and mefluidide suppress flowering in grasses. MH suppresses flowering above 4.0 kg ha^{-1}, while mefluidide which gives best suppression is active in this respect at doses as low as 0.2 kg ha^{-1}. PP333, in contrast, does not supress flowering and its retardant effect is more dependent on species. Culm heights of *H.lanatus*, *Poa* sp. and *L.perenne* were reduced, while no effects were noted on *A.elatius*, *E.repens*, and *D.cespitosa*. The early-growing grasses, *Anthoxanthum odoratum* and *Alopecurus pratensis*, were also apparently unaffected by mid-April applications of PP333. Fescues and *Agrostis* spp. were well retarded. MH and mefluidide appeared to be active against all grass species. Effects on dicotyledons were few; mefluidide did not affect (and may have encouraged) white clover (*Trifolium repens*), but there were temporary effects observed on the flowers of some plants notably buttercups (*Ranunculus bulbosus, R.repens*). Twisting and petal loss were seen following a July application.

Experiences with the retardants dikegulac, EL500 and WL83801 are limited. EL 500 had no measurable effect in summer or Spring 1982. WL 83801 was also ineffective in April 1982. Both these compounds are soil-active and their movement in the soil may have been inhibited in the exceptionally dry Spring of 1982. Foliar-acting dikegulac produced retardation, but at high doses in excess of 7.5 kg a.i./ha. Such doses are reported by Diamond Shamrock to be prohibitively expensive.

Preliminary trials indicated that retardants could be useful; grass retardation could be achieved for about 10 weeks with the foliar compounds, longer with PP333 which at doses of over 4.0 kg ha^{-1} had some carry-over effect into the following season.

3.2. Main retardant experiments

3.2.1 Methods

A total of ten experiments were set out to investigate the use of growth retardants at finite doses. The experiments listed in Table 19 were sprayed with an Oxford Precision Sprayer (OPS) at 200 l ha^{-1}. Additional applications in experiments NC-8-81 and NC-9-81 were made using a Micron Herbi, which gives controlled droplet application (CDA); the spray droplets are a uniform 250u size. In experiment NC-7-81, timing of application was investigated by spraying on a number of dates over a three month period.

Table 19

Experiments with growth retardants applied at finite doses.

Trial Code No.	Location	Comments
NC-4-80	WRO	3 annual applications
NC-1-81	Merrist Wood Agric. College	
NC-2-81	Merrist Wood Agric. College	
NC-3-81	Whiteleaf Cross Picnic Area	
NC-6-81	WRO	2 annual applications
NC-7-81	WRO	Timing of application
NC-8-81	Ferry Meadows Country Park	OPS v. CDA
NC-9-81	Marlborough College	OPS v. CDA
NC-2-82	WRO	New compounds
NC-5-82	Wooburn Green Picnic Area	Large plots

The experiments were assessed for appearance using a subjective "brownness" score, ranging from 0 = all green to 9 = all brown. Sward heights were measured using a sward stick techique (Castle, 1976). A plastic plate weighing 68 g and having an area of 305 cm^2 was lowered until supported by the sward. At least five readings were taken in each plot. Effects on flowering of grasses were monitored by estimating the numbers of emerged panicles of each grass species. Individual species heights were estimated by recording the maximum height achieved in each plot. Numbers of dicotyledonous species per plot were noted at irregular intervals, while detailed sward composition assessments were made in the spring.

3.2.2. Experiment descriptions

3.2.2.1. NC-4-80 WRO

Treatment details

This experiment was sited on permanent pasture, which was previously grazed. Treatments were continued for three seasons, with annual spring applications. In the first year, as in each successive season, three mowing treatments were superimposed on the retardants: A = No mowing; B = mown a fortnight before spraying; C = mown a fortnight after spraying. In the second season the 2m by 4m main plots of the four replicates were divided in half and a pre-season cut of one of the subplots made at random. Subsequently an end-of-season cut of all plots has been made. The retardants and doses used were as follows:

MH	5.6 kg ha^{-1}
PP333	2.0
Mefluidide	1.0
MH + 2,4-D	5.6 + 5.2
MH + PP333	4.0 + 1.0

The dates of treatments during the three seasons are given in Table 20.

Table 20
Dates of treatments applied in experiment NC-4-80

	Season		
Treatment	1980	1981	1982
Sprayed	23.4.80	17.4.81	15.4.82
B cut	9.4.80	2.4.81	2.4.82
C cut	7.5.80	1.5.81	30.4.82
End of season Cut: 1 subplot	17.2.81	-	-
End of season cut: all plots	-	11.11.81	3.12.82

Results

In the first season mowing had a significant effect on sward height, with A>B>C (shortest) for 15 weeks. Mefluidide caused a rapid cessation of growth, and treated plots were the shortest for 6 weeks. The B and C cuts tended to reduce the difference in sward height on foliar retardant plots, though mefluidide gave significantly shorter plots on B cut areas. PP333 activity appeared to be delayed for about 6 weeks with the dry weather following spraying. On unmown A plots, the differences in the effects of the retardants are well demonstrated (Fig.3.). Grass flower head numbers were significantly affected by the retardants and by mowing. Mefluidide gave significantly fewer grass heads than any other treatment, with MH and MH + 2,4-D giving lower numbers than other treatments. PP333 did not affect grass head numbers.

In the second season, main plots were split into subplots which had been cut in February and those which had not. Subplots which had been cut in February had consistently better appearance and lower score. Greatest discolouration was noted on mefluidide plots, and least on PP333 plots. Sward heights showed similar patterns to 1980; mowing treatments gave average differences with A>B>C for 14 weeks. The February cut effects were modified by the mowing treatments at spraying. Subplots which were not mown and which subsequently received a B cut, were more severely affected by sprays, though subplot height differences were not statistically significant.

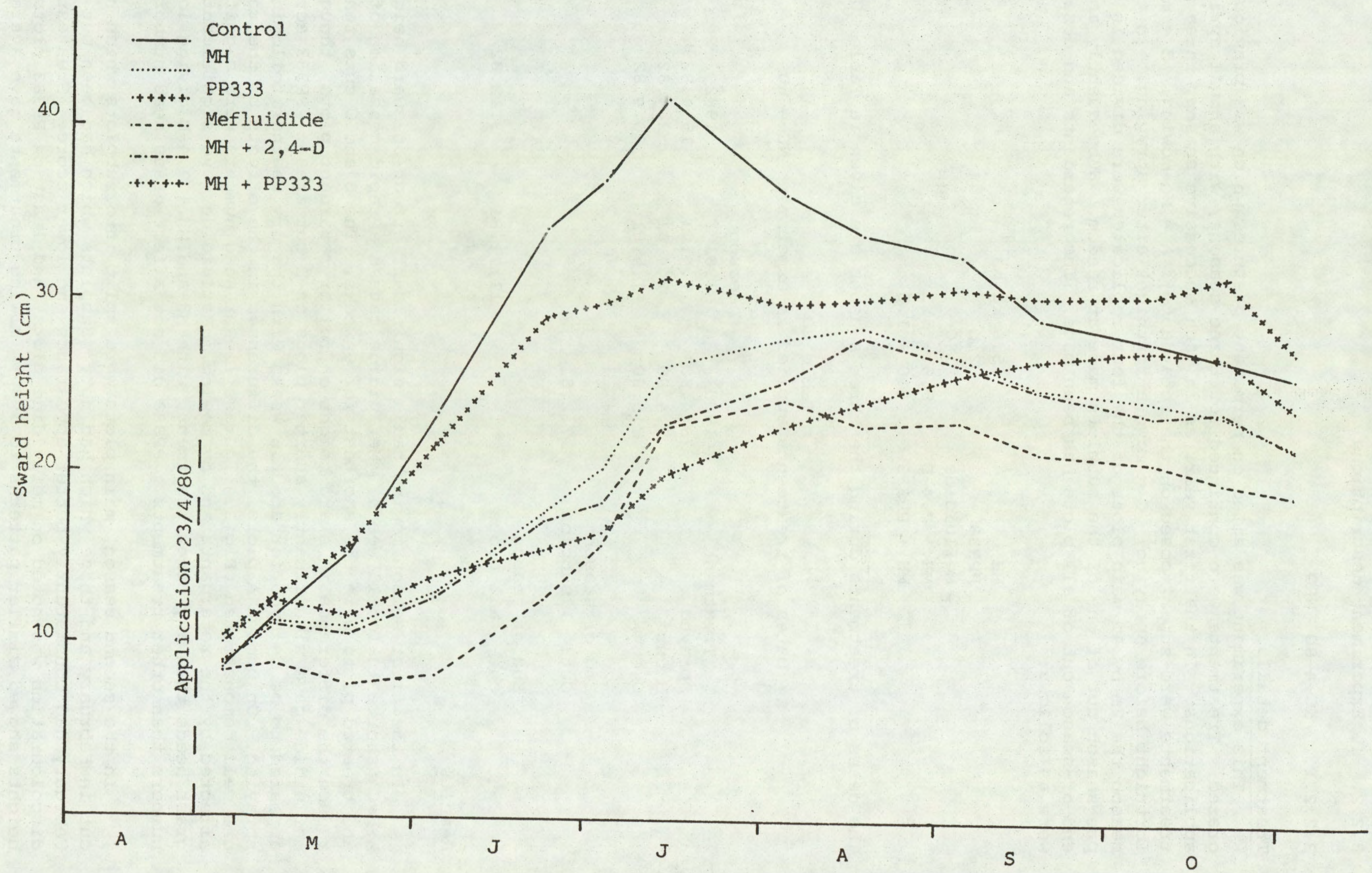

Fig.3. Sward heights of unmown (A) retardant-treated plots in 1980, the first season of application. Experiment NC-4-80.

On unmown A plots, mefluidide was the only retardant to give shorter swards than controls for 4 weeks. After 7 weeks the foliar-acting retardants gave similar height swards, which were shorter than controls. The mixture of MH + PP333 and PP333 alone were more active than in 1980, probably reflecting the wetter conditions. Flower head numbers were lowest on mefluidide plots, and greatest on PP333 plots, as found in 1980. The February cut did not significantly affect total grass heads, but some effects were noted on *H.lanatus* and *Agrostis* spp. (Marshall, unpubl.). Individual maximum grass heights generally showed shortest plants occurred on mefluidide plots, and on C mown plots (A>B>C).

In 1982, after the plots had been cut in autumn, results were similar to previous years. The dry spring weather did not favour PP333, and sward heights were never different to controls (Fig.4.). Mefluidide plots were again the shortest over the first weeks, but differences between other treatments were not significant. On mown B and C plots differences between all the retardants other than PP333 were not significant. Appearance scores showed that mefluidide plots were poorest, though similar to MH + 2,4-D plots. After 7 weeks mefluidide plots improved, while MH + 2,4-D plot appearance remained poor, with some bare patches following phytotoxicity.

Flower heads of grasses were suppressed by mefluidide and MH, particularly on MH + 2,4-D plots. Total flower head densities in the three seasons are given in Table 21.

Table 21
Total grass flower head densities (m^{-2}) on retardant-treated plots in July 1980, 1981 and 1982.
Experiment NC-4-80

Year	Mowing	Control	MH	PP333	Mefluidide	MH + 2,4-D	MH + PP333
1980	A	270	122	267	52	101	151
	B	263	92	263	41	72	109
	C	197	67	193	25	56	97
1981	A	87	63	109	28	47	80
	B	101	55	127	28	55	94
	C	73	36	107	13	23	60
1982	A	124	42	130	7	11	60
	B	114	35	134	4	16	52
	C	111	26	120	4	8	49

The data are in fact the maxima recorded during each season, so a decline in total head densities is a real effect. The reasons for the decline reflect the change in overall management of the sward and these effects are considered below. Mefluidide has consistently given the best head suppression. Mowing later in the season (C) removes more flower heads.

Sward composition

Assessments of the composition of the sward were made in March 1980, 1981 and 1982. A line transect technique was used; species were recorded as present if any vegetative part crossed a transect running through the centre of each plot. Species were recorded in 10 cm lengths, 10 lengths in each subplot. Statistical analysis cannot validly be made between years, so data from each year were tested separately for differences between treatments. Data were augmented in August 1982, by recording species present in 30 cm by 30 cm quadrats. 10 quadrats were placed at random in each subplot.

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