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THE SELECTIVE SUPPRESSION OF WEED GRASSES IN YOUNG PERENNIAL RYEGRASS SWARDS BY DALAPON AND ASULAM

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Summary The effects of late June/July applications of dalapon and asulam on young perennial ryegrass swards are described in terms of dry matter yield and tiller density. Suppression of Poa trivialis, Agrostis stolonifera and Holcus lanatus was achieved by both chemicals without long-term detriment to perennial ryegrass. The long-term effect of dalapon on white clover was negligible whereas asulam caused a reduction. There was a slight increase in the broadleaved weed content following application of dalapon. Of the two treatments, dalapon caused less initial damage to perennial ryegrass than did asulam but in both cases full recovery had taken place 10 weeks after spraying. The close mutual proximity of ryegrass plants ensured that reasonably successful colonisation of the chemically induced bare spaces in the sward was achieved, although ingress by Poa annua and P. trivialis occurred.

INTRODUCTION

Work on the suppression of P. trivialis, A. stolonifera and H. lanatus in old perennial ryegrass swards using dalapon at 2.5 lb ae/ac was reviewed during the mid 1960's (Elliott and Allen, 1964). The importance of nitrogen as an aid to sward recovery following treatment was subsequently shown (Allen, 1969) when it was suggested that evenly distributed ryegrass reduced the danger of ingress from any remaining weeds.

The object of the experiments reported here was to confirm the influence of dalapon and added fertilizer on a series of young swards where there was a uniform distribution of perennial ryegrass. Asulam was included for comparison because past research carried out at the Weed Research Organization had shown this chemical to have similar selective properties to dalapon.

The short-term effect of each treatment on the sward was measured in terms of yield, and the more lasting consequences by the botanical composition of the sward involving the measurement of tiller density.

METHOD AND MATERIALS

A series of 13 sites were chosen in a range of climatic and edaphic situations from Northants to Monmouthshire, as shown in Table 1.

Lay-out, treatments and conditions of spraying

The plots, measuring 12 yd x 5 yd were laid out in a latin square design. The herbicide treatments were applied on the various sites during the period 24 June to

Table 1

Details of the 13 experimental sites

Site No.	Location	Average Annual Rainfall (in.)	Soil Type	Age of Sward at Spraying (months)	Method of Sward Establishment	Pre-Spraying Management
1	Aston Clinton Bucks.	25	Clay loam	12	Undersown to spring barley	Cattle grazed
2	Begbroke Hill Oxon.	24	Silt loam	21	Paraquat - rot. cult. then drilled	Cattle grazed
3	Bourton-on-the-Water, Gloucs.	30	Clay loam	9	Conventional cults. and drilling	Sheep and pig grazed
4	Brinsop, Hereford (1)	25	Fine sandy loam	3	Paraquat then drilled with combined rot. cult./ grass drill	Cattle grazed
5	Brinsop, Hereford (2)	25	Silt loam	3	Paraquat then drilled with combined rot. cult./ grass drill	Cattle grazed
6	Harrington, Northants	25	Loam overlying clay	21	Conventional cults. and drilling	Cattle grazed
7	Llantrisant, Mon.	40	Silt loam	27	Conventional cults. and drilling	Cattle grazed and silage cuts
8	Newent, Gloucs.	30	Clay loam	12	Paraquat - then drilled with combined rot. cult./ grass drill	Cattle grazed
9	Newnham, Gloucs.	33	Fine sandy loam	9	Conventional cults. and drilling	Cattle and sheep grazed
10	Tintern, Mon.	37	Silt loam	15	Conventional cults. and drilling	Cattle grazed
11	Usk, Mon.	40	Silty clay	15	Conventional cults. and drilling with barley nurse crop	Cut for hay
12	Weedon, Northants.	25	Sandy loam	27	Paraquat - then drilled with combined rot. cult./ grass drill	Cut for hay
13	Wroxton, Oxon.	28	Sandy loam	15	Conventional cults. and drilling. Undersown.	Sheep grazed

Table 2

Botanical composition at 12 sites immediately before spraying, expressed as mean number of grass tillers, clover petioles and broadleaved plants ft^2

Species	Site Number 1	2	4	5	6	7	8	9	10	11	12	13	MEAN
L. perenne	228	514	296	526	448	182	448	258	329	315	606	241	366
P. trivialis	10	78	22	4	628	95	603	59	87	37	9	26	138
P. annua	0	0	708	139	3	11	7	18	7	31	241	21	99
A. stolonifera	147	26	175	33	7	102	38	9	11	0	7	37	49
H. lanatus	51	38	1	6	4	72	3	0	0	0	0	0	15
Other grasses	0	55	0	0	1	28	26	0	3	19	19	0	13
T. repens	3	24	21	28	2	11	24	164	48	40	414	24	67
B'leaved weeds	2	7	24	10	3	1	1	1	5	6	3	0	5

30 July, 1969 and consisted of:

Treatment No.	Treatment
1	Dalapon at 2.5 lb ae/ac
2	Asulam at 2.5 lb ai/ac
3	Unsprayed control

The chemicals were applied in 20 gal/ac aqueous solution containing 0.1% Agral 90 surfactant. The solutions were sprayed at 30 lb/in^2 pressure through '00' ceramic fan jets fitted to a 2.5 yd boom on an Oxford Precision Sprayer. Thus, two adjacent runs were necessary on each plot and these were made in the same direction.

A fertilizer treatment consisted of two applications, the first made immediately after herbicide treatment and the second six weeks later. A total of 146 lb N and 157 lb P_2O_5 + 157 lb K_2O per acre was broadcast.

The treatments were applied under similar weather conditions; days were chosen that were free of wind and without risk of rain for at least 6 hours after spraying. A sward height of approximately 2-3 in. was achieved at each site.

Grazing animals were excluded from all sites for a period of at least 10 weeks after spraying in order that yields could be taken.

Assessments

Herbage yield

Harvest cuts were taken where possible, 5 weeks (Table 3) and 10 weeks (Table 4) after spraying. In all yield assessments an autoscythe was used to cut a 1 yd wide swathe down the centre of each spray run on each plot leaving a stubble of approximately 2 in. The area thus harvested consisted of 2 x 12 yd x 1 yd (24 yd^2). All the cut material was weighed fresh. Random samples of the cut herbage were weighed and kept in cold storage for later sorting into species, which were subsequently dried at 100°C for at least 6 hours and weighed.

Botanical composition

Six months after spraying, ten 4.25 in. diameter turf cores were removed from each plot using a statistically randomised selection of co-ordinates. The number of grass tillers, clover petioles and broadleaved plants on each core were recorded (Table 5).

RESULTS

Dry matter yields, 5 weeks after spraying

Total herbage production was significantly reduced at all sites by dalapon (Table 3). Asulam had an even greater depressive effect on most of the sites, reducing mean yields by 74 per cent compared with a reduction of 44 per cent by dalapon.

Ryegrass yields were significantly reduced at all sites by both dalapon and asulam. Asulam was more harmful to ryegrass than dalapon, reducing mean yields by 72 per cent compared with a reduction of 42 per cent by dalapon.

Dalapon and asulam were very effective in reducing the *Poa trivialis* content at all sites. *Holcus lanatus* and *Agrostis stolonifera* were also reduced on the majority of sites where these species occurred. In general, asulam was more effective than dalapon in reducing the proportion of these weed grasses.

Dry matter yields, 10 weeks after spraying

Total dry matter yields on the herbicide treated plots (Table 4) were comparable to the control plots at nearly half of the sites; with asulam, the mean reduction in total dry matter yield was only 12 per cent, and on two sites, dry matter yields were significantly increased compared with the control treatment.

Ryegrass production when measured 10 weeks after spraying (Table 4) was recovering on the herbicide treated areas, there being only 2 sites where significant reductions still prevailed on the dalapon areas. Indeed, on the asulam areas ryegrass yields were significantly higher than the control areas on 4 sites - although on 3 other sprayed sites ryegrass yields were still significantly less than the unsprayed areas.

Yields of *P. trivialis* were still significantly lower on the dalapon treatment at 3 out of the 7 sites; with asulam, 2 sites were significantly lower than the unsprayed treatment.

H. lanatus was showing little signs of recovery following the use of either of the herbicides on any of the sites where it has occurred originally, while the control of *A. stolonifera* was also reasonably good, particularly following the use of dalapon.

There was a tendency for *T. repens* to increase after dalapon usage and decrease after spraying with asulam.

Broadleaved weeds were encouraged by dalapon; asulam tended to produce a better control of broadleaved weeds, particularly at site 10, which was infested by *Rumex obtusifolius*.

Tiller production, 6 months after spraying

The production of ryegrass tillers was not impaired following treatment with either dalapon or asulam. Dalapon did not consistently affect production of white clover petioles whereas a slight reduction in petioles was noted after asulam application (Table 5).

In all but a single instance, in respect of each species, dalapon reduced P. trivialis, A. stolonifera and H. lanatus satisfactorily; asulam did not control P. trivialis to a similar degree, although A. stolonifera at all but one site and H. lanatus were severely reduced.

The presence of Poa annua, a species not easily detected by means of a yield cut due to its short growth habit, was recorded in both the pre-spraying (Table 2) and 6-month post spraying (Table 5) assessments of tiller density.

DISCUSSION

The present results, which support previous work carried out on permanent pasture (Allen, 1969), confirm that a low dose of dalapon applied in late June/July is effective in suppressing the main weed grasses in young ryegrass swards. Satisfactory control of P. trivialis and A. stolonifera was achieved, although the effectiveness of controlling Poa spp. was masked to a certain extent by the re-invasion of bare spaces, particularly by P. annua. Ryegrass quickly recovered from the initial check, aided by the fertilizer treatment. The response of white clover was generally favourable.

Asulam was as effective as dalapon in selectively controlling the weed grasses and although the initial check to ryegrass was more severe, recovery was as satisfactory. This check would probably have been less severe if a lower dose of asulam had been chosen; the degree of weed control achieved would imply this to have been possible. Asulam gave better control of broadleaved weeds, especially where docks were present but unfortunately also reduced white clover.

The initial success of both dalapon and asulam in improving botanical composition did not appear to be conditional on either environmental factors or sward management generally.

However, it is the long-term effect on the sward by which the efficiency of the chemical treatment is judged and in this context environment and management emerged as important factors.

The invasion of a newly sown sward by P. annua was illustrated on the two 3-month old sites (sites 4,5), although this could perhaps be attributable to an added influence in that both sites had been direct drilled following chemical sward destruction. Control of mature P. annua on both sites was good, nevertheless any survivors would be allowed to shed seed and, given a suitable environment, germinate. The advisability of employing the use of dalapon or asulam in such a situation can therefore be questioned.

As far as the influence of management is concerned, it is interesting to note that on the only site not grazed (site 13) but which was cut for hay, the incidence of weed grasses in general was low. Recent work at Begbroke has shown that Poa spp. are less common under hay conditions.

The influence of climate is associated with the re-invasion by Poa spp. of the bare spaces left in the sward due to their vacation by susceptible mature species. This Poa spp. re-invasion has proved to be an important factor in the success or failure of selective grass control and tends to mask, in the long term the effectiveness of an application of dalapon. Although no significance could be attached regarding the experiments reported here, more recent work has shown that a greater prolifacy in germination of Poa spp. was recorded in a wet climatic situation than in a drier one (Oswald - unpublished data).

The timing of the dalapon application, namely July, is probably the main reason why Poa spp. later re-invade the bare patches; the main flush of Poa seed germination is known to occur under grazing conditions, in August (Oswald - unpublished data). It could therefore be argued that the dalapon technique should be complemented by the use of a soil-acting, persistent herbicide, which would prevent the seedlings of weed grasses from establishing - and hence allow the established ryegrass plants to tiller out and colonise the bare patches.

The timing of the asulam treatment could be delayed, with advantage, until the autumn. Experience has shown that when applied at this time for the control of docks, good control of weed grasses was also achieved (Oswald - unpublished information).

The success of dalapon in a wide range of climatic and edaphic situations and on swards varying from the very young to others of greater longevity has been demonstrated: however it should be realised that a single application in July cannot be an absolute remedy for a weedy sward. The problem of Poa spp. re-invasion has proved to be a real one and the factors which contribute to it require investigation.

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Table 3

Mean dry matter yield (lb/ac) from 10 sites, recorded 5 weeks after spraying

Species	Treatment	Site number 1	2	4	5	7	8	9	10	12	13	Mean
L. perenne	Control	1308	1054	1607	1404	2815	2401	1853	676	1777	697	1523
	Dalapon	662	390	1128	1034	1433	605	1287	384	1522	395	884
	Asulam	173	167	192	452	589	432	420	123	1286	496	433
	S.E.	41.8	54.4	76.3	102.0	173.8	119.2	114.9	60.0	88.6	62.4	
P. trivialis	Control	35	11	62	300	65	66	92	7	91	16	75
	Dalapon	9	3	25	9	8	16	27	2	119	9	23
	Asulam	3	1	6	11	10	12	7	0	33	11	9
	S. E.	8.8	0.5	14.1	15.1	8.8	4.0	12.8	1.4	20.6	1.1	
A. stolonifera	Control	110	0	56	12	37	0	0	1	0	27	24
	Dalapon	10	0	10	109	9	0	0	1	0	3	14
	Asulam	3	0	33	6	4	0	0	0	0	0	5
	S.E.	20.6	-	130.0	4.4	10.9	-	-	0.4	-	1.5	
H. lanatus	Control	142	109	0	25	233	0	0	0	0	0	51
	Dalapon	27	2	0	0	10	2	0	0	0	0	4
	Asulam	4	0	0	0	16	0	0	0	0	0	2
	S.E.	0.8	4.4	-	1.4	65.1	0.4	-	-	-	-	
T. repens	Control	0	2	13	5	34	82	120	74	252	9	59
	Dalapon	0	3	5	0	17	7	116	34	313	1	50
	Asulam	0	1	2	2	3	5	13	3	37	0	7
	S.E.	-	0.2	2.1	0.3	4.7	2.2	18.5	12.4	48.5	1.0	
Broadleaved weeds	Control	0	0	42	0	9	17	29	141	0	0	24
	Dalapon	0	18	43	0	7	0	21	140	0	0	23
	Asulam	0	1	30	0	8	0	4	35	0	0	8
	S.E.	-	1.1	18.8	-	5.2	2.4	14.5	0.6	-	-	
Total yield	Control	1658	1221	2280	1746	3357	2434	2144	913	2569	761	1908
	Dalapon	213	432	1233	1170	1586	822	1529	587	2179	413	1016
	Asulam	293	178	272	475	713	506	454	166	159	511	373
	S.E.	76.2	59.9	100.3	111.0	144.1	149.2	93.2	49.7	111.5	66.3	

Table 4

Mean dry matter yield (lb/ac) from 7 sites recorded 10 weeks after spraying

Species	Treatment	1	4	5	7	9	10	12	Mean
L. perenne	Control	1737	2054	2696	1040	679	2199	921	1618
	Dalapon	1539	2179	2523	1145	529	1888	986	1541
	Asulam	1138	2376	2244	1448	465	2825	1271	1681
	S.E.	71.5	62.2	64.9	106.0	41.4	176.8	98.1	
P. trivialis	Control	52	68	21	22	10	28	25	32
	Dalapon	58	48	17	22	7	7	26	26
	Asulam	43	57	0	24	7	33	32	28
	S.E.	13.8	14.1	0.9	4.0	1.0	7.1	6.7	
A. stolonifera	Control	22	9	31	6	0	30	0	14
	Dalapon	2	4	0	5	0	0	0	2
	Asulam	47	10	0	6	0	0	0	9
	S.E.	14.4	10.1	3.5	3.4	-	13.7	-	
H. lanatus	Control	126	0	39	92	0	0	0	37
	Dalapon	42	0	0	16	0	0	0	8
	Asulam	28	0	0	2	0	0	0	4
	S.E.	28.8	-	0.8	14.1	-	-	-	
T. repens	Control	0	0	0	14	8	119	59	29
	Dalapon	0	0	0	55	15	144	90	43
	Asulam	0	0	0	16	32	14	16	11
	S.E.	-	-	-	8.7	5.0	39.5	54.7	
Broadleaved weeds	Control	0	2	0	13	0	115	0	19
	Dalapon	0	9	0	61	1	561	0	90
	Asulam	0	29	0	2	1	47	0	11
	S.E.	0	0.2	-	23.6	0.5	12.6	-	
Total yield	Control	2030	2322	2997	1535	795	3067	1095	1977
	Dalapon	1708	2441	2720	1404	615	2925	1175	1855
	Asulam	1319	2645	2408	1618	540	3583	1385	1922
	S.E.	67.6	63.4	74.4	111.9	42.0	56.3	148.0	

Table 5

Botanical composition recorded 6 months after spraying at 13 sites
Mean number of grass tillers, clover petioles and other broadleaved plants per ft^2

Species	Treatment	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
L. perenne	Control	355	397	571	235	341	551	267	327	459	267	523	386	705	414
	Dalapon	344	434	528	296	280	561	357	258	451	283	666	393	775	433
	Asulam	294	439	532	406	381	593	484	303	411	448	741	416	854	485
	S.E.	39.1	40.8	67.7	38.5	31.8	27.5	83.2	30.6	35.4	56.9	65.5	29.2	43.8	
P. trivialis	Control	42	22	179	25	-	716	58	49	2	9	18	11	109	103
	Dalapon	8	49	104	12	-	95	44	30	0	3	7	8	69	36
	Asulam	22	75	24	19	-	109	64	83	6	4	11	8	29	46
	S.E.	6.12	22.1	79.4	14.2	-	39.2	29.4	46.0	1.90	1.46	10.6	5.64	36.0	
P. annua	Control	-	-	17	90	2	-	45	10	8	-	26	36	141	42
	Dalapon	-	-	93	91	28	-	48	49	27	-	20	2	216	64
	Asulam	-	-	62	116	8	-	68	104	6	-	6	4	225	67
	S. E.	-	-	18.9	47.1	15.1	-	33.3	27.2	11.2	-	26.1	5.46	70.6	
A. stolonifera	Control	166	22	21	136	68	13	250	9	4	10	-	6	80	65
	Dalapon	25	13	4	11	5	1	123	12	1	0	-	2	39	20
	Asulam	59	22	6	27	16	3	25	1	1	0	-	13	12	15
	S.E.	18.3	10.6	7.07	33.6	35.7	4.30	42.5	15.3	5.16	4.00	-	4.62	6.32	
H. lanatus	Control	39	89	-	-	-	-	63	-	-	-	-	-	-	64
	Dalapon	50	3	-	-	-	-	12	-	-	-	-	-	-	22
	Asulam	15	0	-	-	-	-	0	-	-	-	-	-	-	5
	S.E.	19.0	19.1	-	-	-	-	16.4	-	-	-	-	-	-	
T. repens	Control	-	11	-	3	-	4	41	16	43	150	49	74	35	43
	Dalapon	-	32	-	3	-	2	65	45	40	140	90	131	51	60
	Asulam	-	20	-	7	-	1	19	32	205	16	21	33	31	39
	S.E.	-	11.6	-	2.02	-	1.78	24.0	22.4	27.4	19.3	19.9	26.3	30.5	
Broadleaved weeds	Control	-	2	6	1	-	-	-	-	1	2	-	-	-	2
	Dalapon	-	7	17	1	-	-	-	-	1	6	-	-	-	6
	Asulam	-	11	16	3	-	-	-	-	14	6	-	-	-	10
	S.E.	-	1.51	1.66	0.89	-	-	-	-	3.92	2.23	-	-	-	

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DOCKS IN GRASSLAND, THEIR INFLUENCE ON HERBAGE PRODUCTIVITY

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Summary At three sites, on plots with various levels of dock infestation yields of grass, docks (*Rumex* spp.) and total herbage were recorded throughout the 1971 season. The results indicate that docks can make a major contribution under a system of cutting for conservation. Grass yields had increased by up to 50% where docks had been controlled, but the highest total dry matter yields did not necessarily coincide with the lowest levels of dock infestation.

INTRODUCTION

Spedding (1966) in a review paper on weeds in grassland concluded that to define a weed species it is necessary to establish first that it is less productive than the crop species, and in what way, also to show that it is reducing the productivity of the crop and not simply occupying vacant space. Although the dock in a grazing system is often ignored by stock and stands apparently self-confessed as a non-contributor to productivity, (Ormrod 1966), precise evidence on this is lacking. Under a cutting system, however, it is obvious that docks make a contribution to the total dry matter production. The present investigation sought to measure the actual yield of docks and grass under cutting/high nitrogen treatments and to study the response of the grass to reductions in population of docks. Baker *et al* 1958, 1960 had shown that with *Ranunculus repens* increased productivity from the grass did not necessarily follow removal of the weed and that other management factors might also require attention.

METHOD AND MATERIALS

Herbage yields were measured at three sites where a study of dock control by herbicides had been conducted over the period 1968-1970 (Courtney, 1970). The aim was to measure the contribution of docks (mainly *Rumex obtusifolius*) to herbage yields and to establish the extent to which grass yields compensated where increased levels of dock control had been achieved. At the three sites,

I Ballygowan, Co. Down

II Loughry, Co. Tyrone

III Magheragall, Co. Antrim

a series of clips was taken during the 1971 season (Table 1). Sites II and III were cut for conservation throughout the year. Site I was rotationally grazed, although the second cut (22 June) was conserved.

Each of these sites was managed intensively. Sites I and III received approx. 300 kg/ha of nitrogen and Site II approx. 200 kg/ha.

Table 1

Site details and dates of cuts in 1971

Site No.	I			II			III		
Pasture type	*Agrostis* spp. *Poa trivialis*			Ryegrass *Poa trivialis*			Ryegrass *Poa trivialis* *Agrostis* spp.		
1971 fertiliser	N	P	K	N	P	K	N	P	K
Application kg/ha	340	75	75	200	0	0	313	50	50
	+ Slurry and basic slag						+ slurry		
Dates of cuts	1. 30 April			26 May			9 June		
	2. 22 June			28 July			19 Aug.		
	3. 29 July			13 Oct.			28 Oct.		
	4. 6 Sept.								

The herbicide treatments (1 - 10) which had been applied on three occasions between 1968 and 1970, resulting in a range of levels of dock infestation were as follows:-

1. Dicamba/mecoprop
2. Asulam
3. Asulam/MCPB/MCPA
4. Asulam/mecoprop
5. Mecoprop
6. 2,4-D
7. MCPA
8. Dichlorprop
9. MCPA/dicamba
10. Untreated control

For further details see Courtney (1970)

The yield data was recorded from sample clips taken with an autoscythe from the central area of each plot. The area harvested from each plot was 5·8 m^2. At Sites II and III, sample cuts were taken during the season immediately before the areas were cut for silage. At Site I, which was grazed with dairy cattle, four clips were taken from the same marked sample strips in each plot throughout the year. A separation of docks and other herbage was made in the field and their fresh weights recorded. Both fractions were sub-sampled for dry matter assessment and a botanical separation carried out on the herbage portion.

RESULTS

Yield data Tables 3 and 4 show the contribution of docks and grass respectively relative to the control, for each of the clips, also the annual total. Table 5 shows the annual yields of docks, grass and the total herbage, again relative to the controls. The control treatments (Treatment 10) in each case were those plots which had not received any herbicide in the previous years and which had the highest population of docks.

Dock yields At each site, on the control plots, docks made a significant contribution to yield, (Table 2). The respective annual dry matter yields of docks of 1·31, 3·07 and 2·61 metric t/ha at sites I, II and III represented 10·8%, 28·0% and 20·8% of the total yield of dry matter. The seasonal pattern of dock productivity was different from that of the grass. The contributions of docks to total yield was least in the first cut and increased later in the season.

Table 2

Dock contribution (d.m. %) to total herbage yield

Untreated control		Cuts			
Site	1	2	3	4	Annual yield
I	3·4	12·9	9·9	19·9	10·8
II	8·8	56·6	31·9		28·0
III	18·4	26·1	15·9		20·8

At Site III the higher proportion in the first cut was probably due to this cut being delayed until 9 June.

The levels of dock dry matter relative to the control on each of the treatments also increased in the later clips, e.g. Site III Treatment 1.

Dock d.m. % relative to the control

Cuts		
1	2	3
14	25	46

Grass yields The annual dry matter yields of grass (Table 4) from the three sites were 10·30, 7·86 and 9·88 metric t/ha, the higher yields came from the two sites which had received the highest levels of nitrogen. At each site, on the controls, production was high in the first cuts and decreased later in the season. The maximum response of the grass, relative to the control, to the reduced dock infestations came also not in the first cut but rather later in the year, i.e. Treatment 1 at Site II the grass dry matter yield relative to the control was - Clip 1 - 100%; Clip 2 - 221% and Clip 3 - 193%. The annual yield response of the grass (Table 4) varied according to the site and the levels of the docks resulting from the previous herbicide treatments. However, where dock control had been good grass yields had increased by between 15% and 50%. Even on those plots where the docks had been diminished to only a slight extent the grass showed a response approaching 10%, Fig. 1 shows for Site II the response which both grass and total herbage showed as dock dry matter production relative to the control was decreased. In this case grass yields continued to respond till the dock contribution had been reduced to 50% of that of the control.

Table 3

Dock Dry Matter Yields, as a Percentage of Untreated Control Yield, for Individual Clips, and Annual Total

	TREATMENTS											
	1	2	3	4	5	6	7	8	9	10	Sig Level	S.E. Mean
Site I												
Clip No.												
1	21	44	101	15	17	42	107	-	-	(0·11)	NS	±0·03
2	19	25	45	21	28	18	88	-	-	(0·44)	*	±0·08
3	39	99	108	40	63	169	56	-	-	(0·33)	NS	±0·16
4	28	22	54	41	26	26	74	-	-	(0·44)	*	±0·07
Annual Total	29	46	72	34	39	62	83	-	-	(1·31)	NS	±0·24
Site II												
Clip No.												
1	14	9	41	6	16	43	55	13	51	(0·51)	NS	±0·09
2	25	22	35	12	61	75	79	24	93	(2·14)	**	±0·40
3	46	43	41	23	37	112	87	76	113	(0·42)	*	±0·08
Annual Total	26	22	37	13	50	75	76	29	89	(3·07)	**	±0·49
Site III												
Clip No.												
1	17	59	33	39	11	36	64	38	100	(1·27)	**	±0·20
2	25	116	80	61	26	86	99	43	110	(1·14)	NS	±0·27
3	19	102	63	87	24	62	130	53	112	(0·20)	*	±0·05
Annual Total	20	87	56	52	19	60	84	42	105	(2·61)	**	±0·40

( ) d.m. Yield metric tonnes/ha.

Table 4

Grass Dry Matter Yields, as a Percentage of Untreated control yield, for Individual Clips and Annual Total

TREATMENTS

	1	2	3	4	5	6	7	8	9	10	Sig. Level	S.E. Mean
Site I												
Clip No.												
1	111	95	97	107	104	106	97	-	-	(3·03)	NS	±0·18
2	125	100	136	138	142	128	119	-	-	(2·89)	NS	±0·45
3	119	100	132	109	120	114	115	-	-	(2·76)	NS	±0·30
4	95	143	102	131	103	117	116	-	-	(1·62)	NS	±0·33
Annual Total	114	105	118	120	119	116	111	-	-	(10·30)	NS	±0·67
Site II												
Clip No.												
1	100	113	113	112	105	120	103	113	107	(5·30)	NS	±0·33
2	221	159	229	255	215	147	134	199	142	(1·67)	*	±0·48
3	193	207	173	184	168	128	116	171	106	(0·89)	***	±0·12
Annual Total	137	133	144	150	135	126	111	138	115	(7·86)	**	±0·70
Site III												
Clip No.												
1	117	113	126	119	128	120	112	138	97	(5·62)	*	±0·41
2	131	96	88	113	119	98	88	118	65	(3·20)	NS	±0·45
3	132	116	122	109	146	109	107	106	92	(1·06)	NS	±0·16
Annual Total	123	108	113	116	127	112	104	128	86	(9·88)	*	±0·49

( ) d.m. yield metric tonnes/ha

Table 5

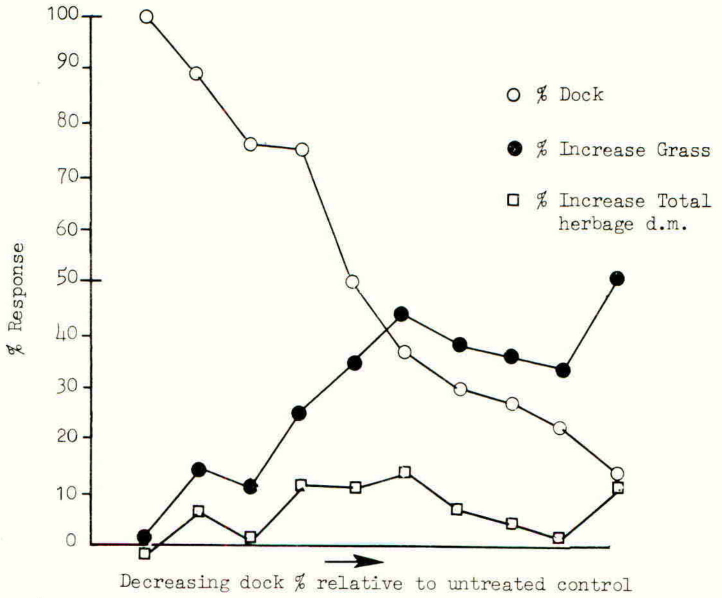
Annual Yield, Grass, Docks, Total Herbage, as Percentage of the Control

Treatment		1	2	3	4	5	6	7	8	9	10
Site I	Grass Yield	114·4	105·4	118·4	119·9	118·8	116·3	110·0	-	-	(10·304)
	Dock Yield	28·5	45·9	72·0	33·8	38·8	61·8	83·4	-	-	(1·313)
	Total Herbage	100·9	97·5	110·0	106·1	105·6	105·8	103·4	-	-	(12·105)*
Site II	Grass Yield	136·5	133·1	144·5	150·4	135·0	126·3	110·6	137·7	114·2	(7·855)
	Dock Yield	26·1	22·3	36·6	12·5	49·8	74·9	76·2	29·5	88·9	(3·069)
	Total Herbage	105·3	102·0	114·2	111·7	111·1	111·9	100·9	107·3	107·1	(10·943)*
Site III	Grass Yield	123·0	107·8	113·0	116·0	127·0	111·7	103·9	127·9	86·1	(9·875)
	Dock Yield	20·3	86·8	55·5	52·1	18·6	59·6	84·1	41·5	105·3	(2·608)
	Total Herbage	101·1	103·5	100·4	102·1	103·9	100·3	99·8	109·4	89·8	(12·551)*

( ) d.m. yield metric tonnes/ha

*This figure includes broad leaved weeds in addition to grass and docks.

Fig. 1: Site III The response of grass, total d.m. production Annual total) to diminishing dock representation in the sward.



Botanical composition Although the representation of the individual grass and weed species in the herbage was recorded throughout this trial, no significant difference between treatments was found so that although there did appear to be seasonal trends with Poa trivialis decreasing and Agrostis spp. increasing late in the season, the treatments themselves either directly, of as a secondary effect of the dock control, had not significantly altered the balance of components in those swards.

Total herbage yields Considering total herbage production (Table 5) the sum of the production from docks, grass and broad-leaved weeds. At the three sites, the contribution from other broad-leaved weeds was small i.e. for the controls at Site I 0·49 t/ha, Site II 0·02 t/ha and Site III 0·07 t/ha. The total herbage yields are thus essentially the sum of the docks and the grass.

The major contribution which the docks made to yield of cut herbage has already been mentioned. Because of this, total herbage dry matter production on plots where the docks had been controlled showed a lower response relative to the controls than had been recorded for the grass yields (Table 5). Fig. 1 shows how at Site II although total grass yields had shown a response of up to 50% increase, the total herbage response showed a maximum of only 10%. Although this is not entirely clear from the data at Site II, it does appear that the maximum herbage production did not necessarily come from those plots where the dock population was low, but more often from those plots where the dock level had been reduced sufficiently to allow the grass to respond but where the contribution from docks was still being maintained.

DISCUSSION

Although no direct comparison of the productivity of docks and grass species has been made, the capacity of *Rumex* spp. to contribute to total dry matter was apparent at all these sites. It appeared however that the pattern of production differed from the grass, with the peak production from the docks coming in the later cuts in the season. Considering the further criteria which Spedding (1966) suggests should be applied to define a weed i.e. do they suppress the production of the grass, the response in grass yields (Fig. 1) to the reduced presence of the docks clearly demonstrates the extent to which this was true under the conditions of high nitrogen usage at this site.

A point which requires further consideration is that in many instances, plots containing high proportions of docks in the grass gave greater yields of dry matter than plots containing lower proportions of docks. Whilst there is not necessarily merit in dry matter production alone, farmers report that, conserved in silage, docks are acceptable to stock and experiments are now in progress to establish the contribution which docks make to digestible organic matter.

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HERBICIDES FOR CONTROL OF DOCKS (RUMEX SPP) IN GRASSLAND

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Summary Four series of studies on the control of mature docks (mainly Rumex obtusifolius) in established grassland were conducted in south-west Scotland during 1970 - 72. The first two series (3 sites) dealt with control from herbicide types, application rates and combinations of spraying times. No herbicide achieved total control. A double spraying of dicamba was particularly effective (76-86%) but at exorbitant cost for farm-scale use. The next best control (62-67%) was attained by dicamba-based herbicides sprayed in May successively for two years. In Series 3 (4 sites), herbicides were sprayed at either spring or autumn periods. For both periods, dicamba-based herbicides gave the best results when evaluated a year later (62-65%). Examination of the suppressive effect of herbicides shortly after spraying (Series 4, all sites) showed a range of 'apparent kills' between 35-100%, with best results again being obtained from dicamba or dicamba-based mixtures. Herbicides for dock control must be chosen on cost and probable effectiveness in relation to the degree of dock infestation.

INTRODUCTION

R. obtusifolius and R. crispus are found throughout the British Isles and are adapted to a wide range of climatic, topographical and substratum habitats and plant communities (Cavers and Harper, 1964). They are prolific seed producers and the seed can survive in the soil for many years. Milton (1936) recorded populations of up to five million seed/ac to a depth of seven inches for R. obtusifolius. In Dr. Beal's seed viability experiment, seeds of R. Crispus were still viable after 80 years' burial, although the low germination percentage (2%) indicated that the period of survival was nearly ended (Darlington and Steinbauer, 1961). Survival is also aided by the ability to regenerate from fragments of underground stems and roots. Chancellor (1970) stressed the importance of prevention of seeding for dock control, since once seeds are in the soil, control measures must be repeated over an extended period.

The problem of dock infestation in grassland has increased almost concomitantly with intensification of grassland management. High-yield herbage crops, produced from increasing levels of fertilizer nitrogen, are being utilized via high stocking rates and bulky conservation crops; swards with a much more open sole than was customary in the past have resulted and this has given docks the opportunity to become established from the reservoir of viable seed in the soil. A questionnaire on weed problems sent to 450 farmer-members of the South-West and Central Scotland Grassland Societies (resulting in some 112 replies) showed that docks were their major weed problem and had worsened in recent years (Hunt, 1970). Recent Proceedings of the British Weed Control Conferences have also reflected increasing concern about the control of docks (1 paper in 1966, 3 in 1968 and 6 in 1970).

Experiments reported here were undertaken in the West of Scotland during 1970 - 72 to compare the effectiveness in controlling docks of a wide range of herbicides. The chemical make-up of these varied from single to triple mixtures and from specificity for docks to general-purposeness for a spectrum of weeds including docks.

METHOD AND MATERIALS

Series 1 To assess the effectiveness of a range of herbicides in controlling docks, experiments were initiated in May, 1970 at each of two sites (Argyllshire and Wigtownshire). The grassland was dominantly perennial ryegrass at both sites and was used intensively for grazing/cutting. The docks present were mainly *R. obtusifolius*, with some *R. crispus*. At spraying, the docks were at the fully-expanded leaf stage. A split-plot, randomized-block layout was used with two replicates of three combinations of spraying times as main plots and eight herbicides plus a no-spraying control as sub-plots, giving a total per site of fifty-four sub-plots, each 4 yd x 12 yd. The three spraying combinations were a) May, 1970 plus May, 1971 b) September, 1970 plus May, 1971 and c) May, 1970 plus September, 1970. Herbicide application was made in 25 gal/acre aqueous solution using an Oxford Precision Sprayer. The solutions were sprayed at 25 lb/in^2 pressure through 'o' ceramic jets fitted to a 5 ft boom. Weather conditions at spraying in this (and other series) were generally cloudy with sunny intervals. The herbicides used, together with their application rates and costs are listed in Table 1.

Prior to spraying the presence of docks on each sub-plot was scored visually using a 0-10 scale, where 10 represented 100% of the plot area covered with dock foliage, 9 represented 90% coverage and so on *pro rata*. A similar procedure was adopted each time the presence of docks was assessed.

Series 2 A further experiment was laid down at the Wigtownshire site in September, 1970 to measure the effectiveness of additional herbicides in controlling docks. The docks were again mainly R. obtusifolius at the fully-expanded leaf stage. Two newly-released 'dock-control' herbicides were included together with several rates of dicamba, which had shown great promise in Series 1 for rapid, total suppression of dock foliage, but at the rate used was very expensive. A randomized-block layout was adopted with three replicates of nine herbicides plus a no-spraying control giving a total of thirty plots, each 4 yd x 12 yd. Details of the treatments are shown in Table 2. Spray application and assessment of dock presence were carried out as for Series 1.

Series 3 To evaluate the effectiveness of a further range of herbicides, experiments were conducted using a single spraying during May-July, 1971 at four sites (Dunbartonshire, Lanarkshire, Perthshire and Renfrewshire). Altitude ranged from 200-800 ft. The swards were again dominantly perennial ryegrass used for intensive grazing/cutting. The docks, mainly *R. obtusifolius*, were at the flowering shoot-emergence growth stage at three of the sites and the full leaf stage at one site. A randomized-block layout was used with ten herbicides plus a no-spraying treatment per block. At two of the sites, there were three replicates but only one at each of the other two sites. The plot size throughout was 4 yd x 12 yd; spraying procedure and assessment were again as described for Series 1. Treatments are listed in Table 3.

Series 4 This series comprised all the foregoing series plus a miscellany of plot, field-scale and pilot trials at Auchincruive and in the south-western Scottish counties. At all these trials, assessments were made of the suppression of dock growth 4-5 weeks after each time the plots were sprayed, using a visual scoring scale 0-10, where 10 represented 100% suppression, 9 represented 90% suppression and so on *pro rata*. For a single herbicide there were observations from up to 12 sites and 36 replicates. Table 4 shows details of the herbicides used.

Table 1

Dock growth 18-24 months after initial spraying of various combinations of spraying times (Series 1)

(Means of 2 sites/4 replicates)

Herbicides (in 2 applications)				Sprayed: May 1970 + May 1971			Sprayed: Sept. 1970 + May 1971			Sprayed: May 1970 + Sept. 1970		
				Dock scores		%	Dock scores		%	Dock scores		%
Constituents	Pints /ac	Lb a.i. /ac	Cost+ £/ac	May 1970	May 1972	reduction	Sept. 1970	May 1972	reduction	May 1970	May 1972	reduction
Dicamba	12.0	6.0	25.50	7.0	1.0	86	6.0	1.3	78	6.3	1.5	76
Dicamba) Mecoprop)	8.0	np++	7.00	6.0	1.5	75	6.3	2.0	68	5.8	2.3	60
Dicamba) MCPA)	10.6	np	3.00	6.0	2.0	67	5.5	2.5	55	6.3	3.5	44
Dichlorprop	8.0	5.0	2.70	6.8	2.8	59	6.3	3.0	52	6.0	3.3	45
Mecoprop	12.0	4.5	2.40	6.5	3.0	66	5.5	2.8	49	4.5	3.3	27
Dicamba)+++ Mecoprop) MCPA)	8.0	np	2.50	6.5	2.5	62	5.8	3.0	48	4.8	3.8	21
Asulam	4.0	2.0	4.00	6.5	3.5	46	6.5	3.8	42	6.5	4.0	38
MCPA	10.0	3.12	1.30	6.3	3.3	48	5.8	4.0	31	5.8	3.8	34
Untreated	-	-	-	6.0	6.3	(+5)	4.0	4.8	(+20)	6.5	6.3	3

\+ Cost of material only ++ Not published +++ Formulation 1 of these three constituents

RESULTS

Series 1 Table 1 shows the persistency of dock control achieved by the herbicides at the various combinations of spraying times. Dicamba gave the best control (76-86%), but at a herbicide cost of £25.50. The dicamba-mecoprop mixture achieved 60-75% control at a cost for spray material of £7.00. The other dicamba-based mixtures gave control of between 62-67% for the double spring sprayings but much poorer results for other combinations of spraying times. Mecoprop gave a 66% control at low cost when sprayed in springs of successive years. The other herbicides gave poor results regardless of spraying time. In general, spraying in May for two successive years gave the best results whereas spraying twice in the same year gave the poorest results.

Series 2 The dock control achieved by spraying in September, 1970 plus May, 1971 is shown in Table 2. Dicamba at 6 lb a.i./ac was again outstanding with 74% control but was closely followed by the dicamba-mecoprop mixture at 70%. Decreasing the rate of dicamba reduced the control but 60% was still achieved at 1.0 lb a.i./ac. Herbicides based on mecoprop-dichlorprop gave poorer results.

Table 2

Dock growth 18 months after a Sept. 1970 and May, 1971 spraying combination (Series 2)

(Means of 1 site/3 replicates)

Herbicides (in 2 applications) Constituents	Pints /ac	Lb a.i. /ac	Cost £/ac	Dock scores Sept. 1970	Dock scores May 1972	% reduction
Dicamba	12.0	6.0	25.50	5.0	1.3	74
Dicamba) Mecoprop)	8.0	np	7.00	4.3	1.3	70
Dicamba	8.0	4.0	17.00	4.7	1.7	64
Dicamba	4.0	2.0	8.50	5.0	2.0	60
Dicamba	2.0	1.0	4.20	5.7	2.3	60
Dicamba)+ Mecoprop) MCPA)	8.0	np	7.00	6.7	2.7	60
Mecoprop) Dichlorprop) MCPA)	10.0	np	6.20	5.7	2.7	53
Dicamba	1.0	0.5	2.10	5.7	4.0	30
Mecoprop) Dichlorprop)	6.0	3.76	1.80	6.7	4.7	30
Untreated	-	-	-	4.3	4.0	7

+ Formulation 2 of these three constituents

Series 3 Table 3 shows the results obtained 10-12 months after single sprayings of herbicides in the May-July period of 1971. The best degree of control was achieved by dicamba-based herbicides with the exception of granular dicamba and the low rate (0.5 lb a.i./ac) of liquid dicamba. Mixtures which included dicamba-mecoprop gave 62-65% control.

Table 3

Dock growth 10-12 months after spraying in May-July, 1971 (Series 3)
(Means of 4 sites/8 replicates)

Herbicides (single application) Constituents	Pints /ac	Lb a.i. /ac	Cost £/ac	Dock scores May-July 1971	Dock scores May 1972	% reduction
Dicamba) Mecoprop)	4	np	3.50	5.3	2.1	65
Dicamba)+ Mecoprop) MCPA)	4	np	3.50	5.8	2.2	62
Dicamba) Mecoprop) 2,4,5 - T)	4	1.8	3.50	5.3	2.3	57
Dicamba	2	1.0	4.25	5.2	2.5	52
Mecoprop	8	3.0	1.60	4.6	2.8	39
Asulam	2	1.0	2.00	5.7	3.6	37
Granular) Dicamba)	-	2.0	np	5.2	3.9	25
Mecoprop) Dichlorprop) MCPA)	5	np	3.10	5.7	4.3	25
Dicamba	1	0.5	2.10	5.3	4.1	23
Granular) Dicamba)	-	1.0	np	5.8	4.8	17
Untreated	-	-	-	4.3	5.9	(+37)

\+ Formulation 2

Series 4 The suppression of dock growth or 'apparent kill' 4-5 weeks after spraying is shown in Table 4 for a range of herbicides at spraying periods May-July and August-September. Suppression ranged from 38-99% for the first period and from 35-100% for the latter. The order of effectiveness was fairly similar in both periods; herbicides based on dicamba were generally superior to others. Even granular dicamba at the higher of the two rates achieved a suppression of 75-77% in spite of the inherent difficulties of evenly spreading granules as opposed to spraying a liquid. Herbicides which gave the best suppression were equally effective at both periods; the generally less effective herbicides gave better results from spraying in the May-July period.

Table 4

Suppression of dock growth 4-5 weeks after spraying (All sites)

Constituents	Pints /ac	Lb a.i. /ac	Cost £/ac	Dock suppression scores for spraying periods: May - July	Aug. - Sept.
Dicamba	6.0	3.0	12.75	9.9	10.0
Dicamba) Mecoprop)	4.0	np	3.50	9.5	9.4
Dicamba	2.0	1.0	4.25	9.2	9.6
Dicamba	4.0	2.0	8.50	9.3	9.3
Dicamba) 2,4,5 - T) Mecoprop)	4.0	1.8	3.50	8.9	9.5
Dicamba)+ Mecoprop) MCPA)	4.0	np	3.50	8.8	9.3
Dicamba	1.0	0.5	2.10	8.3	8.9
Dicamba	0.5	0.25	1.05	8.7	7.7
Dicamba) MCPA)	5.3	np	1.50	8.3	6.9
Granular) Dicamba)	-	2.0	np	7.7	7.5
Dicamba)++ Mecoprop) MCPA)	4	np	1.25	7.2	6.2
Mecoprop) Dichlorprop) MCPA)	5	np	3.10	7.1	5.8
Mecoprop	8	3.0	1.60	7.8	5.0
Asulam	2	1.0	2.00	5.8	4.6
Granular) Dicamba)	-	1.0	np	5.4	5.0
Dichlorprop	4	2.5	1.35	5.8	4.1
Mecoprop	6	2.25	1.20	5.6	4.4
Mecoprop) Dichlorprop)	3	1.88	0.90	5.0	3.3
MCPA	5	1.56	0.65	3.8	3.2

+ Formulation 2 ++ Formulation 1

DISCUSSION

<u>Persistency of control</u> Some indication of this can be gauged from the experiments started in 1970 and finally assessed in Spring, 1972 (Series 1 and 2). The most effective herbicides were those based on dicamba alone or mixtures which included dicamba. The results from certain of the chemicals agree fairly closely with those previously reported by Courtney (1970) working in an environment similar to the West of Scotland. Farm-scale use of dicamba alone at the higher rates used (2-6 lb a.i./ac) must be precluded on account of high cost. The dicamba-mecoprop mixture cost £7.00/acre for a double spraying and the control attained was 70-75%. The docks remaining at the spring 1972 assessment appeared to be regrowths from old rootstocks rather than from seedlings. Much of the effective control is achieved at the first spraying; at the second, a good deal of the spray material will fall on herbage rather than dock foliage. Spot treatment with a knapsack sprayer would seem to be the practical solution. If high labour costs militates against this, the alternative is to switch to a low-cost herbicide, particularly if it controls other weeds in addition to some degree of control of docks e.g. mecoprop.

The results in Table 3 from Series 3 show the short-term effect of a single spraying. Mixtures based on dicamba-mecoprop achieved the best results although the highest degree of control after 10-12 months was only 65%. As in previous series, the docks remaining appeared to be regrowths. The difficulties of obtaining an even spread of granules would seem to preclude the use of granular dicamba for dock control other than for spot application. After treatment with the three herbicides giving the best results, the dock scores ranged from 2.1 to 2.3. On a farm-scale such levels of dock presence clearly do not justify a repeat spraying of material costing £3.50/acre. As was suggested above, spot treatment or the use of a low-cost multi-purpose herbicide could be used to maintain dock suppression.

Dock seedlings are not competitive and cannot establish in a closed plant community (Cavers and Harper, 1964). Grassland management measures for preventing infestation in the first instance or preventing re-infestation after spraying must be geared to the maintenance or re-development of a dense pasture sole. It is difficult to maintain a dense sward and at the same time carry high stocking rates with attendant treading damage or remove heavy conservation crops with attendant development of sward openness. These deleterious effects can be minimized by a) adequate soil drainage and good soil fertility b) the use of herbage species/varieties with dense tillering ability and resistance to treading e.g. pasture-type perennial ryegrass c) the use at susceptible times of 'sacrifice' fields that are to be ploughed up d) the use of long-rotation pastures and e) minimal grazing during winter.

<u>Short-term dock suppression</u> Rapidity of control has advantage in that the competitive effects of dock foliage on herbage growth is quickly removed; this permits more vigorous herbage growth. Recolonization by herbage species of the surface area hitherto occupied by docks should be encouraged by fertilization of the sward shortly before spraying. A rapid suppression of docks following spraying also gives a psychological boost to the farmer in that he sees an immediate effect for his expenditure. If the 'apparent kill' of docks recorded 4-5 weeks after spraying with herbicides (Table 4) is compared with the longer-term persistency of control (Tables 1-3), the extent to which dock regrowth takes place is clearly seen. However, in these experiments, the herbicides which gave the best immediate suppression also gave the best persistency of control.

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THE EFFECT OF ASULAM ON BRACKEN FROND NUMBER, RHIZOME VIABILITY, AND FROND CARBOHYDRATE RATIOS

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Summary Treatment of dense bracken with asulam at 2, 4, 6 and 8 kg/ha in the summer of 1970 gave a reduction of up to 98% in frond number in 1971. Analysis in 1972 showed a continuing effect of treatment but with some regeneration occurring. Visual analyses of frond rhizome and storage rhizome showed the possibility of a reduction in the proportional weight of frond rhizome at 6 and 8 kg/ha and increased death or abnormal development of buds at the 8 kg/ha rate. The ratio of reducing sugars to total carbohydrate in treated fronds was not significantly different from that of untreated fronds and treatment with asulam was considered not to influence the possibility of increased grazing of fronds.

INTRODUCTION

Asulam has shown potential as a bracken herbicide (Holroyd *et al.*, 1970) but its value as an economic treatment depends to a large extent on its long-term effects on the fern and on the indigenous herbage. The present report summarises its effects one and two years after treatment as a guide to estimating long-term results in the west of Scotland. Fears have been expressed that cattle or sheep may more frequently graze bracken fronds which have been sprayed and thus suffer from bracken poisoning, an extension of the known effects after spraying ragwort (*Senecio jacobaea* L.). This report outlines the results of analyses of carbohydrates in treated bracken fronds and ragwort in an attempt to show whether or not increased free sugars could affect the palatability of sprayed fronds.

METHODS AND MATERIALS

Dense bracken at Knocknairling, Galloway (Map ref. NX 612771) and in Glen Douglas, Loch Lomondside (Map ref. NS 325980) was sprayed with asulam at the rates of 2, 4, 6 and 8 kg/ha using a knapsack sprayer. The water carry was 400 l/ha. The plots were 5 m square with 1 m discards between, and were duplicated. The plots at Knocknairling were sprayed on the 25th June 1970. At Glen Douglas, spraying took place each month from August 1970 - July 1971, the spraying date being on or near the 25th of each month. Analyses were carried out in mid-August 1971 and 1972.

The rhizome samples were taken from the plots sprayed in August 1970 and consisted of all the rhizome present in a ½ m square pit as deep as necessary (maximum of 45 cm.). Each sample was separated into the upper frond-bearing rhizome and the generally lower storage rhizome. Thereafter a separation into obviously dead and apparently living material was carried out. After weighing these fractions, sections were cut of the rhizomes and of buds in both rhizome groups and these were examined visually and where necessary by microscope.

The material for the carbohydrate content analyses was obtained at Dalry, Galloway (Map ref. NX 635798); dense bracken was sprayed with asulam at 4 kg/ha or MCPA at 6 kg/ha in 400 l/ha of water. Cut samples were also taken. The reducing sugar and total carbohydrate contents were obtained by the methods of Shaffer and Somogyi (1933).

RESULTS

Table 1

Effect of asulam on bracken frond numbers

(Expressed as % age reduction from untreated)

Sprayed	Knocknairling June 1970				Glen Douglas August 1970				Glen Douglas June 1971				Glen Douglas July 1971			
Rate kg/ha	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8
1971 analysis	98	97	98	97	64	75	80	87								
1972 analysis	81	90	96	93	48	68	78	81	96	98	99	97	97	++	98	98

(++ .. these plots have had to be abandoned).

As will be seen from Table 1, June and July sprayings gave an excellent response in terms of frond number reduction at all levels of herbicide rate used. The August spraying was much less successful, reducing the cover by only 75% on average. There was no response to spraying at the quoted rates during the months September - May inclusive. Trials are in hand at five sites throughout the west of Scotland to investigate the poor response to August spraying and the nil response from September spraying, since this may be an effect local to Glen Douglas.

Regeneration on the June 1970 plots has resulted in an average reduction to 90% of the untreated bracken and on the August 1970 plots to 76% of the untreated bracken. Originally the plots carried 450 and 365 fronds per plot respectively.

The height of the treated bracken varies from 100 cm down to 75 cm as dosage rate increases on the 1970 plots (compared with 125 cm on the untreated) and is generally 40 - 45 cm on all the 1971 plots.

The rhizome material from the August 1970 plots was separated into frond-bearing rhizome, storage rhizome and dead material. The comparative weights of these fractions is shown in Table 2 where it will be seen that there is a possible reduction in frond rhizome weight at the 6 and 8 kg/ha rates.

Table 2

Effect of asulam on bracken rhizome

Comparative % weight of rhizome from ½ m square pits

(Treated August 1970, assessed August 1972)

kg/ha	Frond Rhizome	Storage Rhizome	Dead	Total wt. g
2	13.0	66.4	20.5	2192
4	14.9	67.5	17.5	2120
6	6.3	75.2	18.4	2106
8	8.5	74.4	17.0	1982
Untreated	17.0	70.1	12.9	1778

Sections of the frond and storage rhizome were cut at random points along their lengths and the viability of the rhizome was assessed. Within these apparently healthy rhizomes it was found that there were short lengths which were dead and that some of the frond buds were dead or showed gross sclerenchymatous thickening, accompanied by a brown staining of the cell walls and contents, particularly in the outer layers. The dead rhizome lengths tended to be near the point of junction with a complex of frond base, axillary bud and short length of axillary rhizome. Similarly, the dead or affected frond buds were almost always adjacent to a frond base left from some previous year's growth. The exact year of growth of such frond bases was impossible to determine. As can be seen from Table 3 there was a considerably higher number of dead or affected buds in the 8 kg/ha material.

Table 3

Comparative % of "affected" rhizome and buds from apparently healthy material (treated August 1970, assessed August 1972)

kg/ha	Frond Rhizome: Rhizome	Frond Rhizome: Buds	Storage Rhizome: Rhizome	Storage Rhizome: Buds
2	16	28	2	15
4	9	10	4	13
6	13	15	10	14
8	10	45	4	46
Untreated	8	23	8	14

In the four samples taken there was a total of six rhizome tips; all of these were healthy.

Table 4

Effect of treatments on carbohydrate ratios in bracken (Reducing sugars as % age of total carbohydrate)

	Days after treatment 1	2	3	4	5	6	7	8	9	12	Mean
Untreated	34.7	42.3	25.5	24.4	55.8	30.5	37.3	37.0	47.6	39.5	37.5
Asulam 4 kg/ha	41.6	48.3	47.1	26.6	62.1	46.2	56.0	60.8	34.2	23.5	44.6
MCPA 6 kg/ha	32.3	44.1	55.0	67.2	79.5	58.8	71.8	54.7	64.9	57.1	58.5
Cut	34.2	47.8	72.7	58.8	91.3	96.9	78.9	96.2	59.5	-	70.9

L.S.D. between means (5%) .. 13.6

It has been suggested that there may be a greater incidence of grazing of herbicide treated bracken fronds leading to cases of bracken poisoning, and that this could be due to an increase in free sugars in the fronds after treatment, increasing the palatability of the fronds. The results in Table 4 show that treatment with asulam or MCPA does not increase the reducing sugars content as much as does cutting, yet cutting is not generally regarded as an operation which will lead to increased grazing of fronds. It is generally accepted, however, that cut or sprayed ragwort (*Senecio jacobaea* L.) is more likely to be grazed than fresh material, yet analyses similar to those carried out on bracken showed no significant difference in the amount of reducing sugars among untreated, cut, asulam (4 kg/ha) or MCPA (1.5 kg/ha) treatments of ragwort, the mean percentage content being 43.8.

DISCUSSION

The use of asulam as a bracken herbicide in the west of Scotland offers a frond number reduction in the first year after treatment better than any other herbicide investigated by the present authors when one uses £12 per acre as a limit to the gross cost for chemical alone. The rate of regeneration in areas where fertilising, re-seeding or stock control cannot be practised due to economic or physical restrictions will determine whether or not this chemical, and others, is a possible and economic solution to the problem of bracken infestation.

It would appear from visual evidence above ground and from that derived from the rhizome and bud viability analyses presented above that there is little translocation of asulam away from the bases of sprayed fronds. The untreated bracken around and between plots remains remarkably free of epinastic effects or reduction in vigour. Only at the highest rate used was there any evidence of increased death or abnormal development of frond buds.

Regeneration rates will continue to be assessed annually on the plots in these trials.

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CONTROL OF BRACKEN WITH ASULAM IN THE NORTH OF SCOTLAND

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Summary Results of field trials carried out in 1970 and 1971 with asulam for the control of bracken *Pteridium aquilinum* (L) Kuhn in the north of Scotland are given. Excellent control was obtained with 4.4 and 2.2 kg a.i./ha asulam, applied in early July at full frond development. Volumes of application ranging from 11-540 litres/ha all gave good results. Low volume air-blast knapsack spraying gave results as good as those obtained by medium volume hydraulic knapsack application. Results were very consistent between sites and under varying weather conditions and the herbicide did not appear to require accurate or careful application to achieve success. The trials have not been in progress for a sufficient length of time for the long term control to be assessed but regeneration on treated areas two years after spraying has been very limited.

INTRODUCTION

Bracken fern *Pteridium aquilinum* (L) Kuhn is a serious problem on hill grazings in the north of Scotland. Its distribution is geographically very sporadic but in certain areas e.g. Strathnaver, Sutherland, large tracts of land (100's of ha) covering many farms may be infested. Elsewhere smaller areas (1-50 ha) of potentially useful land on individual farms are heavily infested. Bracken is usually associated with grass type moorland on hill sheep farms where extensive uncontrolled grazing is practised but dense very vigorous infestations may also be found on neglected inbye land and in sheltered birch scrub woodland. Bracken grows best on well drained mineral soil and it is therefore the potentially best areas of the hill land which are affected by this weed.

The productivity of land infested with bracken is seriously reduced especially where the cover is so dense as to almost completely inhibit grass growth beneath the canopy of fronds. Stock will not normally penetrate such areas and they are virtually non-productive. Where shorter more open bracken is present there is usually a good sward of bent and fescue grasses beneath which may be capable of sustaining a reasonable number of stock in the spring before bracken growth commences and in the autumn after frost has destroyed the bracken foliage.

On many hill farms there is an excess of summer grazing available and the loss of grazing on land infested with bracken may not limit the output of the holding. Under these conditions control of bracken is not warranted until stock numbers have been raised to the limit of the available summer grazing.

Bracken may also constitute a problem in forestry particularly during the establishment of young trees and on heather moors where the weed interferes with the utilization of the moor for grouse shooting.

Control of bracken in the past has been based on cultural and mechanical methods, herbicides having failed to provide a satisfactory economical method of control. Ploughing and reseeding completely eliminates bracken and in the north of Scotland areas which are suitable for this technique have generally already been reclaimed although the improvements in modern tractors and machinery are making it possible to deal with areas which hitherto would have been considered as impossible to plough. On land which is unsuitable for ploughing, control of bracken was based on repeated cutting or crushing. The acreage so treated has however declined progressively due to the increasing cost of such operations and also possibly to disillusionment with the results since regeneration of the weed gradually takes place when cutting or crushing are discontinued.

Control of bracken with herbicides has been attempted by many workers in the past but results have been indifferent. Previous work at the North of Scotland College of Agriculture has included trials with 4,CPA; amino triazole; dicamba and high doses of MCPA all with either unsatisfactory or unreliable results. Alternatively where good results were achieved, as with picloram, the herbicide was too expensive and had undesirable side effects.

On the advice of the Weed Research Organisation a series of plots were laid down in July 1970 to test asulam as a herbicide for bracken control under the climatic and husbandry conditions prevailing in the north of Scotland. Initially a high rate (4.4 kg/a.i./ha) which was known to be effective was compared with herbicides previously tested. Later lower rates and various methods of application were tested, since if this herbicide is to be widely used for bracken control it must be relatively cheap and practicable methods of application on rough steep hill land must be available.

METHOD AND MATERIALS

In 1970 asulam ("Asulox" - May and Baker 40% w/v aqueous concentrate) was applied in early July at about full frond development at 4 sites, details of which are given below. Other herbicides and a cutting treatment were applied for comparison purposes. All herbicides were applied by a hydraulic knapsack sprayer at a pressure of about 100 kN/m^2 in a volume of 540 litres per hectare water, using a single wide angle anvil type jet to give a sprayed swathe about 2 m wide. Plots were sprayed twice over at right angles in an attempt to improve coverage but owing to the roughness of the terrain and the difficulty in penetrating chest high bracken it proved difficult to ensure even distribution of the herbicides. The imperfections of spraying techniques were very apparent in the paraquat treated plots.

In 1971 asulam only was used as the results achieved with this herbicide were far superior to those obtained with any other material. Various rates and volumes of application were tried in an endeavour to reduce the cost of the treatment. An air-blast knapsack sprayer (Motoblo) was used to achieve reasonable coverage at low or very low volumes of application. Plots were sprayed once over only except where the highest volume (540 litres/ha) was applied by hydraulic knapsack sprayer, when the plots were sprayed twice over as in 1970.

All plots were approximately 0.04 ha in size and were as nearly square as the site permitted in order to minimise the risk of re-invasion by bracken from the margins of the plots. Observations in 1972 of plots clear of bracken in 1971 suggests that inward vegetative spread is about 1 m per year. When making counts the edges of plots were deliberately avoided.

Sites were selected to represent a range of climatic and husbandry conditions likely to be encountered on bracken infested land in the north of Scotland. In 1970 sites A, B, C and D were used. In 1971 sites A and D were abandoned as the area of bracken suitable for experimentation was exhausted and a new site E with a large area of bracken available was utilized. There was considerable variation in bracken density within the sites. Controls were always selected with frond densities approximately equal to those of the treated plots.

Site details

A - Culloden, Inverness-shire. Dense, tall (approximately 0.9 m) bracken amongst birch scrub on steep, south facing slope. Cattle grazing area. Low rainfall 60-80 cm/year.

B - Glenelg, Inverness-shire. Very dense, very tall (approximately 1.4 m) bracken on steep, south facing slope. Sheep grazing only. High rainfall 150-200 cm/year. Shorter less dense bracken utilized in 1971.

C - Rogart, Sutherland. Dense, tall (approximately 0.9 m) bracken on very steep, south facing slope. Sheep grazing only. Low rainfall 60-80 cm/year.

D - Durris, Kincardineshire. Short (approximately 0.7 m) open bracken in small patches on heather moor on north facing slope. Sheep grazing only. Low rainfall 60-80 cm/year.

E - Glen Urquhart, Inverness-shire. Dense, tall (approximately 0.9 m) bracken amongst scattered large birch trees on south facing slope. Cattle and sheep grazing. Medium rainfall 80-100 cm/year.

All spraying was carried out under good weather conditions but at site C in 1970 spraying was followed soon after by very heavy rain. At site E in 1971 the spraying carried out on 19 July was preceded by light rainfall.

RESULTS

The results were assessed by frond counts in July of the year following treatment on 10 random 1 m^2 quadrats per plot. The figures given in the tables of results are an average of these 10 counts. There was no indication of re-infestation by plants produced from spores and it is considered that the fronds present in the year following spraying were a result of regeneration from rhizome buds which had not been affected by the herbicide treatment. Sample digs confirmed that these fronds were attached to the existing rhizome system.

Table 1 gives the results of the 1970 trials in which asulam was compared with other herbicides and cutting. It will be seen that asulam at 4.4 kg a.i./ha gave bracken control far superior to that obtained with any other herbicide or with cutting. At the lower rate of application (2.2 kg a.i./ha) promising results were obtained particularly at site A where cattle were fed on the plot during the winter after spraying.

Table 1

Fronds per m^2 one year after treatment

Treatment July 1970	Rate kg a.i./ha	Site A	B	C	D	Mean number fronds	Percentage control
No treatment	-	32.2	41.5	30.1	24.1	32.0	0.0
Asulam	4.4	0.2	1.2	3.2	3.2	1.9	94.1
Asulam	2.2	0.0	-	-	5.3	-	-
*Amino triazole (activated)	4.4	27.6	19.8	32.2	7.8	22.9	28.4
Paraquat	1.1	34.4	47.0	37.2	21.2	34.9	0.0
MCPA	35.8	21.6	21.4	26.5	4.3	18.4	42.5
**Dicamba (oil emulsion)	2.2	52.7	-	-	18.7	-	-
Cutting once in July	-	26.0†	42.0	23.9	18.6	27.6	13.7

L.S.D. (5%) = 8.7

*many fronds yellow or brown scorched appearance 1971.
**fronds showed morphological abnormality in 1971.
†second cut of regrowth in August.

In Table 2 the results of applying asulam from 1.1-4.4 kg a.i./ha in July 1971 are given. All rates gave very good control. There is an indication of decreased control with the lowest rate (1.1 kg a.i./ha) but the result would probably still be within the limits of commercial acceptability.

Table 2

Fronds per m^2 one year after treatment with asulam

*Rate kg a.i./ha	Site B	C	E	Mean number fronds	Percentage control
None	22.7	24.1	27.2	24.7	0.0
4.4	0.5	1.7	0.4	0.9	96.4
3.3	-	2.4	0.6	1.5	94.0
2.2	0.4	1.8	1.8	1.3	94.7
1.1	1.2	3.9	-	2.6	89.5

*all treatments applied in July 1971 using hydraulic knapsack sprayer; 540 litres spray/ha at site B, 270 litres spray/ha at sites C and E.

The long term effectiveness of control is very important and in Table 3 results of an assessment in 1972 two years after spraying are given. These show that only a very slight increase in the number of fronds regenerating has taken place in the second year after spraying (89.8% control compared with 94.1% in 1971, see Table 1). Observations of all plots will continue over the next few years.

Table 3

Fronds per m^2 two years after treatment with asulam

Rate kg a.i./ha	Site A	B	C	D	Mean number fronds	Percentage control
None	38.2	38.6	24.1	24.5	31.4	0.0
4.4	0.9	3.4	3.1	5.5	3.2	89.8
2.2	0.2	-	-	8.2	-	-

Table 4

Effect of method, time, volume and rate of application on control of bracken with asulam at site E

Type of sprayer	Date of treatment	Volume of spray l./ha	Rate kg a.i./ha	Average number fronds/m^2 1972	Percentage control
-	None	-	-	27.2	0.0
Hydraulic knapsack	6 July 1971	540	4.4	0.7	97.5
		270	4.4	0.4	98.5
		270	3.3	0.6	97.8
		270	2.2	1.8	93.4
Motoblo	19 July	11†	4.4	0.7	97.5
		55	4.4	3.4	87.5
		55	3.3	4.0	85.3
		55	2.2	3.3	87.9
		110	4.4	0.8	97.1
		110	3.3	0.2	99.3
		110	2.2	5.6	79.4‡
	16 August	110	4.4	0.4	98.5
		110	3.3	0.6	97.8
		110	2.2	0.9	96.7
		110	1.1	0.7	97.5
	6 September	110	4.4	0.6	97.8
		110	3.3	1.4	94.9
		110	2.2	1.1	96.0
		110	1.1	8.6	68.4‡

†neat "Asulox" applied.
‡results on these plots would probably be commercially unacceptable.

The results in Table 4 although unreplicated show that there appears to be a reasonable period of at least 2½ months during which asulam will effectively control bracken. The volume of application does not appear to be critical and the present formulation seems to be quite satisfactory for very low volume air-blast application. There is a slight indication of poorer control with the lower rates of application although this is influenced by two rather aberrant results for which no satisfactory explanation is available. Apart from these two results all other treatment combinations could be described as giving a satisfactory commercial control of bracken and one or two appear to have achieved an almost complete suppression of the weed.

Observation of the trial plots revealed no apparent damage to the grass sward, mainly Holcus mollis and Festuca sp, where this was present beneath the bracken nor was heather Calluna vulgaris damaged at site D. Birch Betula sp, rowan Sorbus aucuparia and wild rose Rosa sp in the plots showed no adverse effects of the herbicide.

DISCUSSION

The results of the trials reported in this paper agree with those of Holroyd, Parker and Rowlands (1970) in confirming that asulam is capable of giving excellent control of bracken as measured by frond counts in the first and second years after treatment. Lower rates of application (2.2 and 1.1 kg a.i./ha) than those suggested by the Weed Research Organisation and recommended by the manufacturers, (see May and Baker Technical Bulletin) have given promising results. It is obviously very important that the cost of treatment be kept to a minimum if this herbicide is to be used to control bracken in land of inherently low value and further investigation into the use of low doses is in progress. The effectiveness of repeated very low doses in successive years is also worthy of consideration as there is a possibility that this may give more complete control than a single massive dose in one year only.

In the trials with various methods and volumes of application good results were achieved with the air-blast knapsack sprayer at low and very low volumes of application using the present "Asulox" formulation. This suggests that aerial application which is probably the only practicable means of spraying many areas will be quite effective. A trial area near Inverness of about 10 ha was sprayed in July 1972 by helicopter in conjunction with May and Baker. The results of this work will be available in 1973.

Further investigation of the long term effects of asulam is necessary. Results to date indicate that the herbicide is capable of giving a very high degree of control but not eradication of the weed. Regeneration of fronds from rhizome buds not killed by the herbicide may eventually lead to recovery of the weed. Provided sufficiently large areas are treated re-invasion by vegetative spread from the margins of the treated area would not appear to be a problem and re-infestation by plants produced from spores appears to be very rare.

Permanent eradication of bracken will probably depend on the subsequent utilization of areas initially cleared by spraying with asulam. Experience suggests that if extensive uncontrolled sheep grazing continues the bracken will eventually re-infest the land. On the other hand if controlled cattle grazing is introduced there is every possibility that re-infestation will be prevented. Liming, manuring and in some areas reseeding may be necessary to reap the full benefit of bracken control with asulam. Observations of the larger treated areas will be maintained over the next decade in an effort to relate their bracken status to post spraying management.

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SURFACE ORGANIC MATTER IN RELATION TO THE ESTABLISHMENT OF FODDER CROPS IN KILLED SWARD

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Summary Results are presented of two experiments conducted to investigate the effects of overlying organic matter upon the establishment of kale and Italian Ryegrass sown in killed sward without cultivation. Successive reductions in the amount of trash and mat from that present after spraying gave corresponding increases in emergence and establishment of both crops. Ryegrass gave greater increases than kale. The mortality of seedlings during establishment was not affected by varying amounts of organic matter; therefore final establishment was dependent upon the numbers of plants emerging. Normal and dry seedbeds did not affect the numbers of plants emerging or establishing but did affect the speed of emergence.

INTRODUCTION

After spraying a sward with herbicide the environment available for sowing is composed of the mineral top soil and the overlying surface organic matter which subdivides into the vegetative mat and the dead trash. Before direct reseeding can take place it is necessary to know the extent to which these components need to be modified in order to provide satisfactory conditions for the germination, establishment and growth of the sown crop. Experiments have shown that on Begbroke Hill soil and in the absence of mat and trash, no modification of the mineral top soil is needed (Squires and Elliott, 1972). Eleven crops grown at various seasons of the year performed just as well where there had been no surface disturbance as where the mineral soil had been ploughed or cultivated. Additional experiments have shown that the presence of mat and trash over the mineral top soil generally reduces the number of plants establishing but that the growth of the plants, once established, is not affected by either mat or trash. The work now reported seeks to investigate further the effects of surface organic matter.

METHOD AND MATERIALS

An experiment was carried out in each of two grass fields (Canal Turn and Lime Kilns) at Begbroke Hill. Both fields are on alluvium overlying gravel but because of a high water table are poorly drained. Before 1963 both fields had been permanent pasture consisting mainly of *Agrostis* spp., *Festuca rubra* and *Holcus lanatus*, grazing was extensive giving rise to a matted sward with marked deficiencies of lime, potash and phosphate. After 1963 the management in Canal Turn continued much as before but in Lime Kilns the nutrient deficiencies were corrected and reseeding took place to ryegrass ley which was intensively utilised and fertilized. Therefore in Lime Kilns the matted sward has been replaced by a typical open structured ryegrass sward. The two fields provide sites of contrasting current herbage, mat and soil fertility but of common origin.

Fourteen days before sowing the swards were killed using an overall application of paraquat at the rate of 1 lb a.i./ac in 26 gallons of water per acre. One half of each block was covered after spraying to give dry conditions at the time of sowing while the other half received normal rainfall (Table 1).

Table 1

Rainfall at Begbroke Hill during June and July 1972

Date		mm rainfall	Date		mm rainfall
28	Spray	0	15		0
29	Cover dry plots	9.7	16		0
30		0.4	17	Sow Canal Turn	0
1		0.3	18		10.4
2		0.3	19		0
3		0	20	Covers off Lime Kilns	0
4		0	21		1.8
5		0	22		1.4
6		0.7	23		0
7		3.5	24	Covers off Canal Turn	0.3
8		5.5	25		0
9		0	26		0
10		0	27		0
11		0	28		0
12		0	29		0
13	Sow Lime Kilns	0	30		5.4
14		0	31		8.4

The two crops, Italian ryegrass and Kale, and the treatments were then fully randomized within each plot and were replicated 3 times. The treatments applied were:

Lime Kilns

1. Trash removed by burning
2. Trash trimmed and removed
3. Trash lacerated and chopped
4. Trash in situ
5. Trash in situ plus extra trash

Canal Turn

1. Mat and trash removed by scalping
2. Mat and trash burnt
3. Trash burnt
4. Trash trimmed and removed
5. Mat and trash in situ

Sub-plots were 1 yd^2 and 100 randomly selected seeds were sown by hand per sub-plot with tweezers and a small dibber. The spacing of the seeds was regulated by a wooden template containing 100 equally spaced holes. After sowing the experiments were protected with bird netting, slug pellets were broadcast and all plots were hand weeded.

Plant performance was assessed in terms of emergence against time and by the numbers of plants finally establishing on each treatment. Counts were performed by replacing the wooden template in its sowing position, thus isolating the seedlings and enabling the performance of individuals to be monitored.

RESULTS

The kale and ryegrass in both fields emerged satisfactorily but with the kale always giving higher figures on any one treatment than ryegrass. Kale was also always quicker to emerge than ryegrass although full emergence of both crops was achieved at about the same time. Speed of emergence was considerably affected by the mat and trash treatments applied (Fig. 1). The emergence against time curves of treatments 1 and 5 are shown as those representing the greatest contrast; other values having intermediate results have been omitted for clarity. In all cases seedlings on treatment 1, where all mat and trash had been completely removed, emerged more quickly than treatment 5 where there was either full mat and trash or double trash, depending on field site. Treatment 1 also went on to a significantly higher emergence of both crops in both fields than treatment 5. The speed of emergence was influenced to some extent by moisture in the seedbed, particularly in Lime Kilns where the normal rainfall seedbed produced quicker emergence for both crops and all treatments except ryegrass treatment 5 where normal rainfall and dry seedbeds emerged equally. However in Canal Turn ryegrass treatment 5 emerged more quickly under normal rainfall but otherwise in this field there were no differences in speed of emergence attributable to the contrasting normal v. dry seedbeds.

The highest percentage emergence figures in Canal Turn were achieved where the mat and the trash had been removed (Fig. 2). Successive increments in the amount of mat and trash reduced the emergence until the lowest figures were obtained where mat and trash were present in situ, as after spraying. Similarly in Lime Kilns the highest percentage emergence figures were where the trash had been completely removed by burning. The presence of trash in situ (treatment 4) reduced the percentage emergence while the addition of extra trash (treatment 5) further reduced the emergence. Intermediate emergence figures were obtained from the treatments having intermediate amounts of trash.

During establishment kale had a very low mortality of seedlings and so the numbers of plants becoming established was only slightly below the emergence total (Fig. 2). This mortality rate did not differ significantly between treatments, the number of plants becoming established was dependent on the amount of mat or trash present in the same way as emergence so that most plants established on treatment 1 (no mat or trash) and fewest on treatment 5 (mat and trash in situ or double trash). Ryegrass had a higher rate of mortality, up to 20% and so the numbers establishing were below the numbers emerging but there were no significant treatment differences. There was a difference in ryegrass mortality between the two fields, Canal Turn being higher, probably due to the presence of the mat as the removal of this (treatment 1) reduced the mortality to the same order as that in Lime Kilns. Thus ryegrass established most plants where there was least mat or trash and fewest where there was most mat and trash.

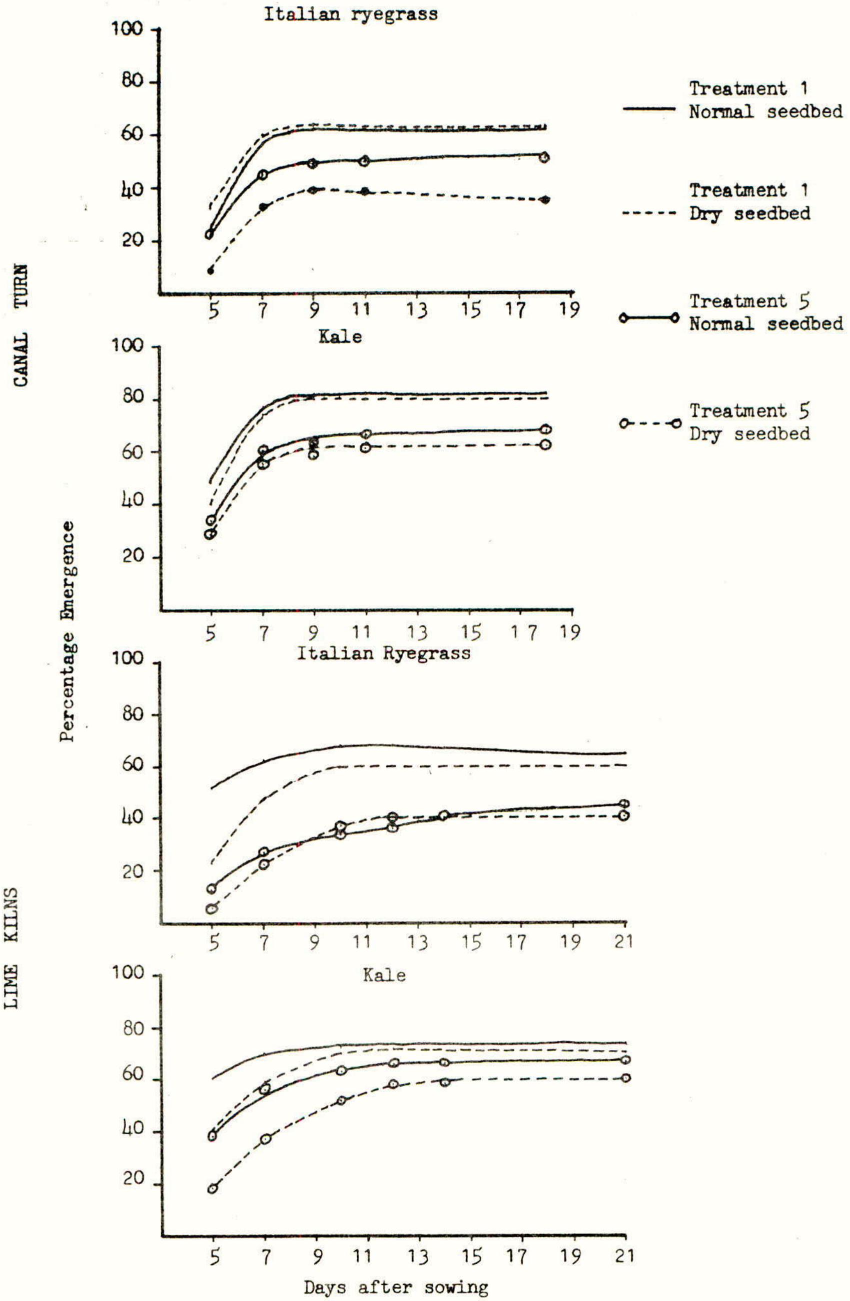

Fig. 1. Effect of amount of overlying organic matter on speed of emergence.

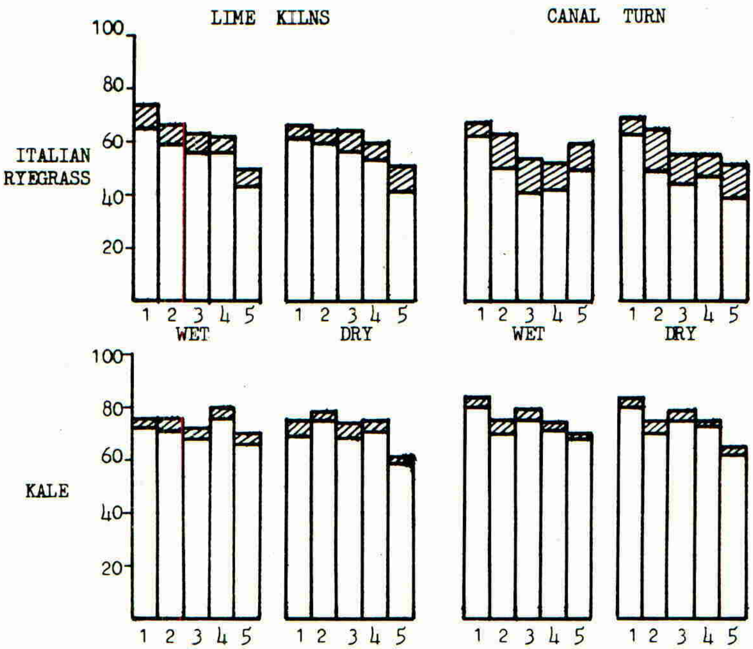

Fig. 2 Mean percentage emergence and establishment in response to overlying organic matter.

DISCUSSION

The results from these two experiments indicate that the overlying organic matter provides a serious hindrance to the satisfactory establishment of fodder crops in a killed sward. In Lime Kilns where the organic matter was loose trash above the surface of the mineral soil an increase of 40% in emergence and 48% in establishment of ryegrass was recorded when the organic matter left after spraying was completely removed so that sowing took place into exposed mineral soil. The comparable figures for kale were 14%and 13%. In Canal Turn where the organic matter comprised both mat and loose trash the increase due to the removal of the organic matter was 28% in emergence and 49% in establishment for ryegrass and 24% and 11% for kale. The processing treatments applied to the organic matter such as partial removal by trimming went some of the way towards alleviating the effects of the organic matter as they allowed increased numbers of plants to emerge and become established. It had been thought that any effects due to the organic matter might be emphasised where the seed was subject to additional stress, such as water shortage at the time of emergence. However the inclusion of a dry seedbed treatment produced no statistically significant differences from the final emergence and establishment figures of the normal seedbed treatment, although in some cases the dry seedbed did cause emergence to be slower than for the normal rainfall seedbeds. It is suspected that the seedbeds were not in fact as dry as had been intended and that the covers should have been placed over the relevant plots earlier.

There are clear differences in the performances of the two crops in response to the organic matter treatments. Kale with its robust seedling was only moderately affected by the presence of overlying organic matter and showed only a small increase in emergence and establishment with successive reductions in organic matter and in addition had a low mortality of seedlings on all treatments. In contrast the Italian ryegrass although it is our most vigorously establishing grass showed a considerable increase in emergence and establishment in the absence of overlying organic matter. The ryegrass also had a higher mortality of seedlings on any one treatment than kale, especially in Canal Turn in the presence of mat. However the mortality of seedlings of either crop did not differ between organic matter treatments and therefore any differences in establishment were inherited from the emergence figures. It is not clear whether these differences in emergence are caused by lack of germination of the seeds in the presence of the organic matter or by their inability to emerge through the organic matter. In order to resolve this point an attempt was made to trace each seed which did not emerge by taking a soil core of each sowing site and then sorting this to find the seed or seedling. However the rate of recovery of seeds was not high enough to draw any firm conclusions, although it appeared to be a lack of germination rather than inability to emerge.

These results show that the dead organic matter remaining above the surface of the mineral soil after sward destruction can greatly reduce the chances of obtaining the good establishment of a direct drilled crop. The emergence and establishment of ryegrass can be greatly increased in the absence of organic matter, be it loose surface trash or the more solid vegetative mat. Although showing the same tendency kale was much less susceptible to the presence of organic matter which is not altogether surprising in view of the acknowledged aggressiveness of the kale seedling which has made possible the successful adoption in commercial farming of the practice of direct drilling this crop into killed sward. Furthermore the results show that any methods employed to reduce the amount of organic matter, i.e. the intermediate processing treatments of these experiments, pay dividends in increased establishment of the crops which would seem to indicate the direction which further investigation might take.

Acknowledgements

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THE EFFECTS OF MALEIC HYDRAZIDE AND 2,4-D FOR SWARD CONTROL IN AN ORCHARD OF COX'S ORANGE PIPPIN: 1965-1971

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Summary: Application of maleic hydrazide (MH) alone or in combination with 2,4-D made twice yearly since 1965 at 2.5-5.0 lb MH a.i./ac and 1.25 lb 2,4-D a.e./ac beneath dwarf pyramid trees of Cox's Orange Pippin have controlled grasses and herbs as effectively as conventional mowing.

In seven years no notable differences were found in stem diameter, extension growth, number of blossom clusters, crop weight, number of fruit, fruit size or the relative proportion of different sizes of fruit but treatments have in general resulted in small increases in tree vigour and yield. Significantly higher levels of tree leaf nitrogen were found in treated plots, and lower phosphorous and potassium, consistent with the reduction of grass vigour on treated plots. Notable changes in sward composition were the decline in *Agrostis stolonifera* and increase in *Poa pratensis*, especially with MH + 2,4-D. *Agropyron repens* was not controlled as effectively as by mowing. Most dicotyledons were reduced where 2,4-D was applied in addition to MH, but not *Veronica* spp.

INTRODUCTION

Traditionally English orchards are planted in arable ground and only grassed down once the trees become established. Growers prefer grassed down orchards because spraying, harvesting, pruning and other aspects of management are more easily and pleasantly carried out on a sward than on arable ground. Traction is better, especially on slopes and there is less risk of erosion or soil compaction. Research at Long Ashton and East Malling has shown that a grass sward improves the soil, tree nutrition and fruit quality (Wallace, 1953), (Montgomery and Wilkinson, 1962). However, the regular cutting of grass is costly and it was foreseen at Long Ashton that continual tractor mowing could become uneconomical and as far back as 1960 attempts were made to control grass growth with TCA and dalapon; two of the few herbicides then available which killed grasses selectively. These were rejected in favour of the growth regulator maleic hydrazide (MH) which appeared to offer the combination of characteristics required to suppress grasses without killing them, and so maintain the sward at a given height. Unfortunately trials with rates as high as 12 lb a.i./ac failed to give consistent and worthwhile results. This was in part due to deficiencies in the spray equipment used and to the extreme sensitivity of the spray to climatic conditions at the time of application. However, working with experimental formulations designed to confer rapid absorption and a degree of weather-proofing, Yemm and Willis (1962, 1966), in association with V.F. Woodham, were able to demonstrate that repeated annual applications of MH and 2,4-D could modify the composition and control the growth of vegetation along roadside verges. Hence with the coincident development at Long Ashton Research Station of equipment specially designed for herbicide applications in plantation crops (Harper et al. 1963, 1964) experiments were resumed to find a feasible chemical method of grass control as an alternative to machine mowing using different rates and times of application of MH, either alone or in combination with 2,4-D. The long term replicated experiment reported in this paper was commenced in 1965 to investigate the effects on the sward and the trees in an established orchard of pyramid Cox's Orange Pippin. A large scale trial, reported by Lyons et al (1972) was also id down, primarily to investigate the problems then current with the application of these materials in orchards and to establish a standardised method of application with tractor mounted equipment.

MATERIALS AND METHODS

Layout

Details of the experimental site have already been given (Stott, 1966) but essentially it consisted of 160 12-year old dwarf pyramid trees of Cox's Orange Pippin spaced 4 ft apart in rows 20 ft apart. The site was divided into five randomised blocks, each of four treatment plots. Each plot consisted of a row of six experimental and two guard trees and extended 10 ft into the alley-way on either side of the trees, giving a plot size of 32 ft x 20 ft. The grass extended right up to the trees.

Treatments

Control plots (treatment 1) were cut monthly throughout the season by a tractor driven rotoscythe, with occasional hand cutting round the base of the trees. Commencing in 1965, MH was applied annually in late April and early July (treatment 2, MH) and in other plots 2,4-D was also included in April (treatment 3, MDA) or October (treatment 4, MDO).

Initially the materials used were MH formulated as the amine salt applied at 5 lb/100 gal/ac and 2,4-D formulated as the amine salt applied at 1.25 lb/100 gal/ac. (The rates of herbicides used are quoted throughout in terms of active ingredient). From 1970 new formulations were used which are appreciably weather-proof and effective at lower concentrations. MH was applied at 1 gal MHW/100 gal/ac giving 3.5 lb/ac MH and 3.5 lb/ac, 2,4-D. The rate applied in July was varied according to the response made to the spring application. Rates and dates of application for the three treatments are given in Table 1.

The herbicides were applied by tractor sprayer with the side mounted boom assembly designed by Harper et al (1963) using cone nozzles and a pressure of 30 lb/in^2.

Table 1

Date and rate of application (lb a.i./ac)

		Treatment			
	MH	MDA		MDC	
	Herbicide	Herbicide		Herbicide	
Date	MH	MH	2,4-D	MH	2,4-D
29 April 1965	5	5	1.25	5	
1 July "	5	5		5	
6 October "					1.25
29 April 1966	5	5	1.25	5	
4 July "	2.5	2.5		2.5	
12 October "					1.25
26 April 1967	5	5	1.25	5	
5 July "	5	5		5	
8 October "					1.25
25 April 1968	5	5	1.25	5	
16 July "	2.5	2.5		2.5	
10 October "					1.25
14 May 1969	5	5	1.25	5	
3 July "	5	5		5	
20 October "					1.25
1 May 1970	3.5	3.5	3.5	3.5	
3 July "	1.8	1.8		1.8	
21 October "				3.5	3.5
28 April 1971	3.5	3.5	3.5	3.5	
13 July "	1.8	2	2	2	2

Assessments

Apples. Annual records were taken of blossom density in May, of crop weight, size and grade in October, of shoot extension in August, and stem diameters in November. Selected leaves from the middle of extension shoots were sampled in August for the analysis of N, P and K. In 1966 samples of fruit were stored and assessed at regular intervals until May 1967 for evidence of storage rots.

Vegetation. The growth and flowering behaviour of the components of the sward and their reactions to the herbicides and to cutting were recorded throughout the season. To assess the area covered by each species a quadrat one foot square was thrown at random 20 times in each plot in early August of the years 1965-1968. The general height of each species was also measured. For the eight main species the results for percentage cover were transformed for analysis and then converted back into the percentages presented in Table 3.

RESULTS

Apples

The parameters presented in Table 2 were measured in most years from 1966 to 1971. In general, treatments had very little effect on tree growth and Table 2 presents typical results, in the main for those years in which significant differences were found. The only significant effect on growth has been an increase in stem diameter in the MDA treatment in the years 1969-1971. In the early years significantly darker foliage was noted in treated plots in mid-season. Increases in leaf nitrogen were found in the years 1966 and 1968 but not thereafter.

Table 2

Effect of treatments on tree growth, nutrition and cropping

Parameter		Year	Treatments 1 Control	2 MH	3 MDA	4 MDO
Stem diameter	(in.)	1970	3.62	3.73	3.84**	3.70
Diameter increment	(in.)	1971	0.03	0.04	0.09*	0.06
Shoot extension	(in.)	1969	13.6	13.3	12.7	12.9
Leaf N	(%)	1968	2.29	2.41*	2.52***	2.46**
Leaf P	(%)	1971	0.31	0.25***	0.26**	0.26**
Leaf K	(%)	1968	2.28	2.28	2.17	2.15
Blossom clusters	(/tree)	1969	384	502*	481*	394
Fruit set	(%)	1971	7.85	6.84	7.85	7.88
Fruit number	(/tree)	1971	155	152	162	168
Crop weight	(lb/tree)	1971	30.9	29.6	31.4	33.1
Fruit size	(% > 2.5 in.)	1971	24.5	22.8	26.2	25.9
Fruit storage	(% discarded)	1966	7	8	11	13

* Significantly different from the control at the 5% level

** at the 1% level

*** at the 0.1% level

In contrast leaf phosphorous has declined significantly compared with the mown plots and the results presented in Table 2 are representative of the values found throughout the period. Values of potassium have tended to be higher in the mown plots but the difference has never reached a significant level. A slight increase in the number of blossom clusters was found in one year out of five but otherwise treatments have never produced any significant effect on percentage set, number, size or weight of fruits, their quality as judged by the proportion of the apple coloured, or in 1966, the one year in which it was assessed, the susceptibility to rotting caused by brown rot, *Gloeosporium perennans*.

Vegetation

Assessments of the composition of the sward made annually in August from 1965-1968 showed that the major changes occurred in the first two years. Some trends continued until 1967, but thereafter the composition remained relatively stable. After the first spray in April 1965, treated plots appeared dull olive green in colour and contrasted conspicuously with the bright green of the mown plots. Little growth was observed until the end of June, about eight weeks after spraying. After the second application of 5 lb/ac of MH on 1st July 1965 the grasses withered slowly and my mid-August a third of the sprayed area was covered by dead vegetation (litter) about 2 in. high. The mown sward was just slightly higher (4.3 in.) than the sprayed sward (4 in.). Tall clumps of Agropyron repens and Phleum pratense were conspicuous, but flowering of all grasses and herbs was inhibited throughout the season. In contrast a neighbouring unsprayed unmown strip supported dense flowering grasses and weeds 15 in. high. Table 3 gives the percentage area covered by the main components of the sward in August 1968 after four years' treatment with an indication of the significance of differences between mown and treated plots.

Throughout the period bare ground occupied about 10% of treated plots, significantly more than in the mown plots. Litter was abundant (38% cover) on treated plots in 1965, but fell by 1967 and 1968 to 10%, about twice that of the mown controls. Treatments achieved a very good control of Agrostis stolonifera in the first two years but somewhat less since then. Treatments have not controlled Agropyron repens; it was locally abundant in MDO plots at the beginning of the experiment and remained so. Phleum pratense and Poa annua have remained constant in both treated and untreated plots but there has been a continuing and highly significant increase in Poa pratensis, particularly with the combined MH and 2,4-D treatments. Even so very significantly less has been present in treated plots since 1966. Rumex spp. were found to be noticeably susceptible to maleic hydrazide and most plants were killed out in the first year. In contrast Veronica spp. (mainly V. agrestis) tended to colonise the bare ground as the grasses died and increased significantly in the first year to a level which has remained constant and significantly greater than on mown plots. Taraxacum officinale has declined since 1965 with always significantly less in treated plots. Though the general abundance of Ranunculus repens has fallen since 1965, significantly more has always been present on plots receiving maleic hydrazide without the addition of 2,4-D.

DISCUSSION

A significant increase in tree diameter was noted in MDA plots in 1969, ($P = .05$), in 1970 ($P = .01$) and in 1971 ($P = .001$). In 1971 MDA trees were significantly larger than the other two treatments ($P = .05$). Other treatments have shown no similar response and there seems no ready explanation why the addition of 2,4-D in October to a regime of MH in April and July should produce increased tree vigour.

The major effect of treatments has been to change the nutritional status of the trees as shown by leaf analysis. In the early years, the reduction in grass vigour, reduced competition for nitrogen and also released nitrogen from decaying grass litter. This was reflected in greener foliage and in an increase in nitrogen in the leaves, and by 1969 a small but significant increase in blossom. However, equilibrium was then achieved and no further differences in N were found. Potassium has declined very slightly in treated plots, but the reduction in phosphorous has been very significant, and has fallen consistently over the period.

Table 3

Effect of four years' application of herbicides on vegetation
Recorded 12-16 August 1968 (% cover)

Treatments	No weed cover	Dead vegetation	Agrostis stolonifera	Poa annua	Poa pratensis	Agropyron repens	Phleum pratense	Veronica spp.	Taraxacum officinale	Ranunculus repens
(1) Control mown	0.5	4.7	48	1.8	33	0.3	0.3	0.3	0.6	6.4
(2) MH only April July	6.7***	9.7*	34	2.7	7***	2.6	0.6	1.1	0.3**	12
(3) MDA (2) + 2,4-D April	8.3***	11**	28	4.8	10**	2.3	0.6	2.8	0.4*	3.7
(4) MDO (2) + 2,4-D October	8.7***	8	14**	4.2	10**	11*	0.6	5.4**	0.3**	3.3

* Figures significantly different from those of the control at the 5% level

** at the 1% level

*** at the 0.1% level

However, since the nutritional status of these trees is still adequately balanced treatments have not affected crop yield or quality - if anything these have been slightly higher on treated plots.

The sward was 10 years old at the start of the experiment and having been mowed regularly was typical of West country orchards, being composed essentially of Agrostis stolonifera and Poa pratensis, with some Agropyron repens and Phleum pratense. The latter two species tended to be locally abundant, A. repens particularly in the shade under the trees. Occasional herbs, such as Taraxacum officinale, Rumex spp. and Ranunculus repens were present. Treatments controlled the growth and flowering of the vegetation and maintained it at about 4 in. high throughout seven years, similar to monthly cutting from April to September. The natural height of this flora is about 15 in.

Changes in composition occurred: notably the increase in Poa pratensis with the combined MH + 2,4-D treatments, which agrees with results reported by Willis (1966, 1972) from similar treatments made to roadside verges. However, in the latter over 15 years, the application of MH alone or in combination with 2,4-D caused a small significant reduction in Agropyron repens but at Long Ashton a small but significant increase was recorded over the four years, so that by 1968, significantly more was present in these plots than in the mown control. Hence under orchard conditions, treatments do not appear to control Agropyron repens as efficiently as mowing. A similar conclusion is drawn by Lyons et al (1972) working over the same period in another orchard at Long Ashton. There was a tendency for dicotyledons to increase in plots treated with MH, notably Veronica spp., which, as was found by Willis (1972), successfully established on the bare areas created when susceptible plants die.

Previously poor results had been obtained at Long Ashton with MH rates as high as 12 lb/ac. Hence in 1965 a rate of 5 lb/ac was selected as appropriate for both spring and summer applications. Due at least in part to the improved spray equipment used, these rates were found to be too high, resulting in the unwanted death of a high proportion of the grasses. For this reason litter reached 38% cover in 1965 but declined thereafter, following the reduction of the midsummer rate to 2.5 lb/ac. As the litter decomposed the area without weeds increased to a maximum in 1966 and then declined as colonisation took place. In each year the second spray was not applied until the sward had recovered and, growing vigorously again, had reached up to 6 in. in height. As Table 1 shows, the effects of the first spray lasted 8-10 weeks depending on the season. The second application then checked growth until the end of the season. In the spring of 1967 grass growth was very vigorous. Applications were made, as before, in the last week in April. This period coincided with severe frost. In 1969 heavy rain fell within five hours of application. As a result the treatments were far less effective. Consequently the rate was increased to 5 lb/ac in July in those years and finally the control achieved was equal to that of previous years.

Since 1970 new commercial formulations have been used which are appreciably weatherproof and effective at lower doses. In 1970 and 1971 lower rates based on 3.5 lb MH/ac applied in April and 1.8 lb/ac in July, either alone or in combination with 2,4-D proved as effective as the higher rates applied previously. It will be seen from Table 1 that from October 1970 modifications were made to the spray programme. By varying the rates and possibly the time of application, this phase of the trial seeks to achieve a more acceptable sward with a lower proportion of Agropyron repens and other unwanted species.

Despite the need for this refinement the overall result is that for seven years two annual applications of maleic hydrazide, preferably in combination with 2,4-D, have controlled the sward as effectively (and more economically) than regular mowing, without detriment to the trees.

Acknowledgments

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Proc. 11th Br. Weed Control Conf. (1972)

THE EFFECTS OF REPEATED APPLICATIONS OF THE GRASS SUPPRESSANT MALEIC HYDRAZIDE ON AN ORCHARD SWARD AND ON THE SOIL FAUNA

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Summary: Maleic hydrazide (MH) at 0.6% applied once in April with cone nozzles at 30 lb/in^2 at 95 gal/ac suppressed grass growth for about 2 months. The same concentration combined in a formulation with 2,4-D (0.375% a.e.) suppressed both grasses and weeds for a similar period. Two applications of the combined materials on the same plot in each of 6 years have proved a practical alternative to the normal orchard practice of 6-10 mowings for sward control.

In the unsprayed, repeatedly mown inter-rows, *Agrostis stolonifera* remained the dominant grass but after 2-3 years of the combined 2,4-D treatment it was superseded by *Poa pratensis* which remained dominant for the rest of the 6 year period.

Treatments did not affect earthworm and other soil fauna populations, or the apple trees.

INTRODUCTION

The reasons why growers prefer grassed-down orchards and the advantages and disadvantages of a grass sward have been summarised by Stott (1972). The need for a more economic method of grass control than conventional mowing lead to the investigation of the growth regulator maleic hydrazide.

The long term effects on the vegetation of roadside verges sprayed with maleic hydrazide (MH) alone and in combination with 2,4-D have been comprehensively studied (Yemm and Willis, 1962; Willis and Yemm, 1966). The most noticeable effect of MH alone was the general suppression of growth and flowering, particularly of the grasses. Over the period there was an increase in dicotyledonous plants but this was prevented when the MH was combined with 2,4-D. These effects offered a possible method of controlling grass and weed growth in orchards as an alternative to repeated mowing throughout the growing season. A large scale trial of MH application for sward control in an apple plantation was begun in 1965 to investigate problems associated with the application of these materials and to establish a standardised method of application for orchards using tractor mounted equipment. Applications continued on the same site until 1970. The applications and their effects on the vegetation and soil fauna are summarised in the present paper.

METHODS AND MATERIALS

The experimental site was an apple orchard planted in 1950 with Cox's Orange Pippin and Cheddar Cross but with some half rows of Ellison's Orange, Bramley's Seedling, Fortune and Winston. The layout was 15 ft between rows and 12 ft between trees in the row, giving 12 inter-rows each 15 ft wide x 336 ft long. Five of these were sprayed with MH alone (5.0 lb a.i./ac), 5 with MH in combination with 2,4-D (2.3 lb a.e./ac) and 2 were repeatedly cut with rotary mowers in the conventional manner. The width sprayed or mown was approximately 10 ft in each inter-row.

The programme begun in 1965, was continued until 1970 with 2 applications per year, one in the second or third week of April and the other generally in the first week of July, sometimes with three quarters of the concentration of chemicals used in the spring application.

The spraying was done with cone nozzles applying 95 gal/ac sprayed at 30 lb/in^2 using equipment specially designed for herbicide applications in plantation crops (Harper, Morgan and Russell, 1963, 1964).

The effects of the spraying on the flora of the inter-rows were examined by noting the frequency of occurrence of each species in 10 random 12 in. square quadrats per treatment.

Earthworm population in the sprayed and mown areas were determined by counting and weighing the earthworms brought to the surface by application of formalin solution in 18 in. square quadrats. The formalin solution contained 38 ml of 40% formaldehyde solution to $1\frac{1}{2}$ gallons of water: $\frac{3}{4}$ gal. was applied to each quadrat and after 20 minutes the remaining $\frac{3}{4}$ gal. was applied. Each autumn from 1966-1970, 10 quadrats were sampled in treated plots and 5 in the control plots. Other soil fauna were assessed from soil cores 1.7 in. diam. x 3.4 in. deep. Cores were treated in Tulgren funnels to drive the animals into collecting dishes for preservation and subsequent identification and enumeration. Eight cores were taken from each treatment at monthly intervals from August 1969 to December 1970.

RESULTS

The main short term effect of the April application of MH alone was a general suppression of growth and of flowering of grasses over a period of about 2 months after which time regrowth (recovery) of grasses had begun. Some broad-leaved weeds such as Convolvulus spp. and Plantago spp. appeared to be unaffected. The second MH application suppressed grass growth for the remainder of the normal growing season.

The combined MH/2,4-D spray suppressed grass growth and flowering and controlled most of the broad-leaved weeds. Repeated applications over 2 or 3 years caused changes in vegetation composition, which then remained fairly constant for the rest of the period. Table 1 compares the proportions of the dominant species in the sprayed inter-rows with those of the mown ones at the end of the 6 years.

Table 1

Inter-row sward assessment after 6 yrs treatment (% occurrence)

	Mown	MH	MH + 2,4-D
Agrostis stolonifera	83	56	15
Poa pratensis	57	25	97
Agropyron repens	0	36	22
Broad-leaved weeds	10	15	0

The main vegetation change was in the dominance of *Agrostis stolonifera* which was reduced by MH alone and was superseded by *Poa pratensis* in the plot sprayed with the combined materials. Mowing appeared to suppress *Agropyron repens* more than the spraying.

There were little or no differences in the components of the soil fauna between the mown and sprayed plots. The earthworm population remained fairly constant at 810,000/ac with a biomass of approximately 1248 lb/ac with no significant differences between mown and sprayed treatments.

Table 2 shows that there was little difference in the population of other soil fauna in the mown plots and those sprayed with MH/2,4-D. A sample taken in June 1967 showed a similar decrease in numbers in both treated and control plots, indicating a seasonal fluctuation.

Table 2

Population of soil fauna/yd^2

	Mown	MH/2,4-D
Parasitid mites	555	497
Oribatid mites	67	95
Astigmatid mites	225	373
Collembola	12,107	10,356
Enchytraeids	1,902	2,424
Nematodes	511	703
Diptera larvae	258	225
Coleoptera larvae	91	120
Chilopods	24	38
Diplopods	5	5

There was no apparent effect on the apple trees in the sprayed areas compared with grass in the mown area.

DISCUSSION

Early in 1960 applications of maleic hydrazide by others appeared to give erratic results sufficient to put the feasibility of its use for orchard sward control in some doubt. This variability could have been associated with the method of application and for this reason large plots were used in the experiment reported here in preference to small replicated ones in order to establish a standardised method of application with tractor-mounted equipment.

Since the active material must enter each plant in order to exert its suppressant effect on cell division, it follows that the spraying must be done in conditions favourable to absorption, i.e. in a warm rainless period when the grass is actively growing. Furthermore, preliminary tests showed that cone nozzles, from which the spray droplets are directed at the target at many different angles, gave better results in dense grass than flat fan nozzles unless the latter were arranged in pairs with one nozzle spraying forward and the other to the rear.

The results are those obtained from the treatment of the centre 10 ft width of the inter-rows; the remaining strips at the bases of the trees received different treatments over the 6 years. The fact that there was a high population of Agropyron repens in these tree-row strips over the whole plantation, less in the sprayed inter-rows and none in the mown inter-rows, showed that the suppression of this grass species by the spraying was much less than that noted by Willis and Yemm (1966) on roadside verges: this might have been caused by the heavier invasion pressure on the orchard site.

Two applications of MH/2,4-D annually would appear to be a practical alternative to the present practice of repeated mowing for sward control in the central area of the inter-rows. Control of the complete sward is feasible in established orchards though additional materials to 2,4-D may be necessary for this purpose.

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LONG-TERM ECOLOGICAL CHANGES IN SWARD COMPOSITION FOLLOWING APPLICATION OF MALEIC HYDRAZIDE AND 2,4-D

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Summary The effects on roadside vegetation of annual sprays of maleic hydrazide (MH) and 2,4-D, both singly and together, have been investigated for fifteen consecutive years. Long-term changes have been assessed by reference to unsprayed plots.

MH brings about rapid changes in sward composition, with strong reduction of tufted grasses such as *Arrhenatherum elatius* and promotion of *Festuca rubra*. Umbellifers are adversely affected, but floristic diversity is maintained as low-growing broad-leaved annuals invade. Flowering is largely prevented and growth of the vegetation limited. The mixed spray (MH + 2,4-D) results in a low non-flowering grassy sward in which *Poa pratensis* dominates and *Arrhenatherum elatius* is much diminished. Most dicotyledonous plants are reduced and some eliminated. The single spray of 2,4-D leads to a grass-dominated vegetation, of low diversity. After spraying for 3-4 years, during which the floristic composition changes progressively, relatively stable types of vegetation arise, characteristic of the various treatments.

INTRODUCTION

The effects of growth regulators such as maleic hydrazide (MH) and selective herbicides such as 2,4-dichlorophenoxyacetic acid (2,4-D) on plants are now well known; these substances have been increasingly used in recent years in the management of swards. However, the effects over a number of years of repeated sprays on vegetation and the long-term ecological implications have been less widely studied. Detailed assessments were therefore undertaken in a series of experimental plots established on wide roadside verges in the Cotswolds in Gloucestershire. Records for fifteen years, dating from 1958, have been made. A major aim was to explore whether, with repeated spray treatments, there are prolonged trends of change and whether a relatively stable type of vegetation ultimately develops.

Sprays of the growth regulator and selective herbicide, singly and in combination, have been applied once annually. In some plots spraying was stopped for a number of years, and then resumed to elucidate the effects of these alterations in spray regime.

The results for the first three years (Yemm and Willis 1962) showed that in addition to the expected effects of the sprays on the dicotyledonous plants, on flowering and on the height of the vegetation, there were highly significant changes in the relative proportions of the grass species. Further details of changes over a longer period have been given (Willis and Yemm 1966) and also some indication of the salient features evident from more recent studies (Willis 1969, 1970). The present paper reports the changes of vegetation in the experimental plots subjected to particular spray regimes for fifteen years, and gives information about the type of vegetation resulting and the stability of these distinctive communities.

METHODS AND MATERIALS

Details of the experimental site and of the methods used have already been given (Willis and Yemm 1966), but for convenience a summary statement is included here. A series of 28 plots (each about 20 m long and 3-5 m wide) was established on the wide verge of Akeman Street, near Bibury, Gloucestershire, on the Oolite of the Cotswolds at about 140 m above sea level (average annual rainfall c. 760 mm). The relative bulk of the various components of the vegetation was assessed (for details, see Yemm and Willis 1962) for each plot as a whole ("general" scores) and also in permanent quadrats (0.5 m^2) in each plot. Records were made initially three times annually, but it was found that the summer (July) assessments were the most informative; these were subsequently the only detailed ones made and are those reported here.

Two plots (with 3 controls nearby) were sprayed with MH only, six (with 3 adjoining controls) with mixed MH + 2,4-D, and two (with 2 controls) with 2,4-D only. One spray was applied per year in early April or early May but, as differences in time of spraying did not lead to appreciable differences in floristic composition or height of vegetation in July, the results are considered together. Other plots of the series were sprayed in mid April, permitted to revert for a period, and then spraying was resumed.

Spray treatment was by means of a boom with cone-type nozzles for high volume application at low pressure. Commercial preparations were used as follows: MH, 5.6 kg MH as the amine salt ('Regulox') in 900 l. water per hectare (5 lb in 80 gal/ac); 2,4-D acid-in-oil emulsion containing 12.5% w/v 2,4-D ('Vergemaster'), 34 l. in 900 l. water per hectare (3 gal in 80 gal/ac); MH + 2,4-D, a mixture of MH and 2,4-D at the above rates.

RESULTS

The vegetation of the verges

The series of plots was originally established in a stretch of fairly uniform vegetation. In the tall, mixed sward, grasses constitute about half of the total vegetation. The most abundant species of this closed community are *Arrhenatherum elatius*, *Dactylis glomerata* and *Heracleum sphondylium*, as shown in Tables 1, 2 and 3. The finer-leaved rhizomatous grasses *Festuca rubra* and *Poa pratensis*, although virtually universally present, nowhere make up more than about one-twentieth of the total vegetation.

A considerable range of dicotyledonous plants is present and, as well as *Heracleum sphondylium*, important components are *Anthriscus sylvestris* and *Urtica dioica*. Other species of wide occurrence are *Cirsium arvense*, *Convolvulus arvensis*, *Galium aparine* and *Stachys sylvatica*, but there are very many species of low abundance and scattered occurrence (see Yemm and Willis 1962, Table 1).

Over the fifteen-year period, the vegetation of the control plots has remained virtually the same with no striking trends of change, although there have been some differences in the amount of growth made from year to year dependent on the weather conditions. In certain of the control plots, too, there has been a small increase in *Anthriscus sylvestris* and *Heracleum sphondylium* in the last five years, and this trend is reflected in a slightly increased proportion of dicotyledonous plants relative to grasses. Nevertheless, the general situation is that the floristic composition of the untreated areas is essentially a stable one.

Nearly all of the plants of the control plots flowered freely throughout the study period, and the overall average height of the vegetation of the control plots in mid July from 1958 to 1972 is 93 cm.

Effects of MH

Repeated annual spraying with MH results in a striking change in floristic composition of the vegetation, much shorter growth and a lack of flowering, notably of the grasses. The chief effects on the composition are decreases in the large tufted grasses, promotion of finer-leaved rhizomatous grasses, the reduction or loss of the two common umbelliferous plants and an increase in certain low-growing dicotyledons.

Table 1

The effects of MH

The values represent percentage relative bulk of the major species in sprayed and control plots, and are averages of assessments for the whole plots ("general" scores) in July for 1958-72. Figures for alternate years only are presented for two plots sprayed once annually with MH; mean values, with Standard Errors, for three control plots for the entire period are shown.

	Controls	Sprayed with MH annually							
	1958-72	1958	1960	1962	1964	1966	1968	1970	1972
Agropyron repens	7.2 ± 0.5	5.5	8.0	6.2	2.6	3.0	11.3	10.0	6.2
Arrhenatherum elatius	22.4 ± 1.8	20.5	10.0	2.5	0.6	1.8	1.3	2.6	3.0
Dactylis glomerata	9.9 ± 1.0	3.0	5.0	5.0	6.3	1.8	5.1	7.5	3.0
Festuca rubra	5.2 ± 0.9	22.5	25.0	37.5	22.5	40.0	20.0	15.0	27.5
Poa pratensis	4.7 ± 0.3	8.0	7.5	5.0	2.5	1.8	6.3	3.0	5.5
Total grasses	55.8 ± 3.5	61.0	57.5	60.0	37.5	51.2	45.0	40.0	47.5
Anthriscus sylvestris	8.2 ± 1.7	5.0	1.0	0.1	0.1	0	0.1	0.1	0
Cirsium arvense	2.7 ± 0.3	2.5	17.5	1.3	0.5	0.5	1.3	2.6	0.1
Galium aparine	1.4 ± 0.6	0	0	0.6	1.7	1.8	1.7	1.5	5.0
Galium cruciata	0.5 ± 0.1	5.5	11.3	12.5	2.5	10.0	12.5	3.8	11.3
Heracleum sphondylium	12.3 ± 1.6	5.5	3.0	2.5	5.0	0.5	0.6	1.3	1.0
Plantago lanceolata	0.3 ± 0.1	0.5	3.0	5.1	35.0	12.5	20.0	15.0	22.5
Av. no. of species	26.7 ± 0.7	22	29	24.5	28	22	28	26.5	25
Av. height (cm)	92.5 ± 4.8	47	35	28	42	33	32	33	39

Details of the major effects of MH on the vegetation are given in Table 1. Although there is appreciable variation from year to year in the proportion of the total vegetation constituted by grasses, this remains, over the fifteen-year period, close to one-half, as in the untreated plots. However, the composition of the grass component is very different in the sprayed and control plots, for the strongly dominant grass in the control areas is Arrhenatherum elatius, whereas the dominant grass in MH-treated vegetation is Festuca rubra. The effect of MH is to reduce Arrhenatherum elatius from a value of approximately one-quarter of the vegetation to about only one-fiftieth after spray treatment for some three years. Dactylis glomerata is also reduced by the MH spray. Agropyron repens is adversely affected by MH, but by virtue of new growth from its rhizome system maintains its relative abundance in the sprayed plots, although it makes much less growth here than in the controls. There is rapid increase in Festuca rubra resultant on spraying and, although there are fluctuations over the years, in general this grass constitutes rather more than one-quarter of the total vegetation. Poa pratensis is only little affected by the spray treatment.

The striking changes in the broad-leaved species include the reduction to the point of extinction of Anthriscus sylvestris, and the very strong decrease of Heracleum sphondylium, tall species which together make up about one-fifth of the untreated vegetation. Among species which increase very greatly after spray treatment with MH are Galium cruciata and Plantago lanceolata. These are of minor importance in the tall vegetation of the control areas, but dominate, at least locally, in the sprayed plots. Galium aparine tends to invade and increase in the sprayed plots (see Table 1).

Although the vegetation is about as diverse in terms of species composition in the sprayed as in the control plots, the MH-treated plots support a number of low-growing annuals including weeds of agricultural land which successfully establish in the bare pockets created by the death of plants highly susceptible to the spray. Of note, for example, are Geranium dissectum, Odontites verna, Stellaria media and Veronica spp.

Whereas flowering is fairly prolific in the control areas, in the treated plots it is much reduced, especially of the grasses. However, Galium cruciata and Plantago lanceolata flower well in the treated plots. Besides the lack of flowering of the grasses in these plots, they make much less vegetative growth. This feature, combined with the reduction of the tall umbellifers, leads to a much shorter stand of vegetation than in the controls. Varying weather conditions may lead to appreciable variation in height from year to year, but generally the height of the vegetation of the treated areas is only about one-third to one-half that of the control plots (Table 1).

The results provide information on the time-scale of changes resultant on spraying. The effects on height and flowering are quickly evident, but the influence of the spray on species composition is protracted over a number of years. The major changes in the grasses take place within two or three years, but the increases in certain of the dicotyledonous plants may extend over five to seven years. However, relatively little overall change is apparent after this period, although records for particular years may show deviations reflecting unusual weather conditions such as prolonged cold or wet periods in spring.

Effects of MH + 2,4-D

The mixed spray leads to rapid change in the composition of the vegetation (Table 2), substantial reduction of flowering and much diminished growth. Strong dominance by Poa pratensis is quickly shown, and dicotyledonous plants are highly reduced, some to the point of extinction. In the sprayed plots the grasses ultimately make up about 90% of the total vegetation, as compared with less than half of the total in the adjoining control areas. The only dicotyledonous plants remaining in quantity are Convolvulus arvensis and Calystegia sepium which, by virtue of their late development, escape the effects of the spray in spring.

Poa pratensis increases from about one-twentieth of the total vegetation in the control plots to nearly three-quarters in the sprayed plots, making up more than one-third of the vegetation even after a single spray (Table 2), and in some plots constituting virtually pure stands. Festuca rubra also increases from a very small proportion in the untreated vegetation to nearly one-tenth of the total in the sprayed plots. In sharp contrast, Arrhenatherum elatius is rapidly (after one spray) reduced to very small amounts, and Zerna erecta and Holcus lanatus are diminished. There is also a reduction of Dactylis glomerata and Agropyron repens,

Table 2

The effects of MH + 2,4-D

The table is constructed as Table 1 except that results are given for all the years (assessments for 1961 are for April). Values for the control plots are based on three replicates, and for the sprayed plots on six replicates.

	Controls	Sprayed with MH + 2,4-D annually														
	1958-72	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Agropyron repens	6.2 ± 0.7	4.5	3.2	12.5	6.5	3.7	3.7	2.3	1.5	2.3	1.0	2.2	2.8	5.2	5.0	4.3
Arrhenatherum elatius	15.1 ± 1.8	1.2	1.7	1.5	5.5	0.8	2.3	1.2	1.1	0.9	0.6	0.9	0.5	1.7	3.1	1.9
Dactylis glomerata	9.7 ± 1.3	5.2	15.8	6.2	10.0	7.9	11.7	6.8	3.4	3.8	4.8	5.2	3.9	10.0	7.1	2.6
Festuca rubra	1.0 ± 0.1	6.8	10.2	10.0	7.8	9.3	5.3	3.9	5.2	10.0	14.7	8.3	7.1	5.3	5.0	16.4
Poa pratensis	5.0 ± 0.8	36.7	35.8	54.2	57.5	55.8	58.3	73.8	72.5	73.3	71.7	74.2	75.0	63.3	68.8	65.0
Total grasses	40.0 ± 3.3	55.5	70.2	84.7	89.4	80.0	82.0	88.8	84.6	92.5	93.3	91.3	92.1	85.9	89.4	92.5
Anthriscus sylvestris	8.9 ± 2.0	0.5	0.3	0.2	0.3	0.1	0.1	0.1	0.1	0	0	0.1	0.1	0.1	0.1	0.1
Heracleum sphondylium	17.9 ± 1.6	12.0	2.3	0.3	0.6	0.6	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
Av. no. of species	17.9 ± 0.4	16.3	16.8	17.7	17.5	15.2	19.2	12.5	16.3	13.8	12.2	13.5	13.0	15.8	15.7	12.2
Av. height (cm)	95.8 ± 3.6	53	32	25	20	27	30	27	33	29	22	20	26	24	28	35

which are adversely affected by the spray, but which make some recovery during the second half of the year. The tall umbellifers Anthriscus sylvestris and Heracleum sphondylium, both major components in the control plots, are quickly reduced to negligible amounts by the spray, and are totally eliminated from some plots. Where they still occur, it is only as a few small non-flowering plants, which appear to arise largely from seeds reaching the plots from unsprayed areas.

Floristic diversity is reduced as a result of the mixed spray, owing to the loss of a number of broad-leaved plants affected by 2,4-D. The control plots of this series are somewhat less diverse than those of the MH series (cf. Tables 1 and 2), but nevertheless there are significantly fewer species in the plots receiving the mixed spray. Among the species eliminated or exceedingly reduced are Cirsium arvense, Galium aparine, Ranunculus repens, Stachys sylvatica and Urtica dioica. Whereas flowering of the grasses is prolific in the control plots, it is suppressed and negligible in the treated plots, only a few late-developing inflorescences being formed. The average height of the vegetation of the sprayed plots in mid July is less than one-third of that in the control plots, the mean value for the ten-year period ending in 1972 being only 27 cm.

Effects of 2,4-D

An annual spray of the selective herbicide alone leads to a strongly grass-dominated community (Table 3); the height of the vegetation is lower than that of the control.

Table 3

The effects of 2,4-D

The table is constructed as Table 1. The results are based on two sprayed and two control plots.

	Controls	Sprayed with 2,4-D annually						
	1959-72	1960	1962	1964	1966	1968	1970	1972
Agropyron repens	4.2 ± 0.6	3.0	10.0	3.8	8.7	12.5	21.2	8.8
Arrhenatherum elatius	18.7 ± 1.2	20.0	22.5	10.0	5.0	3.8	17.5	17.5
Dactylis glomerata	9.5 ± 0.8	15.0	15.0	25.0	25.0	6.2	18.8	20.0
Festuca rubra	4.8 ± 0.5	7.5	5.0	17.5	17.5	25.0	5.0	10.0
Poa pratensis	6.0 ± 1.0	22.5	15.0	27.5	20.0	36.2	22.5	25.0
Total grasses	53.6 ± 1.3	82.5	80.0	93.7	85.0	96.2	90.0	95.0
Anthriscus sylvestris	5.0 ± 1.0	1.0	0.5	0.5	4.2	0.1	0.1	0.1
Heracleum sphondylium	13.2 ± 1.0	5.0	0.5	0.1	0.5	0.6	0.1	0.1
Av. no. of species	32.8 ± 8.9	19.0	13.5	16.5	16.0	15.5	14.5	13.5
Av. height (cm)	91.4 ± 4.6	38	48	61	52	44	52	76

After sprays for several years, grasses make up about nine-tenths of the vegetation, many dicotyledonous plants being reduced or eliminated. Anthriscus sylvestris and Heracleum sphondylium decrease to negligible amounts. Floristic diversity was originally greatest in these particular plots of the series; there is a very pronounced reduction in the average number of species in the sprayed plots relative to the controls.

The most striking change in the grasses is the increase of Poa pratensis, but Festuca rubra and Dactylis glomerata also increase. In contrast Arrhenatherum elatius is reduced. Although the results show appreciable variation from year to year, the contrast in the relative proportions of the major grasses in the sprayed plots with those in the controls is very marked. Instead of the clear dominance of Arrhenatherum elatius typical of the untreated plots, several grasses are co-dominant in the sprayed plots, with Poa pratensis most abundant.

Flowering of the grasses in the sprayed plots is not substantially reduced, but the height of the vegetation is less than two-thirds of that of the control plots.

DISCUSSION

The effects of MH in restricting cell division and extension growth, and in suppression of flowering, are well established and have been long known (Naylor and Davis 1950), but the basis of its marked differential action, especially on the grasses, has not been fully elucidated. As previously discussed (Willis and Yemm 1966), grasses such as Arrhenatherum elatius and Dactylis glomerata, which are relatively broad-leaved and of coarse tussock habit, have a morphology which makes them liable to catch spray extensively. On the other hand, the more diffuse habit and narrower leaves of Festuca rubra and Poa pratensis, and especially their elongated rhizome system, may result in the spray affecting these species to a smaller extent, new shoots readily arising from buds on the rhizomes. Other investigations have indicated that Arrhenatherum elatius lacks the strong tillering capacity shown by a number of grasses, for repeated cutting of the shoot system (simulating grazing) severely weakens the plant and regeneration resulting from the development of buds is limited. This feature may well make Arrhenatherum elatius more susceptible to the effect of sprays (visual symptoms show that existing shoots receiving spray frequently die back) than grasses which have the capacity to produce new tillers freely.

Although MH is herbicidal towards some broad-leaved plants such as Anthriscus sylvestris, Heracleum sphondylium and Rumex spp., floristic diversity is enhanced in MH-sprayed plots as a result of colonization by low-growing dicotyledons, the nature, extent and rate of this colonization being dependent on the supply of seeds from the adjoining vegetation. After treatment with MH for several years, Plantago lanceolata and Galium cruciata became major components of the vegetation, but have not extended further for the last eight to ten years. Indeed there are indications from plots adjoining those of the series described here that after a phase in which Plantago lanceolata dominates, at least locally, it may undergo some decline. However, the results in Table 1 show that, in general, after MH-treatment for several years, a distinctive and fairly stable community develops in which Festuca rubra is a major component.

Besides the expected herbicidal effects of 2,4-D on broad-leaved plants, this spray favours Poa pratensis and leads to reduced height of the grassy sward, to some extent owing to a reduction in Arrhenatherum elatius. A fairly stable type of vegetation of low diversity arises with several grasses co-dominant, as evident from Table 3.

The action of the mixed spray is to lead to a low, non-flowering sward, in which Poa pratensis dominates strongly. With elimination or reduction of other species, Poa pratensis increases progressively for a number of years, but a relatively stable community, of low diversity, results after about five years. As shown by the plots sprayed with 2,4-D only, this herbicide favours Poa pratensis, but the effect is much more marked in the plots treated with MH + 2,4-D, probably because of the adverse effect of MH on Arrhenatherum elatius. The extensive spread of Poa pratensis in the plots receiving MH + 2,4-D makes it a strong competitor with Festuca rubra which although favoured by the mixed spray, does not increase in these plots to an extent comparable with that in the MH plots.

Because of the low sward resulting from treatment with MH and with the combined spray (MH + 2,4-D), these sprays are of value in sward management and have been used to good effect on roadsides for some years. More recently attention has been successfully directed towards the management, by means of the combined spray, of grassy swards under fruit trees such as apples, where the need is for a low, weed-free vegetation. An important aspect in this connection is the general applicability of chemical control of the vegetation, and to what extent results are predictable and reproducible. Information now available from various parts of Britain and also the Continent (Willis 1969) shows that the major changes described above following treatment with MH + 2,4-D are typical and representative of the general situation. Experimental plots near Sheffield show similar trends of change, as have been found in experimental areas in Huntingdonshire and Cambridgeshire (Way 1970). However, differences in the original species composition of vegetation and in site characteristics affect features such as the rate of change, and lead to differences in detail from site to site. Nevertheless, the salient changes reported above are demonstrable on a wide scale.

The results show that characteristic communities arise from the various spray treatments, and that the vegetation remains essentially the same if repeatedly subjected to one spray annually. Of considerable ecological interest is the stability of these communities once spraying is stopped. Results (Willis and Yemm 1966) show that the vegetation gradually reverts to its former character, and after reversion for about five years is very similar to its original composition. A single spray of MH + 2,4-D is found, however, to lead to extensive change (Willis 1970, Table 2) of this reverted vegetation, in accordance with the findings described above. The rapid, but predictable and desirable, changes resulting from the spray treatments make them useful and appropriate in sward management.

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THE USE OF CHARCOAL DIPS FOR PROTECTION AGAINST SIMAZINE DAMAGE IN FRESHLY PLANTED STRAWBERRIES

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Summary Good results were obtained with charcoal slurry treatments in reducing simazine damage to freshly planted strawberries over 2 seasons. Root dips in 20%, 30% and 40% charcoal slurry gave good protection against simazine at 1.5 and 2 lb a.i./ac with the cultivars Cambridge Vigour and Cambridge Favourite. The charcoal was more conveniently applied as slurry than as dry charcoal powder.

INTRODUCTION

Robinson (1964) and Allott (1965) in a series of experiments at Loughgall showed that steam activated charcoal gave protection against damage by simazine when the runner roots were dipped in the charcoal before planting. These results were confirmed by Hughes (1966) and Cleary (1966). The dipping of strawberry runners in dry charcoal powder is unpleasant and dirty work not readily undertaken by workers. The trials described here were undertaken to examine a more convenient method of applying charcoal to the roots of strawberry runners. Charcoal slurry treatments at 20%, 30% and 40% were compared with a dry charcoal treatment on spring and autumn planted runners of Cambridge Vigour and Cambridge Favourite.

METHODS AND MATERIALS

In Experiments 1 and 2 reported in this paper the cultivar Cambridge Vigour was planted 18 in. apart in ridges 34 in. apart and plot size was 2 rows by 10 yd and contained 40 plants. In Experiments 3 and 4 the cultivar Cambridge Favourite was planted 15 in. apart in ridges 34 in. apart and plot size was 2 rows by 10.4 yd long and contained 50 plants. In all four experiments a randomised block design with 4 replications was used. The soil, part of the Clonroche series, was a loam or clay loam derived from Ordivician shale and drift material and in Experiments 1 and 2 contained in the 0-6 in. layer, approximately 18% coarse sand, 11% fine sand, 41% silt and 30% clay. In Experiments 3 and 4 the proportions were 19, 11, 42 and 28% respectively.

The four experiments compare the degree of protection given by either dry charcoal, or 20, 30 or 40% charcoal slurry to strawberry runners sprayed after planting with simazine at 1.5 or 2 lb a.i./ac, using Cambridge Vigour or Cambridge Favourite planted in either autumn or spring. The roots of the runners were dipped in dry or slurried charcoal before planting. The different rates of charcoal slurry were made by mixing the appropriate volume of dry charcoal in water. A treatment which was not dipped in charcoal or sprayed with simazine was included as a control and additionally in Experiments 3 and 4, a treatment which was not dipped but sprayed with herbicide. The undipped, unsprayed controls were maintained weed-free by hoeing.

RESULTS

Experiment 1.

After charcoal treatment, runners of Cambridge Vigour were planted on 1 October 1970. The field had been fallow in the summer previous to planting and at the time of planting was completely weed-free. On 8 October 1970 the charcoal treated plots were sprayed with simazine at 1.5 lb a.i./ac.

During autumn 1970 some leaves on a few plants on all simazine treated plots showed slight marginal yellowing. The treatments had no obvious effect on the growth of the plants in autumn 1970 or spring 1971. Table 1 shows that the treatments had no effect on crop yield in 1971.

Simazine was applied to all plots on 2 August 1971 and on 22 December 1971 at 1 lb a.i./ac. This kept the plots weed-free during autumn 1971 and 1972. In spring 1972 40% of the plants in a plot in a depressed part of the field became very stunted. This plot yielded little fruit in 1972. When a number of the stunted plants were lifted after harvest they displayed symptoms of damage by water logging. The crop yield from this plot was not used in the statistical analysis of the trial in 1972. There were no obvious differences in the vigour of the plants on the other plots. Crop records presented in Table 1 show that in 1972 the dry charcoal and 40% charcoal slurry treatments significantly outyielded the other treatments.

Table 1

Effect of charcoal treatments on crop yield of autumn planted Cambridge Vigour

Treatment	Crop yield (cwt/ac) 1971	Crop yield (cwt/ac) 1972
Untreated	30.1	154.3
Dry Charcoal	26.5	178.0
20% Charcoal slurry	27.9	151.6
30% Charcoal slurry	26.1	151.1
40% Charcoal slurry	29.7	168.9
'F' test	N.S.	**
S.E.	± 2.32	± 4.50

Experiment 2.

A trial similar to Experiment 1 was laid down on Cambridge Vigour in an adjacent plot in the same field in spring 1971. Charcoal dipped runners were planted on 1 April 1971. The ground was completely weed-free when planted. On 8 April 1971 the charcoal treated plots were sprayed with simazine at 1.5 lb a.i./ac.

During spring and summer 1971 some plants in all simazine treated plots showed slight marginal yellowing of the foliage. The treatments had no obvious effect on the vigour of the plants in 1971, but crop yield was significantly reduced by the 40% charcoal slurry treatment compared with the control treatment and the 20% and

30% charcoal slurry treatments (Table 2). The dry charcoal treatment and the 20% charcoal slurry treatment also significantly decreased crop yield compared with the control.

Simazine was applied to all plots on 2 August 1971 and on 22 December 1971 at 1 lb a.i./ac. This maintained the plots weed-free during autumn 1971 and 1972. The treatments had no effect on the growth or vigour of the plants in 1972. In 1972 the control treatment significantly outyielded all charcoal slurry treatments (Table 2). The dry charcoal treatment also gave a significantly higher yield than the 20% and 40% charcoal slurry treatments.

Table 2

Effect of charcoal treatments on crop yield of spring planted Cambridge Vigour

Treatment	Crop yield (cwt/ac) 1971	1972
Untreated	8.2	182.4
Dry charcoal	5.9	174.6
20% charcoal slurry	6.4	145.2
30% charcoal slurry	6.9	155.8
40% charcoal slurry	4.8	145.4
'F' test	**	*
S.E. (df = 12)	±0.49	±7.46

Experiment 3.

This trial was laid down to test the effectiveness of charcoal treatments on the cultivar Cambridge Favourite. After charcoal treatment runners were planted on 5 October 1971. Two plots of plants which received no charcoal treatment were also planted in each replication. On 14 October 1971 the charcoal treated plots and one untreated plot in each replication were sprayed with simazine at 2 lb a.i./ac. During October the plants established well. In early November the plants which had received no charcoal treatment before simazine application showed symptoms of simazine damage. The emerging leaves on all plants on these plots were pale yellow and some leaves were scorched. The damage became more severe throughout the winter and early spring. In March several plants on the unprotected simazine treated plots were dead. During April and May the damaged plants recovered.

Several plants on the charcoal treated plots also showed slight symptoms of herbicide damage in November and December 1971. The emerging leaves of these plants were pale yellow but no further symptoms of herbicide damage appeared.

Plant counts made on 22 June 1972 showed that over 5 times as many plants died on the plots which received no charcoal protection before the simazine application as had died on the other plots and as Table 3 shows these plots yielded significantly less than the plots which had received charcoal treatments. The unsprayed plots (which had to be hand weeded twice) yielded significantly less than the plots which had received charcoal slurry treatments.

During autumn 1971 and spring 1972 the simazine treatments gave good weed control although a few Agrostis stolonifera and Agropyron repens plants had to be removed by hand. The plots which were not treated with simazine became badly infested with annual weeds, mainly Stellaria media, Fumaria officinalis and Viola arvensis. These plots were weeded by hand on 28 March 1972. During May and June all treatments became infested by Agrostis stolonifera. All plots were cultivated and cleaned by hand on 26 June 1972.

Table 3

Effect of charcoal treatments on autumn planted Cambridge Favourite

Treatment	% dead plants (22/6/72)	Crop yield (cwt/ac)
Untreated, unsprayed	3.5	8.9
Untreated, simazine 2 lb a.i./ac	22.0	6.7
Dry charcoal, simazine 2 lb a.i./ac	4.0	10.9
20% charcoal slurry, simazine 2 lb a.i./ac	4.0	12.8
30% charcoal slurry, simazine 2 lb a.i./ac	1.5	12.8
40% charcoal slurry, simazine 2 lb a.i./ac	2.5	12.5
'F' test		**
S.E. (df = 15)		±1.07

Experiment 4.

A trial similar to Experiment 3 was laid down on Cambridge Favourite in an adjacent plot of ground in the same field. The runners received similar treatments and were planted on 29 March 1972. On 12 April 1972 the charcoal treated plots and one untreated plot in each replication were sprayed with simazine at 2 lb a.i./ac.

In late April slight simazine damage showed up on all plots which had been treated with simazine. The damage consisted of slight yellowing of the leaf margins. During early May the herbicide damage became more severe on the plots which had received no charcoal protection. Some plants on these plots became badly scorched while the damage was less severe on the other plants. During late May and early June a number of plants died on the unprotected plots. The less severely damaged plants recovered during June. There were no symptoms of severe herbicide damage on the other treatments (although a number of plants failed to establish).

During April, May and June all treatments gave excellent weed control. In July the unsprayed plots became badly infested with annual weeds, mainly Viola arvensis and Fumaria officinalis. All other plots remained weed-free.

Plant counts on 22 June 1972 showed that almost 50% of the unprotected simazine treated plants were dead while less than 7% of the plants on all other plots were dead. Table 4 also shows that crop yield was significantly lower from the unprotected plots which were sprayed with simazine than from all other treatments. The plots treated with 20% and 40% charcoal slurry yielded significantly less than the unsprayed plots.

Table 4

Effect of charcoal treatments on spring planted Cambridge Favourite

Treatment	% dead plants (22/6/72)	Crop yield (cwt/ac)
Untreated, unsprayed	5.0	8.1
Untreated, simazine 2 lb a.i./ac	49.0	2.3
Dry charcoal, simazine 2 lb a.i./ac	3.5	6.6
20% charcoal slurry, simazine 2 lb a.i./ac	1.0	5.6
30% charcoal slurry, simazine 2 lb a.i./ac	3.0	6.9
40% charcoal slurry, simazine 2 lb a.i./ac	6.0	6.2
'F' test		***
S.E. (df = 15)		±0.58

DISCUSSION

The results show that charcoal slurry gives good protection against simazine damage, and hence that dipping of strawberry runners in charcoal slurry is worthwhile if simazine is being applied. The charcoal slurry treatments were effective during the most important planting periods and on the two most widely grown cultivars in Ireland.

In both trials with Cambridge Vigour there was a tendency for crop yield to be lower with the two lower doses of charcoal slurry. However, in the trials with Cambridge Favourite all rates of charcoal gave good protection against simazine damage.

In Experiment 2, 40% charcoal slurry reduced crop yield in 1971 and 1972 while the dry charcoal treatment reduced crop yield to a lesser extent in 1971. The runners in this experiment were planted under moist soil conditions on 1 April 1971, but the first 21 days of April 1971 were warm and dry at Clonroche with .28 in. of rain. Hence it is possible that the two highest doses of charcoal (40% charcoal slurry and dry charcoal) may have reduced the uptake of soil moisture during the critical post-planting period and so reduced crop yield.

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TOLERANCE OF SIX STRAWBERRY VARIETIES TO PHENMEDIPHAM APPLIED SHORTLY AFTER PLANTING

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Summary Results are presented which demonstrate good tolerance by six commercially grown strawberry cultivars to rates of phenmedipham ranging from 1.0 - 4.0 lb/ac. Although initial yellowing of the leaves was observed in Cambridge Favourite at 4.0 lb/ac, this was not reflected in yield at harvest.

While there are several broad leafed weeds which phenmediphan alone will not control, its ability to control troublesome *Veronica* spp. when applied in addition to the standard soil acting herbicides, merits its use by growers in newly planted or established strawberries.

INTRODUCTION

Until recently the control of annual weeds in strawberries has been achieved by the use of soil acting herbicides such as simazine, lenacil or chloroxuron. These herbicides are known to be extremely dependant on adequate soil moisture for effective action and they have been found to give inadequate control of certain weeds such as *Veronica* spp. The emergence of weed seedlings after planting, even following the use of one of the above soil acting herbicides, has lead to the need for a foliar acting herbicide which could be used post-planting in strawberries.

Robinson and Rath (1970) and Allott and Uprichard (1970) presented results which suggested that both newly planted and established strawberries possessed good tolerance to the contact herbicide phenmedipham and that this material might be used to supplement the standard soil acting herbicides. Because it is foliar acting, it might be expected that phenmedipham tolerance in strawberries could vary from one cultivar to another, according to characteristics such as the shape and surface texture of the leaves. An experiment was therefore established at Loughgall to examine the tolerance of six commercially grown strawberry varieties to a range of phenmedipham doses.

MATERIALS AND METHODS

The experiment was established on a sandy clay loam. A split plot experimental design was used with varieties forming the main plots, each main plot was divided to allow the application of 4 sub-plot phenmedipham treatments. There were 4 replicates of each main plot. Each variety was planted on 10 May 1971 in rows 36 in. apart with plants 18 in. in the row. Lenacil at 2.0 lb/ac was applied to all plots on 14 May. On the 25 May when the plants were established and had started to grow phenmedipham was applied overhead using an Oxford precision sprayer and 50 gallons of water per acre. No further herbicide applications were made. All herbicide doses refer to active ingredient. A weed score was taken on 21 October 1971 using a 0 - 5 scale, where 0 = no weeds and 5 = weeds dominant. Due to the late planting, runners were deblossomed in 1971 and crop yield recorded in 1972.

Table 1

Effect of phenmedipham doses on the yield of six strawberry cultivars and on total weed control

Cultivar / Herbicide applied 1971	lb/ac	CROP YIELD LB/PLOT JULY 1972: Cambridge Vigour	Cambridge Favourite	Templar	Talisman	Gorella	Red Gauntlet	Mean weed score 21.10.71
Lenacil	2.0	42.03	34.50	58.87	37.84	25.45	27.84	2.64
Lenacil + phenmedipham	2.0 1.0	41.14	35.42	56.27	40.44	22.21	32.48	1.33
Lenacil + phenmedipham	2.0 2.0	40.85	32.10	60.97	39.51	21.42	27.57	1.46
Lenacil + phenmedipham	2.0 4.0	49.84	33.49	58.90	35.87	24.96	24.03	1.23
S.E. of a difference (d.f. error 15)				± 5.504				

RESULTS

Table 1 presents the mean weed score and the mean crop yield (lb/plot) following the application of a range of phenmedipham doses to six strawberry cultivars. From Table 1 it can be seen that there was no reduction in crop yield due to the various phenmedipham doses, even though four times the normal rate was used. All varieties showed good tolerance to the doses used, although an initial yellowing of Cambridge Favourite leaves at 4.0 lb/ac was observed about 4 weeks after spraying. However this in no way reduced growth and the symptoms soon disappeared to give a satisfactory crop yield at harvest.

The weed scores in Table 1 indicate that there was a beneficial effect due to phenmedipham, although no advantage was gained in this case from using rates above 1.0 lb/ac. Phenmedipham gave good control of Stellaria media, but Senecio vulgaris, Poa annua and Sonchus asper were much in evidence on all plots, irrespective of treatment.

DISCUSSION

It is apparent from this experiment that these six strawberry cultivars are all tolerant to phenmedipham when it is applied overhead at rates up to 4.0 lb/ac. There is apparently no lack of tolerance in newly planted strawberries, even when phenmedipham is applied 2 weeks after a spring planting.

Robinson and Rath (1970) reported that an application of 4.0 lb/ac in bright warm conditions gave a slight check to strawberry growth. Although phenmedipham was also applied in the present experiment during a period of warm, dry sunny weather, no initial check to growth was observed, though leaf yellowing symptoms were noticed in Cambridge Favourite 4 weeks after spraying. Concern was expressed by Robinson and Rath (1970) that differences in cultivar susceptibility might be a feature when this herbicide is used in strawberries, but the results presented in this paper clearly demonstrate that this is not likely to occur at normal rates of application.

While there are several common broad leafed weeds not controlled by phenmedipham alone, its use in addition to the standard soil applied herbicides will give a good overall weed control. Its ability to control Veronica spp. which occasionally presents a problem where soil acting herbicides are used, must commend its use as a post-planting treatment in newly planted or established strawberries. It is apparent that spring applications of phenmedipham will not adequately control Senecio vulgaris, but Robinson and Rath (1970) have suggested that improved control can be achieved by winter use of phenmedipham, especially in areas where mild weather allows this weed to grow all year round. While rates of phenmedipham above 1.0 lb/ac did not improve the overall weed control in these experiments, there is sufficient cultivar tolerance to allow application at higher rates, if established weeds are present.

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RESPONSE OF SOME WEED SPECIES AND STRAWBERRY C.V. CAMBRIDGE FAVOURITE TO PHENMEDIPHAM, TERBACIL AND PRONAMIDE

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Summary: The tolerance of strawberries to phenmedipham, terbacil and pronamide and the susceptibility of weeds were compared in a block of two year old plants of Cambridge Favourite. The ground was cleaned and sprayed overall with lenacil in the autumn, but by late February *Veronica* spp. covered 5% of the surface area. Phenmedipham applied in February checked the *Veronica*. Rotovation was not as effective and significantly depressed crop yields. Rotovation followed by lenacil and then phenmedipham in May gave the best weed control, especially of *Veronica* spp., without affecting the crop. Rotovation followed by terbacil was similarly better than when followed by lenacil or pronamide.

In a test of crop tolerance, rates of phenmedipham up to 16 kg/ha a.i. applied in September produced only transient leaf chlorosis.

INTRODUCTION

Current chemical weed control programmes for strawberries based upon applications of chloroxuron, simazine, lenacil and directed paraquat/diquat mixtures are unsatisfactory for certain weeds, notably *Veronica* spp. and *Agropyron repens*. *Veronica* spp. are especially troublesome in South-West England where they continue to grow throughout the winter months. At Long Ashton, over-wintering *Veronica* spp. can overrun strawberry breeding trials where the rates of herbicide applied are restricted for fear of possible damage to individual, single plant selections. At Efford Experimental Horticulture Station, *Veronica* has been troublesome due to its resistance to the lenacil/simazine/lenacil programme (Hughes, 1970) and this has also been noted in Eire (Robinson and Rath, 1970). Of the more recent herbicides, phenmedipham, terbacil and pronamide show promise against these weeds in strawberries.

Phenmedipham is a foliar acting herbicide to which the strawberry exhibits considerable tolerance. It is effective only on young weeds (less than 50 mm height) but has the advantage of killing a range of weed genera, notably including *Veronica* spp. (Robinson, 1969).

Terbacil shows promise for the control of *Agropyron repens* and other perennial weeds (Robinson, 1969). Canadian trials have shown it to be good for pre- and early post-emergence control, but damaging to strawberries except at low doses (Ricketson, 1969). At Clonroche in Eire, terbacil has proved safe when applied in February, but toxic to strawberries when applied in May (Rath and Robinson, 1970).

Pronamide was shown to be ineffective in Canada (Ricketson, 1969) but is claimed to be toxic to gramineae, cruciferae, caryophyllaceae and polygonaceae and partially tolerated by strawberries (Sumpter, 1970).

The present trial compares phenmedipham, terbacil and pronamide in combination programmes with rotovation and lenacil under South-Western conditions with a view to establishing their potential value to local strawberry growers and for the Long Ashton breeding programme.

METHOD AND MATERIALS

A plot of 900 established strawberry plants c.v. Cambridge Favourite was used for the trial. The plants were mist-rooted runners, planted out in April 1970 at a spacing of 1 m by 1 m. The plot was maintained free from weeds by cultivations and hand hoeing for the first six months, followed by autumn applied lenacil at 2.24 kg a.i./ha. No further weed control measures were taken until February when the first experimental treatments were applied.

The plot was divided into three blocks of eight treatments each, the treatment areas consisting of twelve plants with a double guard-row between adjacent experimental plots.

All treatments were applied by knapsack sprayer using a four nozzle lance covering a swath width of one metre. Spraying took place at a pressure of 130 kPa (20 lb/in^2). The treatments were made at times when the soil was moist. Water retention by the soil (a sandy loam) was good and drainage was excellent due to a south facing gradient.

Veronica spp. formed the majority of weeds that over-wintered to occupy about 5% cover by late February. To control these weeds phenmedipham was applied to one set of treatments in late February (Table 1, treatments 1, 2 and 3) and for comparison the remaining treatments (4-8) were cross rotovated in early March. Treatments 4, 5 and 6 compare the effect of lenacil, terbacil and pronamide following rotovation. The final group, treatments 7 and 8, investigate the effect of phenmedipham in May on actively growing strawberries and weeds. In addition, 4 and 7 compare the effects of applying phenmedipham to plots which were rotovated and followed by lenacil. Treatments 7 and 8 compare the effects of lenacil applied in April on plots which received phenmedipham in May.

The formulations were:-

Phenmedipham - 'Betanal' 15.9% w/v emulsifiable concentrate

Terbacil - 'Sinbar' 80% wettable powder

Pronamide - 'Korb' 75% wettable powder

The wettable powder formulations were applied at 100 ml/m^2 i.e. approximately 100 gal/ac, but it is recommended that the 'Betanal' formulation of phenmedipham should not be diluted more than some thirty times. The maximum dilution was used for both dosage rates, 20 ml/m^2 for the 1 kg/ha rate, 40 ml/m^2 for the 2 kg/ha rate, approximately 20 and 40 galls/acre respectively. Herbicide rates are quoted throughout in terms of active ingredient.

Table 1

Experimental Treatments (1971)

Treatment No. and Code		Treatment
1	Ph	Phenmedipham at 2 kg/ha 22 February
2	(Ph + L)	As No.1 and lenacil at 2 kg/ha 23 February
3	Ph + L	As No.1 and lenacil at 2 kg/ha 2 April
	R	Cross rotovate 30 March followed by:-
4	R + L	Lenacil at 2 kg/ha 2 April
5	R + T	Terbacil at 0.25 kg/ha 2 April
6	R + Pr	Pronamide at 1 kg/ha 2 April
7	R + L + Ph	As No.4 and phenmedipham at 1 kg/ha 19 May
8	R + Ph	Phenmedipham at 1 kg/ha 19 May

Crop Records

The effect of treatments on the growth rate of the strawberry plants was assessed on 2 March and 19 July by scoring plant size on a 0 to 5 scale, 0 signifying dead or missing plants and 5 the largest plants. During the cropping period, ripe fruit was picked, counted and weighed regularly. Twelve picks were made, from 24 June to 16 July.

Weed Assessments

Assessments of total weed cover and that due to the major weeds present, *Veronica* spp., *Senecio vulgaris* and *Convolvulus arvensis*, were made on 22 February, 21 May, 30 June and 15 July by throwing a 0.1 m^2 quadrat five times in each plot and estimating the percentage area covered by each species present. As a check, the three named weed types were finally removed and weighed: *Senecio vulgaris* on 30 June because it threatened to seed a neighbouring experimental plot, and *Veronica* spp. and *Convolvulus arvensis* on 19 July.

On 8 September a supplementary trial was carried out to test the tolerance of strawberries to phenmedipham. Applications were made at 0.5, 1.0, 2.0, 4.0, 8.0 and 16.0 kg/ha a.i. to 20 m^2 plots. All applications were made at 40 ml/m^2 and no difficulty was experienced in applying the 0.5 kg/ha rate although the dilution was four times the recommended maximum.

RESULTS

Table 2 shows there were no significant treatment differences at the 5% level for the plant size scores made before or after the experiment.

Table 2

Plant size, total crop weight and numbers of fruit

Treatment No. and Code		Plant size (score 0-5) 2 March	19 July	Total yield/plant (kg)	Total fruit/plant (No.)	Mean fruit wt(g)
1	Ph	2.25	3.36	1.94	195	10.0
2	(Ph + L)	2.25	3.58	1.93	194	10.0
3	Ph + L	1.97	3.33	1.84	177	10.4
4	R + L	2.22	3.06	1.43	142	10.1
5	R + T	2.36	2.94	1.50	157	9.6
6	R + Pr	1.92	2.89	1.41	152	9.3
7	R + L + Ph	2.25	3.19	1.49	140	10.6
8	R + Ph	2.25	2.83	1.57	161	9.8
Standard error		±0.23	±0.30	±0.19	±20	
		0.68*	0.90*	0.60*	60*	

* Approximate difference between values significant at the 5% level

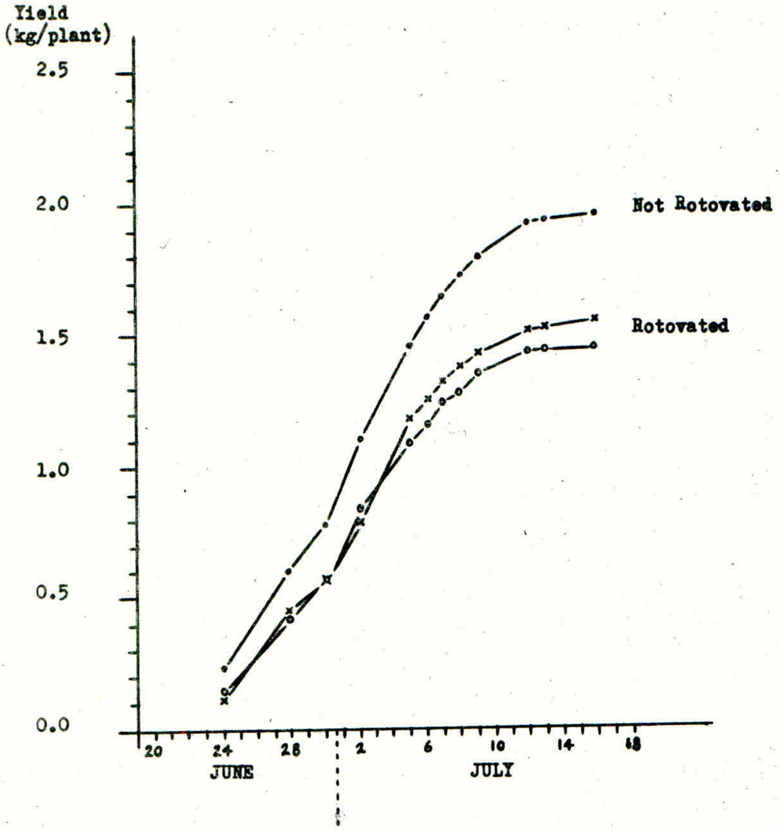
Numbers of fruit picked closely parallel the values for crop weight and although Table 2 shows there was little variation in fruit size between treatments, the higher yields from individual treatments were due to higher numbers of larger fruits.

Figure 1, which illustrates the cumulative yield for the three main groups of treatments, shows that broad differences did occur. Rotovation depressed yield. Treatments 1, 2 and 3, in which phenmedipham was used to control over-wintering weeds gave consistently the highest yields, significantly more than all other treatments at the start of the season ($p = .01$) and finally significantly more than treatments 4, 5 and 6 ($p = .05$). The yield of treatments 7 and 8 which received phenmedipham in May improved as the season progressed and finally their total yield was neither significantly lower than treatments 1, 2 and 3 or significantly higher than treatments 4, 5 and 6.

Table 3 gives the figures of percentage weed cover, after transformation for statistical analysis, for total weeds and for *Veronica* spp. at the four dates of assessment. The levels of significance of the main treatment differences are also indicated.

Fig. 1

Accumulated Crop Yields (kg/plant)



KEY

Mean of treatments 1, 2 and 3

Mean of treatments 4, 5 and 6

Mean of treatments 7 and 8

Table 3

Total weed cover (*Veronica* spp. cover in brackets)

Treatment No. and Code		Area covered (transformed % of total ground area) 23 February	21 May	30 June	15 July
1	Ph	3 (2)	30 (1)	85 (10)	67 (11)
2	(Ph + L)	4 (2)	2 (< 1)	35 (20)	20 (14)
3	Ph + L	3 (1)	14 (< 1)	59 (22)	22 (14)
4	R + L	4 (1)	14 (3)	58 (36)	56 (39)
5	R + T	1 (< 1)	3 (< 1)	32 (1)	34 (3)
6	R + Pr	1 (< 1)	6 (2)	76 (67)	60 (48)
7	R + L + Ph	1 (< 1)	4 (1)	6 (2)	5 (1)
8	R + Ph	1 (< 1)	12 (4)	58 (23)	62 (30)
Significance of main treatment differences					
Total weeds		ns	2,5,6,7 < 1**	7 < 1,6** 7 < 3,4,8*	7 < 1,4,6,8** 7 < 5* 2,3 < 1,6,8** 2,3 < 4*
Veronica spp.		ns	5 < 8**	7,5 < 6,4** 7,5 < 2,3,8*	7,5 < 6,4** 7,5 < 8*

* Difference between two values significant at the 5% level
** at the 1% level

Treatment 4 (rotovation followed by lenacil) may be regarded as the control. During the period February to May, weed growth was slow. Much of the increase in area covered was due to established weeds becoming larger, lenacil having effectively prevented germination. During May and June rapid growth resulted in 58% cover, more than half of which was *Veronica* spp. The weed population then remained relatively stable. (Note that much of the general reduction in weed cover between June 30 and July 15 shown in Table 3 was due to the removal of *Senecio vulgaris* on June 30. From the start of the experiment *Senecio vulgaris* chanced to be a higher than average component of the flora of treatment 3).

There was very good correspondence between the estimate of weed cover in July (Table 3), with the fresh weight of weeds given in Table 4.

Table 4

Fresh weight of weeds per unit area of soil surface

Treatment No. and Code	Senecio vulgaris (g/m^2) 30 June	Veronica spp. (g/m^2) 19 July	Convolvulus arvensis (g/m^2) 19 July
1 Ph	61.6	39.8	30.5
2 (Ph + L)	66.9	36.1	12.0
3 Ph + L	101.0	33.6	28.2
4 R + L	23.8	91.4	48.1
5 R + T	49.1	14.5	47.3
6 R + Pr	103.1	95.4	19.2
7 R + L + Ph	1.1	14.4	26.6
8 R + Ph	15.1	47.4	56.5
Significance of treatment differences	ns	7,5 < 6,4** 1,2,3 < 4,6*	ns

* Difference between two values significant at the 5% level
** at the 1% level

DISCUSSION

Table 2 shows that strawberry plant size was uniform at the start of the experiment, but although treatments did not significantly affect plant growth during the season, it is worth noting that the unrotovated plants (treatments 1, 2 and 3) were on the whole larger. Collectively they gave significantly higher yields than rotovated plants (fig.1). In treatments 2 and 3, where phenmedipham was followed by lenacil, seasonal weed control was at least as good as that provided by rotovation followed by lenacil (treatment 4), and in terms of the amount Veronica spp. present, Table 4 shows that the control of this weed was significantly better. These results suggest that an application of phenmedipham in late February is a better method of controlling over-wintering weeds in strawberries than rotovation in March, probably because rotovation destroys many of the surface roots of the strawberry.

It was necessary to follow the February application of phenmedipham with lenacil to prevent the germination of new weeds, otherwise, as treatment 1 shows, Veronica spp. were only checked and other weeds flourished so that finally this treatment had the highest weed cover.

Of the rotovated treatments (4-8), rotovation followed by lenacil and phenmedipham (7) have a high crop yield and notably the best control of weeds, particularly *Veronica* spp. (Tables 3 and 4). All weeds were controlled until May by rotovation and lenacil and the application of phenmedipham then kept weed cover down to 60% until mid-July, significantly less than most other treatments. The omission of lenacil following rotovation (treatment 8) allowed weeds to develop beyond the stage at which they could be controlled by the May application of phenmedipham.

Treatments 4, 5 and 6 compare the relative merits of lenacil, terbacil and pronamide applied after rotovation. Negligible differences in crop yield were recorded. Weeds were well controlled until the end of May, but not thereafter by lenacil and pronamide. In contrast, as the assessments of weed cover and weight show, terbacil continued to give a reasonable control of weeds, and an excellent control of *Veronica* spp., significantly better, (P =   1) than that of lenacil or pronamide.

The application of phenmedipham at 16 and 8 kg/ha a.i. in September caused strawberry leaf chlorosis, but within a month the plants showed signs of recovery. Slight chlorosis was evident at 4 and 2 kg/ha but no damage was noted at 1 or 0.5 kg/ha. These results from plants growing slowly in September, illustrate the potential selectivity of phenmedipham on strawberry crops.

The results suggest that in South-West England, both terbacil and phenmedipham can be of value for general weed control in strawberries, but particularly for over-wintering *Veronica* spp.

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CONTROL OF PERENNIAL GRASS WEEDS IN STRAWBERRIES WITH PRONAMIDE

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Summary Pronamide applied in the Autumn at rates of 1.25 lb a.i./ac and above gave good control of *Agropyron repens*. Autumn applications of 1.25 lb a.i./ac to established strawberries have been safe except on very light soils. There were varietal differences in the plants' response to pronamide, and these showed up more clearly following spring applications. Cambridge Favourite was the most tolerant and Redgauntlet the least tolerant cultivar. Spring applications of pronamide produced less satisfactory control of *Agropyron repens*. Maiden strawberries were less tolerant than established plants.

INTRODUCTION

Pronamide is a residual herbicide of low toxicity which is particularly effective on annual and perennial Graminaceous weeds. Considerable trials experience has been obtained over the past three years on several crops. This report, following the work of de Sarjas and Perrot (1969) and Sumpter (1970), describes the work carried out on strawberries in the period 1970-72, and the relationships of application rate, weed control, soil type and plant cultivar. Reports on application to top fruit, bush and cane fruit are to be found elsewhere at this Conference.

METHOD AND MATERIALS

Pronamide was applied as a 50% w.p., Kerb 50W, in 30-50 gal/ac. There were fourteen replicated plot trials and nine large plot observation trials, two of which were on maiden plantings. These were carried out in Kent, Essex, Worcestershire and Scotland. Comparisons of Autumn and Spring applications were made at five replicated sites. Treatments were applied using a Van de Weij gas sprayer or a standard tractor mounted sprayer. A standard pressure of 35 lb/in^2 was used. Simazine was applied as a 50% w.p. and terbacil as an 80% w.p. The rates of herbicide used are quoted throughout in terms of active ingredient. The following methods of assessment were used:-

Crop vigour	-	on a 1-10 grading where 10 = untreated
Yield (% of control)	-	obtained by weighing total crop from three non-adjacent row lengths in each plot.
Weed results	-	as % of untreated.

Weed and crop vigour assessments were made just prior to harvest except where otherwise stated.

Table 1

Crop variety, application and replicated site details

Site	Cultivar	Age of plants in years	No. of reps.	Dates of application	Soil type
1	Favourite	5	2	9/12/71 4/ 3/72	Loamy sand
2	Redgauntlet	5	2	9/12/71 4/ 3/72	Fine sandy loam
3	Favourite	3	2	24/11/71 23/2/72	Fine sandy loam
4	Redgauntlet	4	2	24/11/71 23/2/72	Stony fine sandy loam
5	Redgauntlet	2	1	13/12/71	Loamy sand
6	Vigour	3	1	10/11/71	Loamy coarse sand
7	Favourite	3	4	10/11/71 15/ 3/72	Loamy coarse sand
8	Favourite	3	2	12/11/70	Silty clay
9	Redgauntlet	3	2	17/11/70	Clay loam
10	Favourite	4	2	17/11/70	Loamy sand
11	Vigour	2	2	12/ 1/71	Loamy coarse sand
	Favourite	2	2	12/ 1/71	Loamy coarse sand
12	Regina	2	2	12/ 1/71	Fine sandy loam
13	Favourite	3	2	20/ 1/71	Fine sandy loam
14	Favourite	3	6	18/11/70	Fine sandy loam
	Redgauntlet	3	6	18/11/70	Fine sandy loam
24	Redgauntlet	4	2	11/ 1/72	Loam

Table 2

Observation plot details

Site	Cultivar	Age of plants in years	Dates of	Soil type
15	Favourite Redgauntlet	3	15/ 2/71	Stony fine sandy loam
16	Favourite Redgauntlet	3	12/ 2/71	Fine sandy loam
17	Favourite Vigour Redgauntlet Gorella	3	20/ 2/71	Clay loam
18	Favourite	2	9/ 3/71	Coarse sandy loam
19	Redgauntlet	9 months	15/12/71	Stony fine sandy loam
20	Favourite Redgauntlet	9 months	12/11/71	Sandy loam
21	Favourite Talisman Redgauntlet Vigour	2	12/11/71	Loamy coarse sand
22	Vigour	3	21/10/71	
23	Vigour	2	21/10/71	

RESULTS AND DISCUSSION

The results of pronamide on weed control, crop vigour and yield are presented below on Tables 3,4 and 5.

Control of Agropyron repens by pronamide was good to excellent at all application rates. At 1.25 lb/ac applied in November or December (termed Autumn application) pronamide gave a minimum of 90% control except at two sites (5 and 24). Applications of 1.5 lb/ac gave better control, but at two sites (5 and 7) showed slightly less plant tolerance. The tolerance of Redgauntlet at site 4 was very low with the 1.5 and 2.0 lb/ac rates. Overall control with 2.0 lb/ac was only slightly better in degree of control, but its persistent effect was more noticeable on Agropyron repens regrowth by August.

Table 3

Perennial grass weed control as % of untreated

	Site Number	1	2	3	4	5	6	7	8	9	10	11a	11b	12	13	14a	14c	24	Mean
Autumn application																			
Pronamide lb/a.i./ac	1.25	90	95	96	-	85	-	97	94	-	95	-	-	-	-	-	-	80	91
	1.50	90	97	97	-	90	99	95	94	97	95	-	-	-	-	-	-	85	94
	2.00	95	98	97	-	90	99	99	-	-	-	-	-	-	-	-	-	90	95
Spring application																			
Pronamide lb/a.i./ac	1.25	70	-	80	-	-	-	70	-	-	-	-	-	-	97	-	-	-	80
	1.50	75	95	80	-	-	-	75	-	-	-	98	98	99	98	-	-	-	90
	2.00	90	95	85	-	-	-	75	-	-	-	98	98	99	-	100*	100*	-	96

* 2.30 lb a.i./ac

a Favourite

b Cambridge Vigour

c Redgauntlet

Table 4

Effect of pronamide on crop vigour

Treatments lb/a.i./ac	Site Number	1 a	2 c	3 a	4 c	5 c	6 b	7 a	8 a	9 c	10 a	11 a	11 b	12 d	13 a	14 a	14 c	24 c	Mean
Autumn application																			
Pronamide	1.25	10	10	8.5	-	10	-	9.5	10	-	10	-	-	-	-	-	-	10	8.8
	1.50	10	10	9.5	6.0	9.5	9.5	9.0	10	10	10	-	-	-	-	-	-	10	8.8
	2.00	10	10	9.5	4.0	9.0	10	9.0	10	-	-	-	-	-	-	10*	9.0*	9.5	8.5
Untreated control		10	9.5	9.0	10	9.0	10	10	10	10	10	-	-	-	-	-	-	9.0	9.6
Hand weeded control		-	-	-	-	10	-	10	-	-	-	-	-	-	-	10	10	-	10.0
Spring application																			
Pronamide	1.25	10	10	8.0	-	-	-	10	-	-	-	-	-	-	10	-	-	-	8.2
	1.50	10	9.5	7.5	8.0	-	-	9.5	-	-	-	10	9.0	10	10	-	-	-	8.5
	2.00	9.0	9.0	6.0	7.0	-	-	8.5	-	-	-	-	-	-	-	-	-	-	6.9
Untreated control		10	9.5	9.0	10	-	-	10	-	-	-	10	10	10	10	-	-	-	9.8

* 2.30 lb a.i./ac
a Favourite
b Cambridge Vigour
c Redgauntlet
d Regina

Table 5

Saleable yield as % of untreated

Autumn applications

Treatment lb/a.i./ac		Pronamide 1.25	1.50	2.0	2.30	*Control	Terbacil
Site No.	**Cultivar**						
5	Redgauntlet	146	86	55	-	100	-
7	Favourite	97	112	84	-	100	-
14	Favourite	-	-	-	102	100	87
	Redgauntlet	-	-	-	76	100	94

Spring applications

Treatment lb/a.i./ac		Pronamide 1.25	1.50	2.0	*Control
Site No.	**Cultivar**				
7	Favourite	132	124	97	100

* Hand weeded control

Applications made during January to March (termed Spring application), of 1.25 lb/ac did not give as good control as Autumn applications. Treatments of 1.5 lb/ac were variable in their performance, whilst the 2.0 lb/ac performed as well as the Autumn application at the same rate. The mean performance in Table 3 was over 90% control from each Autumn treatment compared with 80, 90, and 96 from the 1.25, 1.5 and 2.0 lbs/ac Spring treatment respectively.

Other perennial grasses, especially *Agrostis stolonifera* and *Agrostis gigantea* are more easily controlled by pronamide, and all application rates were fully effective on these grasses.

Pronamide was tested on established Favourite plants at eight of the replicated trial sites, two of which were harvested for yield. The results show this cultivar to be tolerant to 1.25, 1.5 and 2.0 lb/ac in nearly all cases following Autumn application, notable exceptions being 1.25 lb/ac at Site 3, and 1.5 and 2.0 lb/ac at Site 7. No damage occurred at all in season 1970 - harvest 1971. The slight damage in season 1971/1972 was noticeable as a slight reduction in overall row height, but did not affect flower or fruit production. Fruits were of normal shape, size and colour. There was no noticeable difference in the crop between treatments by August of each year. Site 1 was treated in the two previous years at 1.5 lb/ac and no adverse effect has been noted from the three annual treatments.

Spring applications of 1.25 lb/ac had no adverse effect on Favourite. The higher rates produced slight to medium reductions in crop vigour, but as Table 5 shows, yields were not reduced. However, at Site 3, the highest rate caused prolonged plant dormancy with existing leaves being rolled, very dark green and crinkled. This state was temporary and ensuing leaf production was normal, although the crop was reduced. A visual assessment showed a reduction in saleable yield due to the increased production of mishapen, seedy fruit.

Sites 7 and 14 were picked for yield tests, and showed no reductions from Autumn applications of 1.25, 1.5 and 2.3 lbs/ac, but at Site 7, 2.0 lbs/ac reduced yield by 16%. These comparisons were made with hand weeded controls. Comparisons with strawberries severely infested with *Agropyron repens* (Sumpter 1970), have shown consistent increases in yield. Spring applications at Site 7 produced increases in yield from the two lower rates and a slight reduction at the 2.0 lb rate. The addition of simazine at 0.5 lb/ac produced no adverse effects.

Established Redgauntlet was treated with pronamide at six replicated trial sites. At four of these sites (2, 5, 9, 24) no damage occurred following Autumn treatment at any rate. At Site 4, a severe reduction in crop vigour resulted from 1.5 and 2.0 lb/ac. Prolonged dormancy and symptoms similar to those at Site 3 were produced. Yield results were poor with many small sized mishapen fruits. Crop height and spread means at this site at the end of July, showed no difference from the untreated control. Spring applications at three of the sites produced similar results, though the highest rate caused consistent damage.

Yield estimates at Sites 5 and 14 produced a confusing picture. Though the 2.0 lb rate, with or without the addition of simazine reduced yield, this was not obvious from leaf and flower condition. The 1.25 lb rate also reduced yield, but the 1.25 lb rate produced a yield increase. The 2.3 lb rate at Site 14 also reduced yield.

Commercial observation trials have borne out the replicated work, but definitely showed the susceptibility of Redgauntlet to Spring application. They also showed Cambridge Vigour and Gorella to be tolerant to Autumn applications, but Talisman appeared to be less tolerant and similar to Redgauntlet, at higher rates.

Two observation trials on Cambridge Favourite, Redgauntlet and Gorella in their maiden year at Sites 20 and 21, were carried out, both with Autumn applications. Site 21 was sprayed at 1.25 lb/ac with no damage to the crop. Site 20 was sprayed with 1.0 lb/ac with a reduction in vigour of 10% on both varieties. This resulted in a reduction in leaf cover and subsequent early ripening of the fruits.

There does seem to be a relationship between soil type and crop tolerance. At Sites 3, 4, and 7, where there was some damage following Autumn treatments at the lowest rate, the soils were light and stony. With varieties Cambridge Favourite, Cambridge Vigour, Regina and Gorella, Autumn applications at 1.25 lb/ac appeared to be safe on all soils except very stony light soils. Varieties Redgauntlet and Talisman, which seemed to be more susceptible looked safe when pronamide was applied in the Autumn at the 1.25 lb rate on soil other than light and very light ones. In one of the commercial observation plots on a gradient, slight damage was noticed on rows sprayed up the gradient, due to overdosing because of wheel slip and slower forward speed. This damage noted in March did not however, affect crop yield and plant vigour assessments in June and July, but this and other results, clearly emphasize the importance of careful spraying and avoidance of overlapping of spray treatments.

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Proc. 11th Br. Weed Control Conf. (1972)

RESPONSE OF NEWLY PLANTED CAMBRIDGE VIGOUR STRAWBERRIES TO PRONAMIDE, TERBACIL AND BROMACIL

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Summary Results are presented which show that spring applications of bromacil at 0.25 lb/ac, terbacil at 0.25 and 0.5 lb/ac, and pronamide at 0.5 and 1.0 lb/ac reduced the growth and crop yield of newly planted strawberries (cv. Cambridge Vigour). Autumn applications of terbacil at 0.5 lb/ac and pronamide at 0.5 and 1.0 lb/ac also reduced growth and crop yield, although low rates of terbacil (0.25 lb/ac) and bromacil (0.25 lb/ac) had no adverse effects at this time of year.

Where no alternative means of weed control are available and in view of the high level of control of Agropyron repens which can be obtained with pronamide, the use of this herbicide in newly planted strawberries can be justified in extreme situations, in spite of yield reductions.

INTRODUCTION

The increasing presence of Agropyron repens in strawberry plantations, has recently stimulated many investigations into its control. Rath and Robinson (1970) and Allott and Uprichard (1970) have presented results of experiments in strawberries where established plantations showed a limited tolerance to moderately low doses of bromacil and terbacil. In addition Sumpter (1970) has suggested that pronamide can be safely used in established strawberries at doses below 1.5 lb a.i./ac. These investigators have pointed to the fact that autumn or winter applications of these herbicides caused less crop injury than spring or summer applications. However the problem of competition from Agropyron repens at the immediate post-planting stage still remains, often as a result of improper site preparation. In addition, many growers prefer spring planting of strawberries when the use of herbicides such as bromacil, terbacil or pronamide would cause crop injury. An experiment was therefore established at Loughgall to examine the use of low doses of terbacil, bromacil and pronamide in maiden strawberries and to assess the level of crop injury which these might cause when applied in spring and autumn.

MATERIALS AND METHODS

This experiment was established on 13 May 1971 on a sandy clay loam. Strawberries (cv. Cambridge Vigour) were planted in rows 36 in. wide with plants 18 in. apart in the row. A split plot experimental design was used with main plots being sprayed in spring or autumn. There were three replicates of each main plot. The main plots were divided to facilitate the application of 6 sub-plot herbicide treatments. These consisted of different rates of terbacil, pronamide and bromacil and for comparison the standard commercial rate of lenacil at 1.6 lb a.i./ac was included as a control treatment. Herbicides were applied overhead using an Oxford precision sprayer and 50 gallons of water per acre. Herbicide rates are quoted as active ingredient. The first application of herbicides (spring treatment) was made

2 weeks after planting on 1 June. The autumn treatments were applied on 27 October 1971. Weed scores were taken on 22 October 1971 to assess the spring treatments and again on 19 April 1972 to assess the autumn treatments. Similarily plant height and width measurements (in.) were made on 25 September 1971 and 22 May 1972. Weed scores were on a 0 - 5 scale with 0 = no weeds and 5 = weeds dominant. Due to a late planting, runners were deblossomed in 1971. A crop yield (lb/plot) was recorded in 1972.

RESULTS

Table 1 presents the height and width (in.) of newly planted strawberries following the application of 6 herbicides at two different times of the year. It can be seen that terbacil at 0.5 lb/ac caused a reduction in growth compared to pronamide at 1.0 lb/ac, although this was only significant following spring applications ($P < 0.05$). No significant differences in growth between terbacil and the other treatments were evident following autumn application of herbicides. Growth of strawberries appeared satisfactory following the application of bromacil (0.25 lb/ac). However, there was a tendancy for pronamide to cause a reduction in growth following autumn application, although its use in the previous spring had had no adverse effects.

Table 1

Effect of herbicides on the height and width of strawberry plants (cv. Cambridge Vigour)

		Plant height (in.) 25.9.71	Plant width (in.) 25.9.71	Plant height (in.) 22.5.72		Plant width (in.) 22.5.72	
Time application		Spring	Spring	Spring	Autumn	Spring	Autumn
Herbicide	Rate						
1. Terbacil	0.25	8.63	11.88	12.47	12.60	14.43	15.73
2. Terbacil	0.5	8.72	10.96	12.33	11.67	13.13	14.03
3. Pronamide	0.5	9.70	12.50	12.27	10.80	13.53	13.57
4. Pronamide	1.0	9.67	13.25	13.70	11.70	14.73	13.90
5. Bromacil	0.25	9.75	12.16	12.23	12.97	13.60	16.10
6. Lenacil	1.6	9.08	12.00	11.37	12.67	12.43	14.93
S.E. of a difference (d.f. error 20)		± 0.264	± 0.610	± 0.885		± 1.22	

Table 2 shows the effect on crop yield (lb/plot) and weeds following the use of 6 herbicides. Although there was no significant differences, there was a tendency, following spring applications, for all herbicides to reduce crop yield when compared to lenacil. However, following autumn applications only pronamide (0.5 and 1.0 lb/ac) and terbacil (0.5 lb/ac) caused any noticeable yield reduction.

All herbicides gave satisfactory control of broad leaved weeds - there was no *Agropyron repens* present on this site.

Table 2

Effect of herbicides on weeds and crop yield (lb/plot) in newly planted strawberries

		Mean weed score			Crop yield (lb/plot) July 1972	
		22.10.71	19.4.72			
Time of application		Spring	Spring	Autumn	Spring	Autumn
Herbicide	Rate					
1. Terbacil	0.25	1.33	2.33	0.67	26.61	32.56
2. Terbacil	0.5	1.67	2.67	0.67	25.29	23.79
3. Pronamide	0.5	2.33	2.67	1.67	24.09	21.89
4. Pronamide	1.0	2.00	3.00	1.33	25.88	24.89
5. Bromacil	0.25	2.33	2.67	1.00	28.69	32.35
6. Lenacil	1.6	1.67	2.00	1.00	33.96	32.88
S.E. of a difference (d.f. error 18)					± 4.43	

DISCUSSION

These experiments show that although only terbacil produced a significant reduction in strawberry growth when applied immediately after planting in spring, all herbicides caused an overall yield reduction compared with the lenacil treated control. In the autumn strawberries sprayed with low doses of terbacil and bromacil (0.25 lb/ac) showed satisfactory growth and gave a crop yield comparable with lenacil treated plots. The reduction in crop yield with terbacil in these experiments is similar to that reported for established strawberries by Rath and Robinson (1970), while Sumpter (1970) also recorded a yield reduction in newly planted strawberries following the use of pronamide (1.5 lb/ac).

However it is unlikely that low doses of terbacil or bromacil would provide anything more than a short check to the growth of *Agropyron repens* when used for its control (Myram and Forrest, 1970). The high level of control of *Agropyron repens* which can be obtained with a single pronamide (1.0 lb/ac) application in the autumn (Ryan, 1972), justifies its use in new strawberry plantations in the absence of alternative means of control, although crop tolerance is limited and a reduction in yield will be inevitable.

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FURTHER EXPERIMENTS WITH HERBICIDES FOR THE CONTROL OF PERENNIAL GRASS WEEDS IN STRAWBERRIES

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Summary Terbacil at 2 lb/ac in February gave excellent control of perennial grasses in strawberries. Terbacil at 1.6 lb/ac in August caused no reduction in crop yield but did not give good control of grasses. Pronamide at 1.5 lb/ac in October gave moderate control of grass weeds but caused a reduction in crop yield. Pronamide was more effective than terbacil where a range of broadleaved weeds were present. Bromacil and tetrapion caused very severe damage to the strawberry plants.

INTRODUCTION

Previous trials at Clonroche showed that terbacil in February can give very effective control of perennial grass weeds in strawberry plantations (Rath and Robinson 1970). Because the tolerance of strawberries to terbacil during this period is low, trials were carried out to see how terbacil might be more safely applied or if it might be replaced by another herbicide. One of the experiments now described was started in 1969 (Rath and Robinson 1970) and was continued in 1970 and 1971. Several new trials with terbacil, pronamide, tetrapion and bromacil were carried out to compare crop and weed responses in weed free and weed infested conditions when applied in autumn or spring or in both seasons.

METHODS, MATERIALS AND RESULTS

Table 1 presents a synopsis of the 8 experiments reported in this paper.

Herbicide doses are quoted throughout the paper as active ingredient.

Experiment 1.

This experiment was started in 1969 (Rath and Robinson 1970) and was continued in 1970 and 1971. The experiment was carried out on a plantation of Cambridge Vigour on a grower's holding near Clonroche. The runners were planted in April 1968 and were spaced 2 ft apart in rows 3 ft apart. The plantation became badly infested with *Agrostis stolonifera* and *Agropyron repens* and in November 1969 the area was almost totally covered by these weeds. The soil was a clay loam and contained in the 0-6 in. layer approximately 20% coarse sand, 10% fine sand, 40% silt, 30% clay and 2.3% organic carbon. The treatments listed in Table 2 were applied on 4 November 1969 and on 20 February 1970. Plot size was 8 yd x 2 rows. A randomised block design with 5 replications was used. On 23 December 1970 simazine was applied at 1.5 lb/ac to all plots. On 26 January 1971 the plots received an application of paraquat at 0.5 lb/ac which was directed to avoid striking the strawberry foliage.

Table 1

Synopsis of treatments 1969-1972

Expt.	Herbicide	Season Applied	Year	No of rates or combinations	Incidence of weeds
1	Terbacil	Autumn and/or Spring	1969 1970	12	infested
2	Terbacil	Autumn	1970	4	free
3	Terbacil	Autumn	1970	6	infested
4	Pronamide	Autumn	1970	5	free
5	Pronamide	Autumn	1970	6	infested
6	Terbacil or Pronamide	Autumn or Spring	1971 1972	5	infested
7	Terbacil or Bromacil	Spring	1972	Logarithmic	free
8	Tetrapion	Autumn	1970	4	free

During summer 1970 the high rates used in Treatments H, K and L (Table 2) gave almost complete control of perennial grass weeds. During autumn 1970 Ranunculus repens recolonised the ground on many plots from which the grass had been eliminated. The application of paraquat in January 1971 gave complete control of this weed. Treatments H and L remained almost completely free of grass during 1971 while Treatment K became lightly reinfested. All other treatments were completely covered by grass weeds in 1971.

Treatments L and D caused slight scorching of the strawberry foliage in June 1970. The treatments had no significant effect on crop yield in July 1970. In autumn 1970 and spring and summer 1971 the plants in Treatments H, K and L were much more vigorous than those in the other treatments.

The treatments had no statistically significant effect on crop yield in 1970 although yield was lowest from Treatment L. In 1971 Treatments G, H, K and L, characterized by high rates in spring, significantly increased crop yield compared with the control treatment (A Table 2). Terbacil in February and terbacil in November and February gave large and significant yield increases compared with terbacil in November.

Experiment 2.

This experiment was carried out on the cultivar Cambridge Vigour to test the tolerance of established strawberries to autumn applications of terbacil. The runners were planted on 16 October 1968 and were spaced 18 in. apart on ridges

34 in. apart. The plantation was maintained weed free in 1969 and 1970 by using simazine. Terbacil was applied at 0.0, 0.4, 0.8 and 1.6 lb/ac on 31 August 1970 and repeated on the same plots on 10 August 1971. Plot size was 2 rows x 24 plants. Each treatment was replicated 3 times in a randomised block design. All plots received simazine at 1 lb/ac on 22 December 1970 and on 21 December 1971.

Table 2

Effect of terbacil on crop yield of grass infested strawberries.

Treatment No.	Terbacil (lb/ac) 4 November 1969	Terbacil (lb/ac) 20 February 1970	Crop yield (cwt/ac) 1970	Crop yield (cwt/ac) 1971
A	0.0	0.0	32.7	12.3
B	0.5	0.0	33.4	13.9
C	1.0	0.0	40.4	22.0
D	2.0	0.0	34.2	25.8
E	0.0	0.0	36.6	16.6
F	0.0	0.5	45.3	26.1
G	0.0	1.0	52.4	34.7
H	0.0	2.0	38.7	49.2
I	0.0	0.0	35.4	16.0
J	0.5	0.5	41.8	26.3
K	1.0	1.0	37.3	37.6
L	2.0	2.0	28.6	42.9
'F' test			N.S.	***
S.E. (df = 44)			±2.85	±4.54

No treatment had any effect on the growth or vigour of the plants or on crop yield in 1971 or 1972.

Experiment 3.

This trial was laid down to test the effectiveness of autumn applications of terbacil in controlling a range of perennial grasses. The trial was laid down on neglected grassland in autumn 1970. The principal weeds present were *Agrostis stolonifera*, *Dactylis glomerata*, *Agropyron repens* and *Festuca rubra*. Terbacil was applied to the grass plots on 31 August 1970 at 0.0, 0.4, 0.8, 1.2, 1.6 and 2.0 lb/ac. The soil was moist at the time of application. The plot size was 8 yd x 2 yd. A randomised block design with 3 replications was used.

Scorching of the grass appeared at all doses in early September 1970. During late September the grass on the plots treated with terbacil at 0.4 lb/ac began to recover. In mid-October the grass weeds were badly scorched on the plots which had received terbacil at 1.2, 1.6 and 2.0 lb/ac. In early November the grass weeds began to recover on all plots. In spring 1971 the grass recovered completely.

Experiment 4.

Experiment 4 was laid down to test the tolerance of strawberries to pronamide. The trial was laid down on a plantation of the un-named Dutch cultivar, I.V.T. 6032 which had been planted on 20 October 1969. The plants were spaced 18 in. apart on ridges 34 in. apart. Pronamide was applied at 0.0, 0.25, 0.5, 1.0 and 1.5 lb/ac on 16 October 1970. Plot size was a single row 36 plants long. A randomised block design with 5 replications was used.

The treatments had no effect on plant growth or vigour in autumn 1970 or spring 1971. Pronamide at 1.5 lb/ac reduced crop yield in 1971 (Table 3).

Table 3

Effect of pronamide on crop yield of weed free strawberries

Pronamide (lb/ac) 16 October 1970	Crop yield (cwt/ac) 1971
0.0	160.9
0.25	149.2
0.5	142.4
1.0	150.1
1.5	135.5
'F' test	**
S.E. (df = 16)	±4.04

Experiment 5.

Experiment 5 was laid down to test the effect of pronamide on a weedy plantation of strawberries. The trial was carried out on a grower's holding near the Soft Fruit Research Station, Clonroche. Cambridge Vigour runners were planted in April 1969, 24 in. apart on ridges 30 in. apart. Subsequently this plantation became infested with *Poa annua*, *Agropyron repens*, *Senecio vulgaris* and *Trifolium repens*. The treatments listed in Table 4 were applied on 16 October 1970. Plot size was 10 yd x 2 rows. The trial had a Latin square design. Plots receiving standard weed control were cultivated and hoed on 21 October 1970. Simazine was applied on 26 October 1970 at 1.5 lb/ac and a directed spray of paraquat at 0.5 lb/ac. was applied on 27 January 1971.

Table 4

Effect of pronamide on crop yield of weed infested strawberries

Treatment 16 October 1970	Crop yield (cwt/ac) 1971
Standard weed control	51.4
No weed control	44.4
Pronamide 0.25 lb/ac	40.6
Pronamide 0.5 lb/ac	43.6
Pronamide 1.0 lb/ac	49.4
Pronamide 1.5 lb/ac	37.4
'F' test	*
S.E. (df = 20)	±2.82

The grass weeds on plots treated with pronamide turned yellowish green in late November. Damage to grasses increased and in early January 1971 green grass was completely absent from the plots treated with pronamide at 0.5, 1.0 and 1.5 lb/ac. In late March the pronamide treated plots were infested with Senecio vulgaris and Trifolium repens. During April and May the grass weeds recovered on the plots treated with pronamide and in early June these plots were lightly infested with Poa annua and Agropyron repens. The standard weed control plots remained weed free while the unweeded control plots were infested with Poa annua and Agropyron repens.

During autumn 1970 and spring 1971 no treatment had any apparent effect on plant growth or vigour. Pronamide at 1.5 lb/ac significantly reduced crop yield in 1971 (Table 4).

Experiment 6.

This experiment was laid down to compare the effectiveness of terbacil and pronamide in cleaning a weed infested plantation of Cambridge Favourite. The site had been planted by a grower with Cambridge Favourite in April 1969. The runners were spaced 15 in. apart on ridges 30 in. apart. The trial had a randomised block design with 3 replications. Plot size was 3 rows 15 yd long. During 1971 the plantation became badly infested with Agrostis stolonifera and Rumex acetosella.

The herbicide treatments listed in Table 5 were applied on 4 October 1971 and on 24 January 1972. The standard weed control plots were cultivated with a rotary cultivator in the alleys and the weeds in the plant rows removed by hand on 26 October 1971. These plots were sprayed with simazine at 1 lb/ac on 26 October 1971 and on 3 January 1972. The alleys of these plots were cultivated and the plant rows hoed on 14 April 1972.

Terbacil applied in early October 1971 had scorched the grass weeds by the end of the month and by late December they were almost dead. They recovered almost completely during April and May 1972. Terbacil in autumn caused scorching of Rumex acetosella and of the strawberry foliage.

Table 5

Effect of terbacil and pronamide on crop yield of Cambridge Favourite

Treatment	Crop yield (cwt/ac) 1972
Standard weed control	51.7
Terbacil 1.6 lb/ac on 4/10/71	43.8
Pronamide 1.25 lb/ac on 4/10/71	64.2
Terbacil 1.6 lb/ac on 24/1/72	55.3
Pronamide 1.25 lb/ac on 24/1/72	67.7
'F' test	N.S.
S.E. (df = 8)	±7.26

Pronamide applied in early October 1971 began to kill Rumex acetosella in early December and in late December the grass weeds were also affected. In mid-February 1972 these plots were almost free of green weed foliage. Between mid-April and mid-May the grass weeds recovered completely. The plots remained free of Rumex acetosella.

On the plots treated with terbacil in January 1972 scorching of the leaf blades of the grass weeds occurred in late March and became more severe during April and May. By mid-May the grass weeds were almost entirely eliminated. Surviving grass weeds recovered from mid-July onwards. The treatment had no effect on Rumex acetosella or on the strawberries.

On the plots treated with pronamide in January 1972 grass weeds and Rumex acetosella died back during early April and by mid-April these weeds were almost completely dead. Between mid-May and mid-June the grass weeds recovered completely.

The weeds were well controlled by the standard weed control in autumn 1971 and in spring 1972.

The treatments had no effect on crop yield in 1972 (Table 5).

Experiment 7.

Experiment 7 was laid down on Cambridge Vigour to compare the tolerance of strawberries to bromacil and terbacil. The runners had been planted on 17 September 1970 and were spaced 18 in. apart on ridges 34 in. apart. On 20 January 1972 bromacil and terbacil were applied at rates varying between 4 and 0.4 lb/ac with a logarithmic sprayer. Plot size was a single line 24 yd long. Each treatment was replicated 3 times.

In late March 1972 the plants treated with all doses of both herbicides were pale green. During early April the edges of the leaves became scorched. This scorching occurred at all doses of bromacil and at doses of terbacil greater than 1.9 lb/ac. In May and early June 30% of the plants treated with doses of bromacil greater than 1.9 lb/ac and 15% of the plants treated with doses of terbacil greater than 2.4 lb/ac were badly scorched and stunted. The plants recovered during late June.

In 1972 bromacil at doses greater than 1.4 lb/ac caused large reductions in total crop yield while terbacil at doses over 2.4 lb/ac caused smaller reductions in crop yield (Table 6).

Table 6

Effect of bromacil and terbacil on crop yield of Cambridge Vigour

Dose (lb/ac) 20 January 1972	Crop yield (cwt/ac) Bromacil 1972	Crop yield (cwt/ac) Terbacil 1972
4.0-3.2	47.9	143.3
3.2-2.4	69.2	162.0
2.4-1.9	106.1	215.8
1.9-1.4	138.5	198.8
1.4-1.0	174.1	243.3
1.0-0.75	196.0	262.6
0.75-0.55	193.5	250.3
0.55-0.40	213.5	205.9

Experiment 8.

To test the tolerance of strawberries to tetrapion high doses were applied to the cultivar Cambridge Vigour. The runners had been planted on 16 October

1968 and were spaced 18 in. apart on ridges 34 in. apart. The treatments listed in Table 7 were applied on 25 August 1970. Plot size was 25 plants x 2 rows. A randomised block design with 3 replications was used. The trial area received simazine at 1 lb/ac on 22 December 1970, 13 August 1971 and 21 December 1971.

During December 1970 and January 1971 many crowns died on the plants which received tetrapion. During spring 1971 the damaged plants recovered through the growth of dormant buds. During autumn 1971 a large number of stolons grew from the plants which had received the highest dose of tetrapion while the other plants produced few stolons. There was no apparent difference in the growth or vigour of the plants in 1972.

In 1971 all tetrapion treatments caused large decreases in yield (Table 7). In 1972 the treatments had no effect on crop yield.

Table 7

Effect of tetrapion on crop yield of weed free strawberries

Tetrapion (lb/ac) 25 August 1970	Crop yield (cwt/ac) 1972	1972
0.0	193.2	112.1
1.79	148.4	124.2
3.38	102.6	105.4
6.67		
'F' test	***	N.S.
S.E. (df = 16)	±3.50	±6.71

DISCUSSION

These results show that early February is the most satisfactory period to apply terbacil for the control of Agropyron repens and Agrostis stolonifera in strawberries. In Experiments 1 and 7 terbacil at 2 lb/ac applied during this period caused no reduction in crop yield in the year of application while in Experiment 1 the weed suppression achieved caused a large increase in crop yield the following year. Terbacil was not effective in controlling grass weeds in August, October or November. Terbacil was found to be extremely toxic to strawberries when applied during March and April in earlier work at Clonroche (Rath and Robinson 1970).

In Experiment 5 pronamide applied in October gave moderate control of grass weeds while in Experiments 4 and 5 applications of pronamide at 1.5 lb/ac in October caused significant reductions in crop yield. In Experiment 6 where Rumex acetosella occurred with Agrostis stolonifera, pronamide was more effective than terbacil. While January applied terbacil gave moderately effective control of Agrostis stolonifera, Rumex acetosella became a much more serious problem. The results indicate that where weeds resistant to terbacil, e.g. Rumex acetosella, occur widely with perennial grass weeds in a strawberry plantation, pronamide would be more effective than terbacil.

Both tetrapion applied in late August and bromacil applied in January were very damaging to established strawberries at Clonroche. Allot (1970) got results contrary to those from Experiment 7 at Loughgall when he compared bromacil and terbacil applied in May. The fact that they were applied in May may have affected the relative tolerances of strawberries to these two herbicides because, as previous work at Clonroche has shown, strawberries are very susceptible to terbacil damage during this period (Rath and Robinson 1970).

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TRIALS IN THE WEST MIDLANDS AND CHESHIRE WITH PRONAMIDE AND TERBACIL FOR CONTROL OF AGROPYRON REPENS (COUCH GRASS) IN STRAWBERRY PLANTATIONS

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Summary Autumn application of pronamide at 1.5 lb a.i./ac and terbacil at 2.4 lb a.i./ac gave good suppression of Agropyron repens until after the following harvest, when some regrowth occurred. Autumn applications were more effective than Spring applications and caused less plant damage. These treatments were found to have no effect on the crop yield of Cambridge Favourite, but pronamide caused a reduction of approximately 25% in the crop yield of Redgauntlet.

Terbacil had a less immediate effect on Agropyron repens than pronamide.

INTRODUCTION

The encroachment of Agropyron repens from the headlands, and failure to eradicate it before planting, has reduced the cropping life of many strawberry plantations. A series of observations and trials were started in 1970 to examine the suitability of pronamide and terbacil for spot and overall application to established strawberry plantations.

METHOD AND MATERIALS

Table 1 gives details of 14 replicated trials which were set up in the West Midlands and Cheshire, using pronamide as Kerb (50% a.i.) and terbacil as Sinbar (80% a.i.) at rates from 0.5 to 3 lb a.i./ac. Plot size was generally 1/200 acre, although on 2 sites plots of 8 sq yds were used. Treatments were replicated either 2 or 3 times on the various sites and applications were made by knapsack sprayer.

RESULTS AND DISCUSSION

October - November applications of pronamide and terbacil generally gave better control of Agropyron repens than Spring applications. Some regrowth in July occurred with both application times. Plant damage was less from the Autumn applications and while February applications were generally acceptable, an application of pronamide at 0.5 lb a.i./ac in Herefordshire on 26 April 1971, which was followed by heavy rain, caused severe plant damage. Split treatments in which pronamide at 1 lb a.i./ac was applied in Autumn and again in Spring were no more effective in controlling Agropyron repens than Autumn applications, but caused more damage to the strawberry plants. Terbacil was also more effective as an Autumn application.

An application of pronamide at 1.5 lb a.i./ac in Autumn gave good control of Agropyron repens until July on the Warwickshire site; similarly 1 lb a.i./ac gave adequate control in Herefordshire. Neither application caused excessive crop damage.

Table 1

Treatments

Location	Soil	Variety	Age	Pronamide Rate lb ai/ac	Pronamide Overall	Pronamide Directed	Pronamide Date Applied	Terbacil Rate lb ai/ac	Terbacil Overall	Terbacil Directed	Terbacil Date Applied
Cheshire	Sandy loam	Cambridge Favourite and Redgauntlet	2yrs	1.0	0		22.3.71	0.5	0		23.3.70
				2.0	0		22.3.71	0.8	0		23.3.70
				1.0		D	22.3.71	1.2	0		23.3.70
				1.5		D	22.3.71	0.8	0		22.3.71
								1.6	0		22.3.71
Hereford-shire	Silty loam	Cambridge Favourite	4yrs	2.0	0		4.2.71	1.6	0		4.2.71
				3.0	0		4.2.71	2.4	0		4.2.71
	Silty loam	Cambridge Favourite	4yrs	0.5	0		21.4.71				
				1.0	0		21.4.71				
				1.5	0		21.4.71				
				2.0	0		21.4.71				
	Sandy loam	Cambridge Favourite	3yrs	2.0	0		4.2.71	1.6	0		4.2.71
				3.0	0		4.2.71	2.4	0		4.2.71
	Silty loam	Cambridge Favourite	4yrs	1.0 and 1.0	0		27.8.71 and 9.3.72				
				1.0 and 1.0	0		18.10.71 and 9.3.72				
				1.0 and 1.0	0		23.11.71 and 9.3.72				
	Silty loam	Cambridge Favourite	4yrs	2.0	0		27.8.71				
				1.0	0		27.8.71				
				2.0	0		18.10.71				
				1.0	0		18.10.71				
				2.0	0		23.11.71				
				1.0	0		23.11.71				
Warwick-shire	Sandy loam	Cambridge Favourite	4yrs	1.5	0		26.10.70	2.4	0		26.10.70
		Gauntlet	4yrs	1.0	0		6.4.71	0.8	0		6.4.71
		-"-	4yrs	2.0	0		6.4.71	1.6	0		6.4.71
Worcester-shire	Clay loam	Cambridge Favourite	4yrs	1.5	0		19.2.71	2.4	0		22.10.70
			4yrs					1.6	0		19.2.71

Table 2

Yield of Strawberries (lb)/plots 90 sq ft, 6 replicates

	Cambridge Favourite	Redgauntlet
Terbacil 2.4 lb ai/ac	29.8	31.9**
Pronamide 2.3 lb ai/ac	35.1	25.4
Control	34.9	33.8
Standard Error	+ or - 2.116	+ or - 1.465

** Treatments differ at p = 0.01

A rate of 2 lb a.i./ac applied in March was satisfactory on heavier soils in Herefordshire but caused severe plant damage on light soils in Cheshire. Even the 1 lb rate caused some plant damage on the light Cheshire soil.

Terbacil applied at 1.6 lb a.i./ac in Worcestershire and 2.4 lb a.i./ac in Warwickshire was more effective when applied in the Autumn than the Spring.

Rates of 1.6 and 2.4 lb a.i./ac applied in Herefordshire in February gave good control with slight plant damage at both rates.

Pronamide and terbacil gave satisfactory control of Agropyron repens and Agrostis gigantea until after the strawberry harvest in July when some regrowth was apparent. Pronamide was outstanding in the speed at which grass weeds were killed. Crop weight data could not be recorded during the trials, but data from Luddington Experimental Horticulture Station showed that terbacil at 2.4 lb a.i./ac applied in November 1970 to Cambridge Favourite and Redgauntlet caused no significant crop reduction on either variety. Pronamide applied at the rate of 2.3 lb a.i./ac to Cambridge Favourite and Redgauntlet caused approximately 25% reduction in the yield of Redgauntlet(Table 2).

The trials show that where the life of an established strawberry plantation is likely to be reduced by infestation with Agropyron repens, a worth while control could be achieved by Autumn applications of 1 to 1.5 lb a.i./ac of pronamide or 1.6 to 2.4 lb a.i./ac of terbacil. Statistical data was not recorded and no detailed comparison can be made of effectiveness over the range of application rates.

Acknowledgement

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