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TIME OF HERBICIDE APPLICATION FOR THE CONTROL OF DOCKS (RUMEX OBTUSIFOLIUS) IN A GRASSLAND CONSERVATION SYSTEM

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Summary The importance of time of herbicide application in relation to defoliation for dock control was studied by applying three herbicides frequently used for that purpose (asulam, mecoprop and dicamba/mecoprop) at three spraying-harvest intervals (28, 14 or 7 days) in advance of conservation cuts for silage made in May, August and October 1973. Overall no significant difference between herbicides in the level of dock control was found. Of the main factors investigated, season of application, i.e. which of the conservation cuts spraying preceded, showed the most influence on the level of dock control achieved. The mid season series of applications before the second harvest (August 1973) were the most effective. With regard to the effect of spraying-harvest interval the data supports the efficacy of spraying asulam only 7 days in advance of defoliation. Whilst treatment effects were detectable for total D.M. and grass component D.M. yields in the year of application the yield data from one cut in the following year showed no clear response attributable to the factors investigated.

INTRODUCTION

Experience suggests that lax defoliation which occurs in the most widely practised systems of sward conservation, together with high nitrogen usage, favour the increase of dock infestation. In such conservation systems, where the use of a herbicide as a routine measure is virtually essential, the problem is to know on which occasion to spray during the seasonal progression of harvests, and the best timing in relation to each conservation cut, to obtain adequate control of docks and procure the maximum yield of forage. Despite the wide use of mecoprop and dicamba/mecoprop for the control of docks (Rumex spp.) in grassland there is little published information regarding the influence of timing of application on either dock control or herbage D.M. production. With regard to the timing of application in relation to defoliation of the herbage Soper (1970) reported that the influence of asulam on the grass component may be minimised by allowing at least three weeks' regrowth prior to application while Hibbit and Catchpool (1972) suggested a potential improvement in dock control from a defoliation treatment applied immediately asulam uptake from the leaves was complete, i.e. within 48 hrs of application.

An experiment was designed to determine (a) the effect of spraying with the three herbicides, asulam, mecoprop and dicamba/mecoprop at various intervals (28, 14 or 7 days) prior to conservation cuts taken on three occasions (May, August and

October) during the 1973 season, and (b) the extent to which optimal dock control could be reconciled with minimising any potential adverse effects on the grass.

METHOD AND MATERIALS

The site for the experiment, near Bangor, Co Down, was a field which had been cut regularly for conservation for a number of years. The sward, originally ryegrass, at the start of the experiment consisted (D.M. separation) of: 59% Agrostis spp, 18% Poa spp, 11% Lolium perenne, 7% Rumex obtusifolius and 5% other weeds. The experimental plots were marked out in April 1973. The total number of treatments (three herbicides x three spraying-harvest intervals x three harvests and an unsprayed control) were laid out in a randomised block design, replicated four times. The sequence of spray treatments (each plot being sprayed on only one occasion) was commenced in May and continued till October 1973 (Table I). The individual plots, each 3.7 x 13.7 m, were sprayed with an Oxford Precision Sprayer with 4 '00' ceramic fan jets at 45.2 cm spacing and at a spray pressure of 2.0 bars giving an application volume of 225 l/ha.

Table 1

Details of experimental treatments and field assessments, 1973

Harvest (No) and date	(1) May 28th			(2) Aug. 15th			(3) Oct. 18th		
Date of spraying	1.5	15.5	22.5	18.7	1.8	8.8	19.9	1.10	11.10
Spraying-harvest interval (days)	28	14	7	28	14	7	28	14	7
Botanical Records									
Dock shoots No. per IO quadrats (S.E. ± 1.2)	23.0	8.6	9.8	9.3	14.0	13.7	9.4	11.2	18.6
Dock L.A.I. (S.E. ± 0.15)	0.23	0.16	0.28	0.16	0.89	0.77	0.38	0.63	0.64
*Environmental Data									
Max. temp. °C	12.6	12.4	16.0	17.6	22.6	16.9	15.2	15.3	12.5
Min. temp. °C	2.8	2.5	8.5	11.0	14.2	9.5	12.9	8.1	9.0
Rainfall (mm)	1.4	0	trace	3.5	2.3	8.0	0	trace	0.2

* Data from Helen's Bay (4 miles from experimental site)

The three herbicides were applied at the recommended commercial rates of application: asulam 1.12 kg/ha/ai, mecoprop 3.57 kg/ha/ae and dicamba/mecoprop 0.56 + 1.12 kg/ha/ae. At each spray date, samples of herbage from IO quadrats each 25 x 25 cm were collected from the plots prior to spraying to ascertain dock shoot number per plot and dock and grass leaf area. These samples were taken from outside the area 6.1 x 0.91 m harvested with a motor scythe for the main yield determination. At each harvest all plots of the trial were cut, the dock material separated from the herbage in the field and sub-samples taken of both fractions for D.M. determinations.

Prior to the first conservation cut, 135: 30: 30: kg/ha of N:P:K respectively were applied, followed, prior to the second cut, by a further 102: 23: 23: kg/ha of each material. A fourth harvest of all plots was taken in August 1974 to determine the persistent effect of the treatments.

RESULTS

Dock shoot numbers and L.A.I. With the exception of the unaccountably high shoot numbers recorded on 1st May (28 days in advance of harvest 1) there was a trend towards increased shoot numbers throughout the season and as each harvest approached (Table 1). L.A.I., low preceding the first conservation cut, also increased towards each harvest and was greatest during the July/August period.

Dock Control.

During the year of spraying (1973) The yield of dock component of the herbage for the various treatments expressed as a percentage of that on an untreated control is given in appendix 1. The yield recorded for the first cut immediately following the application of herbicides is biased; a high proportion of dock treated only 14 or 7 days in advance of cutting had not had sufficient time to decay and, though likely to die, was included in the separated yield. Hence, it is considered that the second cut following application reflects best the immediate actual effect of the herbicides. Table 2 shows this effect as a mean for each herbicide, independent of spraying-harvest interval, given as a percentage of the untreated control for applications at harvests 1 and 2. (Results for the September/October applications have been omitted as there was no data for the immediate regrowth period.)

Table 2

Dock D.M. production (% of untreated control) in the regrowth following herbicide application.

* Season of spraying	Asulam	Mecoprop	Dicamba/ mecoprop	S.E.	Mean	S.E.
May	8.3	18.7	4.3	± 13.9	10.4	± 11.3
August	2.3	3.0	7.0	± 9.0	4.1	± 7.0

* Data combined for spraying-harvest interval.

Independent of herbicide, there is a reduction in yield of docks from the August application as compared with the May application; this general pattern is especially marked for mecoprop, but is reversed for dicamba/mecoprop which gives good control at either month of application.

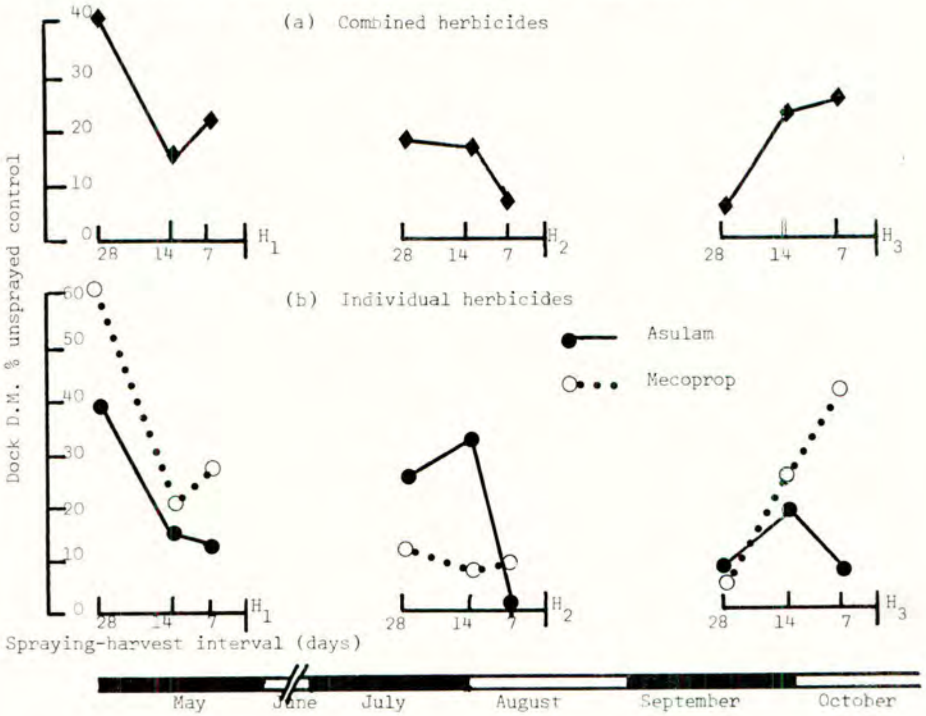
Annual Yield Data The yield of dock D.M. was significantly lower from the earlier dates of application. Independant of herbicide, the mean dock D.M. as a percentage of the control was 18%, 53% and 102% from the applications preceding the conservation cuts made in May, August and October respectively.

Persistent Control - Harvest 4 (August 1974) Assessing the persistency of the treatments approximately 12 months after application, significant differences were established between the three seasons of application (Table 5). The midseason date of application was, in general, the most effective.

This 'seasonal' effect is shown for each of the dates of application in Fig. 1(a), for the combined herbicide result and in Fig. 1(b) for the individual asulam and mecoprop treatments. Fig. 1 also shows how the level of effect declined at the earliest and latest dates of application in May and October respectively. This was especially true for the mecoprop treatment.

Fig. 1

Effect of date of application on dock % (August 1974)



The asulam treatment, although the level of effect did not achieve significance in the analysis, does show an effect attributable to spraying-harvest interval.

In each of the sequences of application, spraying asulam 7 days prior to cutting gave optimum control (28 days prior to harvest 3 was as good). Neither mecoprop nor dicamba/mecoprop was consistant in this response. The efficacy of the 7 day interval for the asulam treatment was demonstrated also from the data (Harvest 4) for the herbicide x spraying-harvest interval interaction. The mean % of dock relative to the unsprayed control for the asulam treatment at 28, 14 and 7 days was 24.0%, 22.3% and 7.3% (S.E. ± 5.6) respectively.

Grass Yields Analyses of variance of the grass component yields (appendix 2) show that neither the interval between spraying and cutting nor herbicides were significantly different at any of the harvests. Similarly it was not possible to show treatments differing from the control. Thus, independent of season of application or interval between spraying and harvesting, the annual yield of the grass in 1973 was not significantly increased. Neither was grass yield increased in the long term (as judged by harvest 4 in August 1974), although, overall, there was a mean increase of grass D.M. due to the treatments, at that harvest, of over 20% compared with the unsprayed control.

It is of interest at harvest 1 that asulam applied 7-days prior to defoliation gave a significant decrease in grass yield relative to the control but that at harvests 2 and 3 the greatest decrease occurred following the 28-day application. At harvests 2 and 3 a significant difference was shown between those plots which had just been sprayed and those sprayed earlier in the sequence. (appendix 2). Grass yields, lowest in those plots most recently sprayed, increased in the immediately succeeding harvest. At harvest 4 in seven cases out of nine herbicide x harvest applications the 28-day spraying-harvest interval shows the lowest increase in grass yield. The overall position for this effect is shown in Table 3, (discussion) where grass yield as a percentage of the control has been meaned over the herbicide treatments, and there is a reduction of 15% compared with the 14 and 7 day dates of spraying.

Total D.M. production The total D.M. data, combining the often complementary effects of the treatments on dock control and grass response, do not reveal any very clear effect from the treatments during 1973 or in the harvest of 1974. Only in a minority of cases is the total D.M. production in 1973 greater than that on the untreated control.

DISCUSSION

Dock Control The general increase in dock shoot numbers throughout the season, which appears to be a common feature of the development of dock infestations in conservation systems (Courtney 1972, Oswald and Elliot 1970) would be expected to have an influence on the control achieved, a better control being anticipated with higher shoot numbers and greater leaf area. The decline in control by mecoprop and dicamba/mecoprop at the end of the season despite high shoot numbers seems likely to have been influenced by environmental factors, probably temperature. At harvest 4, so far as spraying-harvest interval is concerned, a greater degree of control has been maintained by using asulam with a 7-day interval (28 day = 24%; 14 days = 22.3%; 7 days = 7.3%). In this respect asulam differs from either mecoprop or dicamba/mecoprop both of which fail to show any consistent response to spraying-harvest interval. The efficiency of the 7-day spraying-harvest interval for asulam may reflect the availability of higher shoot number and leaf area of the docks at that time of application or, as suggested by Hibbit and Catchpoole (1972), be a result of stimulation of meristematic activity by the defoliation treatment coincident with the time when maximum concentration of the herbicide is present in the crown tissues.

Grass yields and total D.M. production At the time of application, each of the herbicides had some adverse effect on the grass yields but for all the treatments except one the harvest data from 1974 records an increase, with a mean yield of grass component for treatments against the control of 20%. This is of the same order as recorded before in N. Ireland (Courtney 1972) and also in Gt. Britain by Savoury and Soper (1973). That such a sizeable increase could not be established as significant illustrates once more the difficulties inherent in this type of experiment. Total D.M. production in this trial showed a slight decline comparing treatment and control means and this again accords with previous evidence (Courtney 1972, Savory and Soper 1973) where total D.M. remained static or showed only a slight increase. The main advantage in dock control appears to be in increasing the grass content of the sward.

A summary of the treatment effects on dock, grass and total D.M. yield in the August 1974 harvest is shown in Table 3. Because of the lack of significance for most of these responses only tentative conclusions should be drawn.

Table 3

D.M. yields, dock, grass, total herbage, % unsprayed control

	Spraying-harvest interval (days)			Herbicides			Season of application			
	28	14	7	Asulam	Mecoprop	Dicamba/ mecoprop	May	Aug	Oct	S.E.
Dock	23	19	19	18	24	18	27	15	19	± 3.2
Grass	112	127	128	120	126	120	117	129	121	± 5.0
Total herbage	91	101	102	96	101	96	95	102	96	± 3.7

Spraying-harvest interval The 7 and 14 day intervals between spraying and harvesting have given best dock control and the highest increase in grass and total D.M.

Season of Application In terms of both dock control and grass yield the July/ August applications were superior.

Herbicides Asulam and dicamba/mecoprop when combined for dates of application show identical levels of dock control and grass yield. Mecoprop although slightly inferior in terms of dock control shows the highest yield of grass.

Acknowledgements

I should like to thank the farmer, Mr J Turtle for his assistance in providing the trial area for this experiment and his co-operation during the course of the trial.

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Appendix 1

Dock D.M. production (% of untreated control)

Herbicide	Time of application: Harvest	Spraying-harvest interval (days)	1973 Harvests 1	2	3	1973 Annual yield	1974 4
Asulam	1	28	70	19	23	26	39
		14	63	1	14	11	15
		7	57	5	9	12	13
	2	28	-	45	3	80	25
		14	-	70	4	72	33
		7	-	45	O	48	1
	3	28	-	-	12	29	8
		14	-	-	112	139	19
		7	-	-	69	65	8
Mecoprop	1	28	85	27	43	37	62
		14	IO6	16	26	29	21
		7	49	13	13	17	28
	2	28	-	9	4	23	12
		14	-	12	2	19	8
		7	-	69	3	53	IO
	3	28	-	-	O	23	5
		14	-	-	39	112	26
		7	-	-	IIO	IO8	42
Dicamba/ mecoprop	1	28	44	9	15	9	22
		14	39	3	19	IO	13
		7	66	1	25	13	29
	2	28	-	IO	21	29	23
		14	-	88	O	86	11
		7	-	74	O	66	8
	3	28	-	-	O	IOI	8
		14	-	-	12	124	24
		7	-	-	176	216	28
S.E. treatment mean (% untreated control)			87.2	33.9	15.5	27.2	9.6
Control D.M. per plot (kg/ha)			71	389	105	567	1098
S.E. control mean plot (kg/ha)			14	42	16	155	105
Analysis of variance. Source			Sig. level				
Spraying-harvest interval (I)			NS	NS	***	NS	NS
Herbicides (HE)			NS	NS	NS	NS	NS
Harvests (HV)			-	*	***	***	*
I x HV			-	NS	***	*	**
I x HE			NS	NS	**	NS	NS
Hx HV			-	NS	NS	*	NS
I x HE x HV			-	NS	**	NS	NS
Treatments v control			**	***	***	NS	***

* $p<0.05$ ** $p<0.0I$ *** $p<0.00I$

Appendix 2

Grass component D.M. production % of untreated control

Herbicide	Time of application: Harvest	Spraying-harvest interval (days)	1973 Harvests 1	2	3	1973 Annual yield	1974 4
Asulam	1	28	123	120	96	118	102
		14	78	113	85	91	118
		7	74	123	97	94	104
	2	28	-	91	114	93	109
		14	-	102	112	104	159
		7	-	119	102	107	120
	3	28	-	-	60	94	127
		14	-	-	95	91	112
		7	-	-	97	107	133
Mecoprop	1	28	80	130	101	99	119
		14	108	87	98	110	123
		7	93	129	94	105	124
	2	28	-	125	140	110	111
		14	-	104	123	100	132
		7	-	111	86	102	153
	3	28	-	-	119	102	100
		14	-	-	69	110	144
		7	-	-	75	97	118
Dicamba/ mecoprop	1	28	97	114	105	104	99
		14	102	127	97	110	117
		7	86	155	116	113	146
	2	28	-	98	107	93	116
		14	-	81	111	93	123
		7	-	126	104	98	126
	3	28	-	-	93	105	127
		14	-	-	71	105	111
		7	-	-	69	94	113
S.E. treatment mean (% untreated control)			8.7	14.7	13.1	7.0	14.9
Control D.M. (kg/ha)			4732	2962	1304	8999	3454
S.E. control mean (kg/ha)			93	137	170	625	515

Analysis of variance. Source	Sig. level				
Spraying-harvest interval (I)	NS	NS	NS	NS	NS
Herbicides (HE)	NS	NS	NS	NS	NS
Harvests (HV)	-	**	***	NS	NS
I x HV	-	NS	NS	NS	NS
I x HE	**	NS	NS	NS	NS
H x HV	-	NS	NS	NS	NS
I x HG x HV	-	NS	NS	*	NS
Treatments v control	NS	NS	NS	NS	NS

* $p<0.05$ ** $p<0.01$ *** $p<0.001$

Appendix 3

Total D.M. production % of untreated control

Herbicide	Time of Application: Harvest	Spraying-harvest interval (days)	1973 Harvests 1	2	3	1973 Annual yield	1974 4
Asulam	1	28	122	108	91	113	87
		14	83	100	80	87	93
		7	74	109	90	89	82
	2	28	-	85	105	92	89
		14	-	99	106	103	129
		7	-	110	95	103	91
	3	28	-	-	57	91	98
		14	-	-	96	94	89
		7	-	-	95	104	103
Mecoprop	1	28	81	118	97	96	105
		14	108	106	92	105	98
		7	92	115	88	100	101
	2	28	-	111	129	105	87
		14	-	94	114	95	102
		7	-	106	80	99	118
	3	28	-	-	110	97	77
		14	-	-	71	111	115
		7	-	-	77	98	100
Dicamba/ Mecoprop	1	28	96	102	99	98	81
		14	101	112	91	104	92
		7	86	110	108	107	117
	2	28	-	87	100	89	93
		14	-	82	103	93	96
		7	-	120	96	96	98
	3	28	-	-	87	104	98
		14	-	-	66	106	91
		7	-	-	77	102	93
S.E. treatment mean (% untreated control)			8.5	13.0	11.7	6.3	12.1
Control D.M. (kg/ha)			4803	3360	1410	9571	4217
S.E. control mean (kg/ha)			93	138	165	606	510
Analysis of variance.					Sig. level		
Source							
Spraying-harvest interval (I)			NS	NS	NS	NS	NS
Herbicides (HE)			NS	NS	NS	NS	NS
Harvests (HV)			-	*	***	NS	NS
I x HV			-	NS	*	NS	NS
I x HE			**	NS	NS	NS	NS
H x HV			-	NS	NS	NS	NS
I x HE x HV			-	NS	NS	NS	*
Treatments v control			NS	NS	NS	NS	NS

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

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FURTHER WORK ON THE CONTROL OF BRACKEN IN THE NORTH OF SCOTLAND

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Summary Excellent control of bracken was obtained with asulam applied at 2.2 and 4.4 kg a.i./ha by hydraulic knapsack sprayer in 220 litres/ha, air blast machine in 27.5 and 55 litres/ha and by helicopter in 44 litres/ha. Cool wet conditions in July and frost before spraying markedly reduced the effectiveness of treatment. A progressive increase in yearly regeneration of bracken on asulam treated plots has been recorded and it is predicted that in 5-6 years they will reach their former level of infestation.

Glyphosate at 2.2 and 4.4 kg a.i./ha applied in mid July and August gave complete destruction of both bracken fronds and the grass sward beneath in the year of application with almost no regeneration of either in the following year.

INTRODUCTION

Preliminary results of field trials carried out in 1970 and 1971 for the control of bracken fern Pteridium aquilinum (L) Kuhn in the north of Scotland were reported by Scragg, McKelvie and Kilgour (1972) at the last British Weed Control Conference. In this paper the results are reported from more detailed experiments begun in 1972 to determine the optimum time, rate, method and conditions for successful control of bracken with asulam and from aerial application on a commercial scale. Information is given on the regeneration of bracken on areas sprayed in 1970 and 1971. A small observational trial laid down in 1973 to investigate the use of glyphosate for control of bracken is reported.

METHODS AND MATERIALS

Rates and times of application trial

In 1972 a trial was laid down on a south facing hillside (230-280 m above sea level) near Aboyne, Aberdeenshire which had a good cover of bracken at about 20-30 fronds/m^2 ranging in height from 1-1.25 m tall at the bottom of the slope to 0.6-0.8 m higher up. There were a few unavoidable small grassy patches completely free of bracken fronds within the bracken dominated area. The position of these were mapped beforehand and although they were included in the plots for spraying purposes subsequent assessment of the degree of control achieved was confined to the part of each plot known to have been previously heavily infested. Plot size was 400 m^2 and no guard strips were left. Two rates of asulam (40% w/v aqueous concentrate) 2.2 and 4.4 kg a.i./ha were applied by hydraulic knapsack sprayer at a pressure of 100 kN/m^2 in a volume of 220 litres/ha using a single wide angle anvil type jet to give a swathe width of approximately 2 m. Due to irregularities of terrain perfect coverage was not achieved. There were eight times of application at 14 day intervals from early June to mid September, plus a control with no spray treatment. Each treatment was duplicated in a randomised block layout. In order to minimise damage by tramping in the trial area the progressive increase in frond numbers through the season was recorded on dummy plots at the bottom and top of the hillside with about 50 m difference in height above sea level between them.

Rates, methods and conditions trial

In a second trial in 1972 at the Aboyne site asulam was applied at 1.1, 2.2 and 4.4 kg a.i./ha by hydraulic knapsack sprayer in 220 litres water/ha and by air blast knapsack sprayer in 27.5 and 55 litres water/ha. These treatments were applied under hot dry and cool wet conditions in July and after frost in September.

Aerial spraying trial

On 21 July 1972 an area of approximately 10 ha of reasonably uniform dense bracken (mean frond number $31.5/m^2$, range $13\text{-}68/m^2$) at Ballagan, Inverfarigaig, Inverness-shire was sprayed with asulam by helicopter at 2.2 and 4.4 kg a.i. in 44 litres/ha. The area was selected because of its accessibility for trial purposes and because it was considered that it was typical of the circumstances under which bracken control might be economically justified and re-infestation prevented by management practices. The bracken infested area formed part of an enclosed hill grazing (217-250 m above sea level) of about 40 ha on which 50-60 suckler cows and their calves are summer grazed. This above average density of stocking is justified by the quality of the ground, the deep soil being of a light brown mineral nature not excessively acid and with a reasonable nutrient status as shown by soil analysis. Rainfall is in the range of 100-150 cm/annum.

Soil analysis by Macaulay Institute (1973)

	Lime Content	Lime Requirement	pH Value	Phosphate Content	Potash Content	Approx % Organic Matter
West area	Very low	>7.5 tonnes/ha	4.9	Slightly low	Satisfactory	12
East area	Low	5.7 tonnes/ha	5.2	Low	Slightly low	8

There was a dense grass sward beneath the bracken canopy over most of the area, based on Agrostis, Festuca, Deschampsia flexuosa, Holcus and Poa species. Wild white clover was present in patches especially on the lower part of the site. Various lime, fertiliser and wild white clover overseeding treatments were applied in April 1973 in an effort to improve the sward and so prevent bracken re-infestation by inducing stock to graze more heavily on the treated areas.

Glyphosate trial - Aboyne

Owing to the scarcity of glyphosate small unreplicated plots of 8 x 10 m were sprayed at 2.2 and 4.4 kg a.i. in 264 litres/ha on 28 June, mid July and 22 August 1973. Asulam was applied at the same rates and times for comparison purposes.

RESULTS

The results of all trials were assessed by frond counts in July or August of the year following treatment on 10 random 1 m^2 quadrats per plot, the edges of plots being deliberately avoided, and are given as mean frond numbers per m^2 or percentage control compared with the unsprayed plots.

Rates and times of application trial

Some scorching and yellowing of fronds was observed which could be clearly related to time of application, the June treatments being scorched, early July yellowed at the tips of the fronds and later treatments showing no response in the year of application. Table 1 shows the mean frond numbers for the two years of counting since treatment. There was no significant difference in 1973 or 1974 between the two rates of application although the lower rate was usually less effective. Time of application is clearly very important. Within the period mid July to the end of August consistently good control was achieved by both rates of application, minor variations in apparent control being not significant and possibly attributable to the weather at time of spraying or uneven spray coverage. It is obvious that early spraying before full frond emergence is ineffective and that there is a marked decrease in effectiveness when frond senescence begins in early September.

Table 1

Rates and times trial - mean frond numbers per m^2

Spraying Date 1972	Dummy plots 1973		Rates of application: 4.4 kg a.i./ha		2.2 kg a.i./ha		Times Mean	
	Lower	Upper	1973	1974	1973	1974	1973	1974
7 June	11.9	0.3	16.7	18.6	16.3	21.8	16.5	20.2
21 June	20.6	13.3	23.0	23.5	17.3	22.3	20.2	22.9
5 July	26.3	19.1	5.4	8.0	10.1	18.4	7.8	13.2
18 July	24.7	21.2	1.6	3.5	2.9	5.5	2.3	4.5
2 August	22.5	22.5	2.3	7.3	6.7	10.9	4.5	9.1
15 August	19.7	22.6	3.3	5.0	6.0	15.1	4.6	10.1
30 August	22.5	22.3	1.1	3.8	5.0	10.8	3.1	7.3
12 September	18.9	21.6	6.8	24.9	20.3	29.6	13.6	27.3
Rates Mean			7.6	11.8	10.6	16.8		

Control 1973 = 21.1 1974 = 26.2

SE times of application 1973 = 4.8 1974 = 5.5

Rates, methods and conditions trial

No difference was found between the three methods of application which would indicate that very low volume application of asulam is likely to be satisfactory provided even distribution of the herbicide can be achieved. Marked differences were found between the three rates of application and weather conditions as seen in Table 2. Whereas reasonable control can be achieved by the lower rates of application under favourable July weather conditions only the highest rate gave reasonable control (72%) under adverse weather conditions. The September results after frost were all very poor and by 1974 almost all these plots were indistinguishable from the unsprayed area.

Table 2

Rates, methods and conditions trial - percentage control

Conditions	Rates of application 1.1 kg a.i./ha 1973	1.1 kg a.i./ha 1974	2.2 kg a.i./ha 1973	2.2 kg a.i./ha 1974	4.4 kg a.i./ha 1973	4.4 kg a.i./ha 1974	Conditions Mean 1973	Conditions Mean 1974
17 July hot dry	58	42	65	54	91	85	71	60
31 July cool wet	32	0	28	0	72	29	44	10
8 September after frost	19	0	27	0	47	13	31	4
Rates Mean	36	14	40	18	69	42		

LSD rates or conditions means 1973 = 15%

Aerial spraying trial

Excellent control of the bracken was achieved by both rates of application of asulam. A few missed strips were sprayed by knapsack sprayer in 1973. In 1974 the fertiliser plots were assessed separately so that in future years the long term effect of fertiliser and lime treatments on bracken regeneration can be recorded. No apparent change in the grass sward on the fertiliser plots with or without oversowing of clover seed was recorded in 1974. Other weed species such as *Deschampsia caespitosa*, *Urtica dioica*, *Juncus effusus* and *Cirsium arvense* have become apparent on the bracken free area.

Table 3

Aerial spraying, Inverfarigaig

	Before spraying 1972	4.4 kg a.i./ha 1973	4.4 kg a.i./ha 1974	2.2 kg a.i./ha 1973	2.2 kg a.i./ha 1974
Mean fronds/m^2	31.5	0.3	0.6	0.2	0.8
Percentage control	-	99	98	99	97

Regeneration of bracken

Observation and assessment of the regeneration of bracken on sprayed plots has been carried out annually over the period 1971-1974. In Table 4 the results are given for all sites where the normal husbandry characteristic of each area has prevailed. No special effort has been made to prevent regrowth of the bracken but inevitably stock have tended to congregate on the relatively small areas clear of bracken. In Figure 1 certain results are shown graphically to demonstrate the progressive regeneration of the weed and predict when if the present rate of increase is maintained, the bracken will reach a density equal to that of the surrounding untreated areas. The fronds emerging in the first few years after successful asulam treatment spraying are always very small in size and even after four years the vigour of the weed on plots where initial control was good is noticeably lower than untreated areas.

Table 4

Persistence of bracken control 1971-74

Site	Rate kg a.i./ha	Year applied	Percentage control 1971	1972	1973	1974
Culloden	4.4	1970	99	98	93	74
East Inverness-shire	2.2	1970	100	99	96	91
Glenelg	4.4	1970	97	93	82	68
West Inverness-shire	4.4	1971	-	99	99	99
Rogart	4.4	1970	89	87	52	44
East Sutherland	4.4	1971	-	93	93	90
	3.3	1971	-	90	74	52
	2.2	1971	-	93	75	40
	1.1	1971	-	84	66	20
Durris	4.4	1970	87	78	63	+
Kincardineshire	2.2	1970	78	67	50	42
Glen Urquhart	4.4	1971	-	99	99	+
Central Inverness-shire	3.3	1971	-	98	97	+
	2.2	1971	-	93	90	+

+ resprayed by farmer, 1973

Results of glyphosate trial

Excellent control of bracken was achieved with glyphosate applied after full frond emergence in mid July or August (Table 5). Earlier spraying gave unsatisfactory results. The immediate effect of this herbicide was to scorch and kill the fronds within a few days of application. The grass sward beneath the bracken was also completely killed and in 1974 there was only a very little regeneration of a few scattered grass clumps and herbs.

Table 5

Results of glyphosate trial, Aboyne, 1973

	Percentage control			
	glyphosate		asulam	
Rate/ha	4.4	2.2	4.4	2.2
28 June	18	10	49	58
Mid July	93	99	96	96
22 August	98	97	91	90

DISCUSSION

The work described in this paper has confirmed the tentative conclusions reached in our 1972 research report regarding the performance of asulam as a selective herbicide for control of bracken. There is also a large measure of agreement with the results reported by Soper (1972), Pink and Surman (1974) and the claims made by the manufacturers in their product manual (May and Baker 1974).

Optimum time and conditions for application

These are strongly linked and relate to the time of emergence, stage of growth and senescence of the bracken fronds. It is clear that good control will not be achieved until frond emergence is complete and that the date at which this occurs will vary widely from season to season, between different regions of the country and with altitude and exposure. In the north of Scotland it appears that frond emergence will not normally be complete until about mid July whereas Martin, Williams and Raymond (1972) report excellent control and presumably full frond emergence at Glen Douglas, Dumbartonshire in June. During the period mid July - mid August in the north of Scotland the bracken fronds are fully developed and excellent control has been achieved but the work of Veerasekaran and Kirkwood (1972) has indicated that during this period cuticle thickness is likely to increase and absorption and translocation of asulam to decrease so that it is probably preferable to spray in late July rather than mid August. The end of the spraying season as indicated by our Aboyne trials would be late August by which time a generalised bronze tinting of the foliage and some yellowing or death of the lower pinnae indicates senescence of the bracken fronds. Frost can bring about the same result and in 1973 a severe and widespread frost on the night of 10 August brought to a premature end the spraying season in the north of Scotland. In 1974 too many areas of bracken were showing premature senescence by mid August. It is noteworthy that results for Glen Douglas (Martin et al 1972) indicate that despite the milder climate in the south west of Scotland late August (25th) spraying gave poor results in 1970. In practice it therefore appears that any large scale bracken spraying campaign to be carried out in the north of Scotland should be designed to begin about mid July and end early in August.

As expected spraying under wet conditions proved ineffective and in the high rainfall areas delays due to bad weather have proved to be a serious hindrance to large scale operations especially aerial application and have resulted either in rather late spraying or, as in 1973, in the almost complete abandonment of a large commercial spraying programme.

Methods and volumes of application

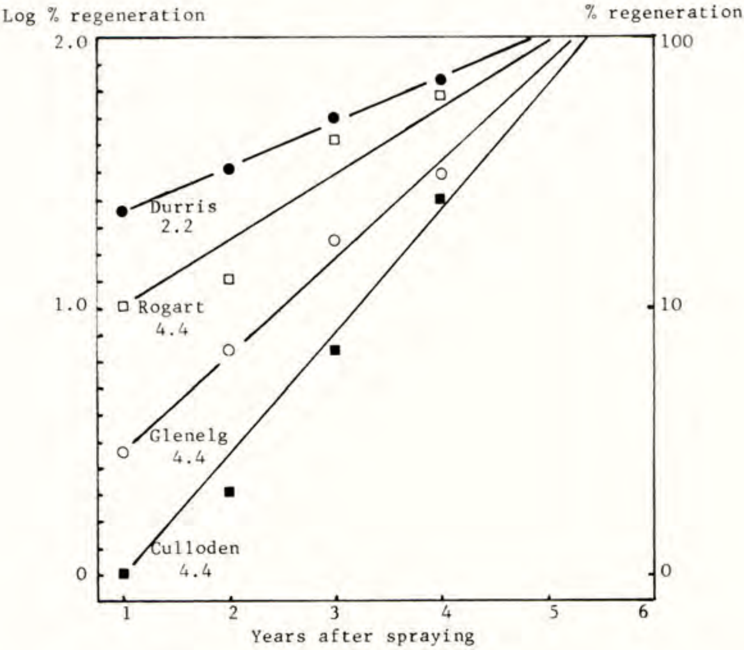
Although good control was achieved by a variety of methods and at a range of volumes of application we consider that aerial application is by far the most suitable for the conditions prevailing in the north of Scotland and our results at Inverfarigaig show an outstanding degree of control on a scale and under circumstances where no other method was feasible.

Rates of application

Good control has been achieved on a number of sites with rates of application as low as 2.2 kg a.i./ha and it seems likely that this quantity of material applied in mid July under ideal conditions may give a degree of control equal to that obtained with the manufacturers recommended dose of twice that amount. There are however indications from both 1972 Aboyne trials that towards the end of the season or under adverse conditions a more reliable result is likely to be achieved by the higher rate. It has been suggested that control may be less persistent with lower rates of application but this opinion is not supported by our results which show that where equally good initial control has been achieved the persistence of control at 2.2 kg a.i./ha is no shorter than with the higher rate.

In view of the high cost of application of asulam on bracken (helicopter 1974 £15/ha) it seems unwise to risk poor control through the use of low rates of application, especially in large scale practice, where it may be impossible to apply the herbicide under ideal conditions.

Figure 1 Bracken regeneration after asulam spraying, July 1970



Reinfestation of cleared areas

Our trial sites have shown progressive reinfestation of sprayed plots as a result of regeneration of fronds from dormant buds on the rhizome system. The work of Conway (1960) and Martin (1972) indicates that this is almost inevitable with a weed having the characteristics of bracken. At first the emerging fronds are small (20-40 cm tall) and very thinly scattered; in later years they become taller and more numerous. It must be borne in mind that the results we give, except for Inverfarigaig, are after knapsack spraying and there were undoubtedly imperfections in the evenness of coverage achieved. It may be that where large areas are more uniformly sprayed as by aerial application regeneration may be appreciably less than in small plots.

The results given in Table 4 show that on most sites there has been appreciable regeneration the extent of which appears to depend largely on the degree of suppression achieved in the first year after spraying. At Culloden and Glenelg where 97-100% control was achieved regeneration has been slow and it is encouraging to note that there are two plots Culloden 2.2 and Glenelg 4.4 1971 where excellent control has persisted for several years. At sites such as Rogart and Durris where initial control was only moderately good, regeneration has been much more rapid and visually the plots now appear to be heavily bracken infested. Figure 1 shows that regeneration follows an exponential increase and that if present rates of regeneration are maintained frond numbers will reach their former levels in 5 or 6 years even where initial control was apparently excellent. In their technical bulletin (May and Baker 1974) the manufacturers of asulam state that control from correctly timed applications can persist for four years which seems a reasonable claim in view of our results.

An equation $\log R_n = 0.34\ (n - 1) + \log R_1$ has been calculated to predict the progress of bracken regeneration from correctly timed spraying once the first year's results are available, where R_1 = % regeneration in 1st year after spraying, n = number of years after spraying and R_n = % regeneration in nth year. There is a slight indication from the Aboyne data that where asulam is applied late or under adverse conditions regeneration will be quicker than predicted even though apparently moderately good initial control is achieved.

Only at Inverfarigaig has any deliberate attempt been made to check regeneration by post spraying management but it is too early to say yet whether any of the manurial treatments or increased cattle grazing of the area will have a permanent suppressing effect on the bracken.

Spraying of regrowth with a low dose of asulam has been tried at Rogart and Glen Urquhart with rather disappointing results. The use of a full dose is impracticable because of the uneconomic cost of the treatment and the possibility of severe grass damage where there is only limited bracken cover. This emphasises the importance of achieving a high degree of initial control by spraying at the optimum time for the particular area and under good weather conditions so that an initial control as near to 100% as possible may be achieved.

Control of bracken with glyphosate

The results given in Table 5 agree closely with those of Williams (1974) although our 2.2 kg a.i./ha August treated plot shows considerably better control than he reported. We agree that grass sward kill is complete and that this herbicide would only be suitable for bracken control under conditions where reseeding is practicable.

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NOTES

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LEGUMES AND BRITISH GRASSLAND, NEW OPPORTUNITIES WITH HERBICIDES

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Summary This review suggests that the decline in the use of forage legumes during the last decade is at an end and that current economic changes, principally the steeply rising price of nitrogenous fertilizers, are favouring a resurgence in legume use. More dependable establishment and growth of legumes can be achieved by using herbicides correctly. Methods of introducing and establishing legumes into grass swards are described, with special attention given to herbicides for regulating the legume balance in mixed swards. The role of herbicides in controlling weeds in forage legumes, and in increasing seed production from these crops, is also discussed. In reviewing work at WRO relevant to legumes the needs for future research are outlined.

INTRODUCTION - THE CHANGING STATUS OF LEGUMES

Past trends and present status of legumes

Since the early 1960's, there has been a decreasing reliance on the use of white clover in grassland. Comparing statistics issued by the Ministry of Agriculture, Fisheries and Food during the period 1971-73 show that 30 per cent less white clover seed was used compared with the period 1960-62. On the other hand, quantities of grass seed fell by only six percent during this period, indicating that a lower proportion of white clover was being used in ley mixtures.

In permanent pasture, the white clover content has probably not changed substantially during the recent past, judging from the surveys of Baker (1960) and Morrison and Idle (1972). Certainly white clover rarely exceeds five per cent of the total herbage cover, except when grazed intensively by sheep.

With red clover, there has been a substantial fall in use during the last 14 years, even more so than with white clover(67% compared with 30%). The use of other forage legumes, too, has fallen: alsike 59%, lucerne 63%, sainfoin, 87% and trefoil 93%.

Thus, the general picture is of legumes being a minor component of British grassland, and being progressively less relied on as forage crops during the last decade or so. Reasons for this decline include: the availability of cheap fertilizer nitrogen; the slow start to legume growth in the spring; the difficulty of managing a grass/legume sward; the animal husbandry problems associated with utilising legume-rich swards (bloat and infertility); and problems associated with growing legumes (diseases and weeds).

Basis for a change in the importance of legumes

There are grounds for believing that current economic changes and technical advances are now operating in favour of a legume resurgence. A key factor is the steeply rising price of nitrogenous fertilizers. During the last two years the price per kilogram of nitrogen has approximately doubled and this must surely encourage interest in alternative sources of nitrogen.

Legumes are an obvious alternative source of nitrogen in grassland. Not only do they provide substantial quantities of high quality leaf protein, but they also result in the transfer of significant amounts of nitrogen to the companion grasses - the actual levels depending very much on soil, climate and management factors (Williams, 1970; Wilman 1970). Most investigators agree that the gross effect of including white clover in grass swards, defined as the amount of nitrogen that has to be added to a pure grass sward to equal the yield of a mixed sward, ranges from 120-160 kg of nitrogen per ha per annum on a dry matter basis, or 200-260 kg on a nitrogen yield basis (Cowling 1961).

Like fertilisers, animal feeding stuffs have also increased in price and it is now important that livestock utilise roughages as efficiently as possible. For this reason the attribute of legumes of increasing the intake of silage by cattle is likely to be further exploited by livestock farmers in the future. Similarly, it is known that the inclusion of clover in the diet of sheep can lead to significant improvements in liveweight gain (Thompson and Raymond, 1970).

Lucerne can produce yields of digestible organic matter of high quality comparable to those of the most productive grasses receiving very high levels of nitrogen (Aldrich, 1974). So can the newer tetraploid red clovers which have been shown to be superior to diploids in yield, nutritive value, persistence and diseases (Frame et al, 1972). Moreover, recent advances in plant breeding have produced disease-resistant varieties of lucerne.

For these reasons, an increase in the acreage of forage legumes is probable, especially of lucerne on the alkaline soils of Southern and Eastern England, and of red clover on the remaining wetter soils (Aldrich, 1974). However, on small, intensively grazed dairy farms, which are dependent on using high levels of fertilizer nitrogen for achieving the necessary stocking rate, there is only limited scope for using grass/legume swards for grazing. On such farms, it will probably be best to reserve the use of legumes for the conservation areas. But, on extensive dairy farms and particularly on beef and sheep farms there is considerable scope for increasing the use of white clover. By so doing the animal production capability of a larger proportion of the 13 million acres of temporary/permanent grassland in the United Kingdom could be increased.

The impact of changing husbandry on methods of growing legumes

The conventional practice of undersowing legumes in cereal crops imposes a restriction on the type of herbicide that can be used. For instance, many broad-leaf weedkillers cannot be recommended for use on cereal crops undersown with legumes. Even when legume-tolerant herbicides are used, certain weeds after prove difficult to control. To some extent these restrictions can be avoided by the increasingly common practice of direct drilling immediately after cereal harvest. Newer techniques, too, of direct-drilling and oversowing into grass swards, or into standing cereal crops are being developed, although with all these techniques the control of broad-leaved weeds during and after establishment is made more complex when legumes are present.

Traditionally, the control of grass/legume balance was achieved by the complementary use of basic slag, low nitrogen and high stocking. This is essentially a long-term process and often the needs of the grazing animals have to be subservient to the requirements of the legumes. Using animals as grazing machines is usually impracticable to-day because the loss of only a few kg/ha liveweight can be costly. Selective herbicides offer a new opportunity to control species composition and, by their use, the conflicting requirements of the sward and the grazing animals can be met more easily. Hence the established role of herbicides in grassland, currently limited to controlling weeds, needs to be widened to include their use as management tools in pasture establishment and the maintenance of grass/legume balance.

ACHIEVING INCREASED LEGUME PRODUCTION WITH HERBICIDES

Introducing legumes into existing grass swards

Ploughing up old grassland and reseeding with a grass/legume mixture is a time consuming and expensive approach to improving grassland, and for this reason is limited in application (Elliott & Squires, 1974). Similarly, improvements to sward composition through fertilisers and grazing management are often slow, especially when white clover occurs sparsely or not at all (Elliott, Oswald, Allen & Haggar, 1974). Hence, some rapid method of introducing clover seed is required, followed by management to ensure successful establishment. Herbicides, coupled with oversowing or direct drilling, have an important role to play. They can be used either to kill the sward in the vicinity of the germinating legumes or to suppress it to the point where competition is reduced sufficiently to permit the introduced legume to establish successfully (Elliott, 1962; Charles, 1967). For sward-killing purposes, quick-acting herbicides, like paraquat (Jones, 1962a, Hammerton & Johnson, 1962) and glyphosate (Oswald, 1972), which have little or no residual activity in the soil, are ideal. In situations where the sward is matted, the mat can be removed to allow the legume seed to be sown in contact with mineral soil (Squires & Elliott, 1972). Alternatively, slower-acting herbicides like dalapon can be used in the autumn so as to allow time during the winter for the old sward to break down in preparation for spring sowing.

Management after sowing is crucial for the successful establishment of legumes (Warboys, 1966) as re-invasion by indigenous grasses often results in failure of the legume. Here again, grass herbicides to which legumes are not susceptible have a use in reducing excessive grass competition.

Herbicides for manipulating the legume content of established mixed swards

It is known that shading from companion grasses is a major factor in the reduction of the white clover content of mixed sward (Stern & Donald, 1962). By grazing in early spring, at a time when grasses are making more leaf growth than clovers, shading can be reduced and clover growth will subsequently benefit (Haggar, Holmes & Innes, 1963). Even so, the success of this technique is very dependent on the weather (Zaleski, 1970) and the heavy grazing involved can severely damage white clover plants.

For these reasons, the use of a grass-suppressing herbicide as a substitute for increased grazing pressure is an attractive alternative. Blood (1962) has shown that paraquat can be used in this way. Similarly, New Zealand workers have demonstrated the value of carbetamide in the dormant winter period for controlling grasses in white clover (Wasmuth & Miles, 1972). Currently, a range of grass-suppressing herbicides, of which white clover is tolerant, are being evaluated at WRO, including paraquat, carbetamide and dalapon. This last herbicide has shown considerable promise, when applied in July, in reducing weed grasses in ryegrass swards (Elliott & Allen, 1964), at the same time allowing the white clover to increase.

Other minor situations where selective herbicides are required include the manipulation of the legume content in experiments aimed at establishing the direct- and indirect effects of legumes (Wilman, 1970) and in work by plant breeders and other research workers wishing to maintain species purity.

Controlling weeds in forage legumes

Crop failures of lecerne are often associated with the invasion of weeds. For instance, during lucerne establishment, Stellaria media can be a problem. Later, grass weeds may reduce the productive life of the crop. Such a build-up of weeds has often discouraged growers from persevering with lucerne, even though some of the older herbicides, e.g., dalapon and paraquat, have already been recommended for this purpose (Green, Evans & Elliott, 1956; Jones, 1962b). It is to be hoped that the marketing of newer herbicides, like carbetamide, will encourage growers to make fuller use of them.

With red clover, grass weeds are less of a problem although, since it is often grown as a cleaning crop in an arable rotation, the control of grass weeds in it is important. There are selective herbicides for this purpose and significant increases in the potential yield of red clover seed have been achieved following their application (Haggar and Oswald, unpublished data).

Herbicides for increasing legume seed production

About 90 per cent of all white clover seed used in Britain is imported, which largely reflects the climatic disadvantages of this country for producing seed (Watkin Williams, 1970). The main weather problem is too much rain prior to flowering (resulting in excessive leaf growth) and during harvest. At both these times herbicides have a part to play. For instance, Blood (1962) and Zaleski (1970) have shown that paraquat can be applied in March to increase white clover seed yields from mixed grass/clover swards. Also, herbicides can be used as desiccants to allow quick harvesting before the weather breaks (Ormrod & Deakins, 1956; Haggar & Holmes, 1963; Roberts & Griffiths, 1973). For example, in really good weather it is possible to spray white clover with diquat in the morning, cut in the afternoon and combine the next day.

RESEARCH AT WRO RELEVANT TO LEGUMES

At WRO new herbicides are screened for biological activity, selectivity and soil persistence, and special attention is given to the tolerance of both ryegrass and white clover. This information is extremely helpful in indicating candidate herbicides for use on legume-based swards.

Manipulating the legume content of mixed swards

A small-plot evaluation programme was started in March 1974 comparing a range of grass-suppressing herbicides on a one-year old perennial ryegrass/white clover sward. Assessments made in July of white clover inflorescences showed that clover growth had been increased several-fold by the use of such herbicides as carbetamide, propyzamide, paraquat and even glyphosate (Haggar, unpublished data). In achieving these results it was necessary to forego some grass growth in the spring but this reduction was only short-lived; by mid-July grass growth on treated plots was at least as good as that from the controls.

Methods of introducing legumes into grass swards

Crop establishment work by Elliott and Squires (1974) has shown that legume seed can establish successfully in undisturbed soil, provided that there is not too much undecayed surface material present. With most grass swards it is necessary to remove this surface trash. For this purpose, a 'ribbon stripper' has been developed which cuts and lays on one side a ribbon of surface material measuring 2-3 cm wide and deep, thus exposing a small trench into which seed, fertilizer and slug repellent can be sown. This one-pass system, coupled where necessary with band- or overall spraying of an appropriate herbicide to reduce inter-row competition, means that clover can be established into all-grass swards with the minimum of cost and interruption to the grazing system. Once established the legumes can be encouraged further by the use of the selective herbicides mentioned previously.

Nitrogen fixation

A detailed assessment is routinely made of the ways in which current herbicides may affect the activity of Rhizobium, a bacterium associated with legumes which is responsible for fixing atmospheric nitrogen. This work has shown that this Rhizobium is usually more resistant to certain herbicides than are the legume host plants (Grossbard, 1970); also that the nitrogen fixing ability of the surviving bacteria appears to remain unimpaired (Grossbard, 1972).

NEEDS FOR FUTURE RESEARCH

An important objective of legume research should be to specify more precisely than at present the conditions for the successful introduction and maintenance of an adequate presence of legumes, mainly white clover, in swards for different livestock systems, and to ensure the maximum contribution of transferable nitrogen, both direct and indirect, in these situations. Hence priority should be given to the evaluation of herbicides as pre-sowing conditioners of the sward, and the development of appropriate drilling systems (incorporating aspects of seed treatment, such as pelleting) to provide a suitable micro-environment for the germination and establishment of - and colonisation by - the introduced legumes. Post-spraying managements involving the use of selective herbicides would be a necessary follow-up exercise.

More information is also required on how herbicides, linked with other aspects of management, can be used to manipulate the legume content of mixed swards to increase their total and seasonal production. In this connection, additional research is needed to see whether legume nodules are released following the application of herbicides, where used at different times of the year, in the same way as they are released when the host plant is placed under stress conditions e.g. defoliation (Butler, Greenwood & Soper, 1959).

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THE REGULATION OF GRASSES IN CLOVER SEED CROPS AND PASTURE USING CARBETAMIDE

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Summary This report describes grower trials and replicated experiments carried out from 1972-74 in red and white clover seed crops and pasture with doses of carbetamide ranging from 0.3 to 4.2 lb/ac applied between November and February. It was shown that a dose of 2.1 lb a.i./ac eliminated grass weeds in clover seed crops and that up to double this dose was safe on established clovers, confirming its potential for grass weed control in clover crops grown for seed.

Some pasture weed grasses, such as *Holcus* and *Poa* spp. were controlled by lower doses of carbetamide, while leaving desirable species, such as *Festuca* and *Lolium* unharmed or able to recover. Hence the herbicide has further potential for restoring a more desirable grass or grass/clover balance in clover seed crops and long-term leys.

Résumé Cet exposé decrit des essais en plein champs faits entre 1972-74 sur trèfles violets et blancs porte-graines, et prairies, utilisant le carbetamide en pulverisations dosées de 0.3 à 4.2 lb/ac. entre Novembre et Février. Le dose de 2.1 lb m.a./ac. à prouvé être apte à eliminer les mauvaises herbes graminées des trèfles porte-graines et que deux fois cette dose n' affectait pas les trèfles installées, ainsi confirmant son valeur de la lutte contre graminées qui envahissent les cultures des trèfles porte-graines.

Le désherbage de certains graminées adventices telles que *Holcus* et *Poa* fut contrôlé par des doses moindre de carbetamide, tout en n' attaquant pas les espèces à conserver telles que *Festuca* et *Lolium* intouchées ou capable de se retablir. De plus l'herbicide à la propriété supplementaire de reinstaller une balance plus equitable de graminées et de graminées/trèfles dans les cultures porte-graines et prairies temporaires à long terme.

INTRODUCTION

Large-scale farm usage of carbetamide for the control of grass weeds and a few broad-leaved weeds in clovers and lucerne began in France in 1967 (Dodel and Guillot, 1965, Boucher and Audy, 1966, idem 1967, Dussel et al. 1967) and was extended to New Zealand in 1971 (Miles, 1969). In 1972 it was decided to conduct a series of grower trials on clover seed crops to confirm that the standard commercial rate (2.1 lb a.i./ac) in use overseas was satisfactory under U.K. conditions.

However, situations do occur in clover-based swards where grass elimination is not desirable, i.e. where weed and sown grasses exist together, when a sown grass has become dominant, or where retention of some grass keeps out broad-leaved weeds or eases seed harvesting. In such situations, reduction of grass competition, or selective grass control, may be required. Further experiments were therefore set up to check the selective effects of low doses of carbetamide in a clover ley and in two established grass pastures.

METHOD AND MATERIALS

In the late autumn of 1972 arrangements were made at 10 sites in East Anglia for farmers to apply carbetamide at 2.1 and 4.2 lb/ac. in 40-100 gal water/ac to unreplicated $\frac{1}{4}$-acre plots of red and white clover seed crops. At an additional site duplicated plots of established clover (and other forage legumes) were treated with the same doses of the herbicide using a small-plot motorized sprayer delivering 40 gal/ac.

In January 1973 a replicated experiment was laid down at Ongar on a long-term ley sown in August 1965, of the following composition: 50% perennial ryegrass, 43% white clover, 5% timothy, 1.5% smooth meadow grass, 0.5% cocksfoot. Rates of 1.4, 2.1, 2.8 lb carbetamide and 0.4 lb paraquat per acre were applied, again using the small-plot sprayer delivering 40 gal water/ac. There were two replicates and the plots were 15 ft square. Using the same equipment and volume, two further replicated experiments were begun in early 1974 to record the effect of carbetamide at from 5 to 30 oz a.i./ac on two old pastures in Essex, composed mainly of meadow grasses (Poa spp.) and Yorkshire Fog associated with red fescue (Shalford) and with meadow foxtail (Ongar). Plot sizes were 10 ft x 30 ft and there were three replicates at Shalford and two at Ongar.

The carbetamide formulation was the 70% w/w wettable powder.

Assessments The E.W.R.C. scale was used for assessing legume tolerance, grass effect in the two pasture experiments, and weed control in the grower trials. Three of the latter (two white clover, one red clover) were harvested using the farmer's own combine. The ley experiment was assessed by counting clover seed heads in 6 x 1 ft^2 quadrats per plot. The percentage ground cover, by species, in 10 x 1 ft^2 fixed quadrats was assessed in the pasture sites before spraying.

RESULTS

The user trials with carbetamide at 2.1 lb a.i./ac applied in November 1972 demonstrated good control of volunteer cereals, mainly barley, at six sites. At a seventh site control was only moderate on volunteer oats. At all five sites where Alopecurus myosuroides occurred this was completely or satisfactorily controlled - the same effect was achieved on Poa spp. at all six sites where present. Control of Stellaria media varied from excellent to only 'fairly satisfactory' over six sites. Carbetamide took at least six weeks for the full effect on weeds to become apparent. Clover tolerance was excellent.

Table 1

Red clover

M&B Grower trials: E.W.R.C. Scores* for weed control and crop safety.
Carbetamide dose: 2.1 lb a.i. per acre

Site	Spray Date	Crop and weed description	Weeks post-spray 5-8	9-12	13-16	17-20	21-24
Linton, Cambs	22/11/72	Crop - Essex Red	1	1	1	-	1
		Weed - Volunteer cereals	6	1	1	-	1
		'Mayweeds'	7	9	9	-	9
		Veronica spp.	7	7	6.5	-	5
		Stellaria media	6	2	1	-	2
Parham, Suffolk	end Nov. 25/11/72	Crop - Maris Leda	1	1.5	-	1	1
		Weed - Volunteer cereals	3	1	-	1.5	-
		Alopecurus myosuroides	6	1	-	1	-
		Poa spp.	6	1.5	-	1.5	1
		Stellaria media	6	1.5	-	2	1.5
Fyfield, Essex	end Nov. 27/11/72	Crop - Essex Red	1	-	1	1	1
		Weed - Volunteer cereals	7	-	1	1	1
		Alopecurus myosuroides	6	-	3	3	3
		Stellaria media	8	-	1	1	1
Monk Soham, Suffolk	8/12/72	Crop - Hungaropoly	1	1	1	1	-
		Weed - Volunteer cereals	5	2	1	1	-
		Alopecurus myosuroides	5	2	2	2	-
		Poa spp.	5	2	2	2	-
		Stellaria media	5	3	2.5	2	-
		White clover					
Ware, Herts	17/11/72	Crop - Kersey (established)	1	1	1	1	-
		Weed - Alopecurus myosuroides	7	6	3	4	-
		Poa spp.	9	7	5	4	-
Ware, Herts	17/11/72	Crop - Kersey (new)	1	1	-	1	-
		Weed - Volunteer oats	6	7	-	6	-
		Alopecurus myosuroides	6	7	-	4	-
		Poa spp.	5	5	-	3	-
		Stellaria media	7	7	-	5	-
Stradbroke, Suffolk	23/11/72	Crop - Kersey	1	-	1	1	1
		Weed - Volunteer barley	3	-	1	1	1
		Poa spp.	6	-	3	1	1
		Myosotis arvensis	6	-	6	6	6
		Viola arvensis	not present	-	7	6	6

continued....

White clover (continued)

Site	Spray Date	Crop and weed description	5-8	9-12	13-16	17-20	21-24
			Weeks post-spray				
Comberton, Cambs.	20/11/72	Crop - Kersey	1	1	1	-	1
		Weed - Volunteer barley	5	1	1	-	1
		Anagallis arvensis	8	4	3.5	-	3
		Veronica spp.	7	6	6	-	4
		Stellaria media	6	2	1.5	-	4
Parham, Suffolk	20/11/72	Crop - Kersey (established)	1	1	-	1	1
		Weed - P.R.G.) *Poa* spp.)	6.5	5	-	5	2
Parham, Suffolk		Crop - Kersey, 2 years old	1	1	-	1	1
		Weed - Perennial rye grass	6	1.5	-	2	2

*EWRC Score: (1-9 (1 = as control, 9 = crop destroyed) for crop safety
(1-9 (1 = complete control, 9 = no control) for weeds

The results of the three sites where seed yields were taken are given in Table 2. At the two white clover sites with severe weed infestation carbetamide increased seed yield compared to the unsprayed controls.

Table 2

Effect of carbetamide on clover seed yield
(3 user-applied unreplicated trials)

Harvested August 1973 | Plot size approx. ¼-acre

Dose of Carbetamide lb a.i./ac	Time of Application	Parham, Suffolk lb/ac	%	Comberton, Cambs lb/ac	%	Parham, Suffolk lb/ac	%
		Seed yield and % increase over control					
2.1	Nov/Dec 1972	684	74	736	32	436	5
2.1	Feb 1973	748	91	716	29	411	0
4.2	Nov/Dec 1972	660	69	-	-	-	-
4.2	Feb 1973	688	74	-	-	-	-
Unsprayed control		388	-	556	-	411	-
Major weed problem		*L.perenne* *Poa* spp.		Volunteer barley		Nil	
Clover/variety		White/S100		White/Kersey		Red/Maris Leda	

In the small-plot tolerance experiments doses of up to 4.2 lb carbetamide per acre applied in December/January were completely safe (EWRC score 1 4-weeks after spraying) to the following established clovers:

White Clovers: Blanca R.V.P., Kent Wild White, Kersey, S100 ('No mark'), S184

Red Clovers: Drewitts and Essex Broad Red, Kuhn, Montgomery, Violetta, S123

Tetraploids: Hungaropoly, Maris Leda, Red Head, Tetri

(Common sainfoin and Europa lucerne were also tolerant)

Table 3 compares carbetamide and paraquat for the restoration of the clover ontent of a long-term ley. Paraquat applied in early January gave a significantly igher seed-head count than all doses of carbetamide applied at the same time, hereas carbetamide gave higher counts when applied in late February, even at .4 lb a.i. per acre.

Table 3

Restoration of clover in a long-term ley using carbetamide

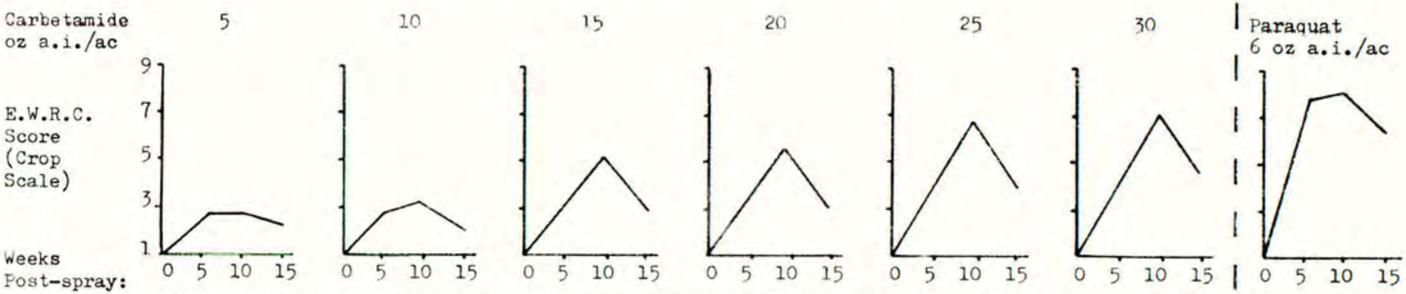
Date of pplication	Dose lb a.i./ac		Mean Height (in.)	Clover Assessment - 26.7.73 % Ground Cover	Trans-* formed Means	Seed Heads per ft^2
2. 1.73	Carbetamide	1.4	6.25	61	51.9	14.7
		2.1	5.75	62	53.3	14.0
		2.8	6.25	80	64.6	23.7
	Paraquat	0.5	7.0	95	78.3	35.0
27. 2.73	Carbetamide	1.4	7.5	71	57.8	25.8
		2.1	7.5	82	67.6	27.0
		2.8	7.25	95	78.6	28.2
	Paraquat	0.5	7.0	64	54.7	15.3
	Controls	i	3.5	35	34.02	3.67
		ii	4.0	17	17.82	1.00
.E. (treatment mean)					5.92	2.89

* Arcsine transformation

In one of the permanent pasture experiments (Shalford) Festuca rubra recovered ore quickly than Holcus lanatus and Poa pratensis at all doses of carbetamide, oth the latter were severely affected even at 5 oz a.i./ac. However, this dose id not affect Lolium perenne. At rates of 20-30 oz a.i./ac the effect on all rass species became more drastic, i.e. similar to paraquat (vide Figure 1).

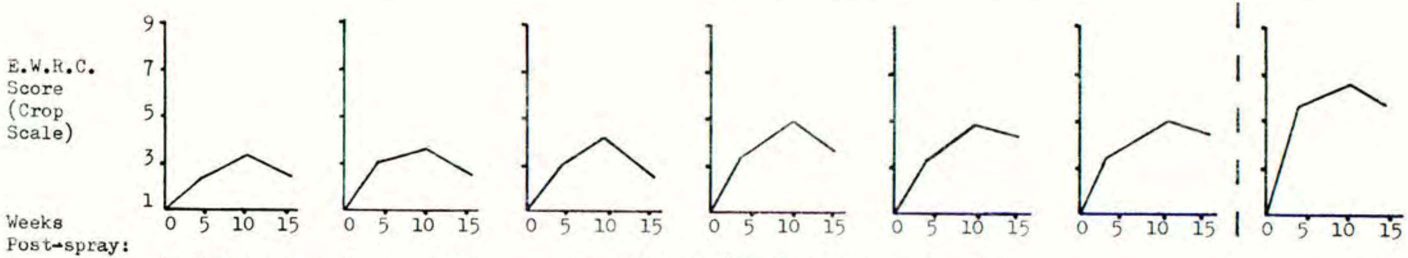
Fig. 1

The effects of carbetamide on two grass swards up to 18 weeks after January application



Site Location: Shalford, Essex.
Spray Date: 31/1/74

Composition:	
Red Fescue	26%
Yorkshire Fog	24%
Perennial Rye Grass	18%
Smooth Meadow Grass	10%
Other grasses	19%



Site Location: Ongar, Essex.
Spray Date: 2/1/74

Composition:	
Smooth Meadow Grass	31%
Yorkshire Fog	22%
Meadow Foxtail	22%
Timothy	10%
Other grasses	13%

DISCUSSION

Seed Crops

In the grower trials the grass weed problems of white and red clover seed crops were considered to fall into two main groups: in short-term or newly-established white clover crops and in red clover, arable weeds such as Alopecurus myosuroides, Avena fatua, and volunteer cereals are important, whereas in established white clover, particularly in later seed years, either indigenous perennials (e.g. Holcus and Poa spp.) may invade or sown grasses (e.g. Festuca pratensis, Lolium perenne) may become dominant. Carbetamide at 2.1 lb/ac, applied overwinter, successfully controlled these grass weed problems and gave an increased white clover seed yield of $1\frac{1}{2}$ to 3 cwt (£60 - £120 increase in gross return) per acre.

With the November applications in particular, there was a mild ingress of non-susceptible composite weeds (e.g. Senecio vulgaris, Cirsium arvense), at a few sites, so later treatment is preferable in this circumstance. February application will give equally good grass control and equivalent clover seed yield, and this timing is also preferable if low rates are to be used for turning a ley into a potential seed crop.

Pasture Improvement

There is limited evidence to show that doses of carbetamide lower than the 1.5-2.0 lb a.i./ac required for partial or total grass suppression show selectivity between productive and weed grass species. This, combined with the proven tolerance of carbetamide by clovers, could enable the chemical to be exploited for pasture renovation. Although the potential benefit has not yet been measured in terms of yield, the reported 50% short-term loss of forage caused by July treatment with dalapon (Allen 1968) might be avoided by overwintering application of carbetamide and a similar end achieved.

CONCLUSIONS

1. The value of using 2.1 lb carbetamide/ac for eliminating grass weeds in clover crops to give improved seed yield has been confirmed.

2. A dose of about 1.4 lb a.i./ac shows promise for the regulation of grasses in clover seed crops if this is the desideratum.

3. A chemical pasture improvement technique, applying carbetamide at 0.5 lb a.i./ac overwinter, warrants further investigation and development.

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CGA 24705, A NEW GRASSKILLER HERBICIDE

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Summary A new compound CGA 24705, 2-ethyl-6-methyl-N-(1'-methyl-2'-methoxyethyl)-chloroacetanilide, has been tested in an extensive field program. Its toxicological properties are favourable. It is a germination inhibitor and is mainly active on grasses. In the soil, it is moderately mobile and has a duration of activity under field conditions which prevents grasses from forming late-season infestations. It is selective in maize, soybeans, peanuts and other crops. The rates for good grass control range from 1.0 to 2.5 kg a.i./ha depending on soil and climatic conditions. CGA 24705 is considered in maize as an ideal product for combination with atrazine. This combination provides a good control of grasses and broad-leaves without any risk of carry-over.

INTRODUCTION

The long-term widespread use of one herbicide for many years may create new weed problems in a crop. For example, the long-term use of atrazine has given rise to the following problems in maize:

- The original flora dominated by annual broadleaved weeds in this crop has been effectively controlled by atrazine. Generally, 1 kg a.i./ha gives a good control of these weeds but insufficient control of grasses such as *Digitaria* spp., *Setaria* spp. and *Echinochloa* spp.. Therefore, a high proportion of maize fields has been invaded by these species.

- An increase to a dosage rate of 2 - 4 kg a.i./ha, effective against these grass species, is often only possible if 2 years of maize cropping is foreseen, since a triazine-sensitive crop of the next year can be damaged by carry-over.

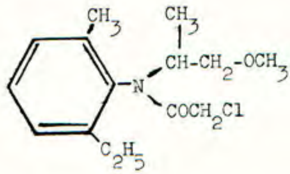
In several other crops, similar problems with many compounds have occurred. The specific problems with atrazine may serve as an example to show that the weed spectrum of various compounds needs to be enlarged by combination with another chemical. The new compound CGA 24705 has been found to be a useful partner for various standard herbicides in different crops. It is predominantly a grasskiller, to combat and counteract the development of grass infestations.

CHEMISTRY AND SAFETY ASPECTS

Chemical and physical properties

The pure active ingredient of this chloroacetanilide herbicide is a colourless liquid with a boiling point of 100°C at 0.001 mm Hg. The solubility in water is

530 ppm and the vapour pressure 1.3 x 10^{-5} mm Hg, both at 20°C.



2-ethyl-6-methyl-N-(1'-methyl-
2'-methoxyethyl)-chloroacetanilide

($C_{15}H_{22}Cl\ NO_2$: molecular weight 283.8)

Emulsifiable concentrates of up to 800g of CGA 24705 per litre have been prepared. CGA 24705 has been combined with atrazine in wettable powder and flowable formulations.

Safety aspects

CGA 24705 is safe to handle (acute oral LD50 rat, 2780 mg/kg; acute dermal rat, >3170 mg/kg; only slight skin irritation but no eye irritation with rabbits). In sub-chronic feeding studies with rats and dogs, no negative toxicological observations were made. When radio-active labelled material was administered to rats, it was rapidly and efficiently excreted. In plants CGA 24705 was also relatively quickly metabolized; no residues of the product were found in grain nor in the green parts of maize (limit of detection 0.04 ppm). In laboratory soil studies, CGA 24705 showed a half life of approximately 26 days.

SOIL BEHAVIOUR OF CGA 24705

Leaching behaviour

The leaching behaviour was tested according to the method of Gerber et al. (1970) using a soil thick-layer chromatographic method and a bioassay to spot the herbicides. Different soils have been used and the leaching index for these soils has been determined (Table 1).

Table 1

Leachability of CGA 24705 on 5 different soil types

Country	Soil type or locality	o.m. %	Clay %	Leaching index
Switzerland	Möhlin	3.8	14	6
Austria	degraded chernozem	4.3	13	7
France	Pau	9.9	15	4
USA	Iowa	5.0	13	5
Switzerland	Evouettes	3.1	9	9

The leaching figures produced by this standard test must be considered as relative figures, since many environmental factors influence the actual result in the field. The results demonstrate clearly that CGA 24705 has only a low to moderate leachability. Compared to the alachlor, CGA 24705 shows about the same mobility. Compared to atrazine, its mobility is distinctly lower.

These results show also that the leaching indices obtained follow the general relation that the higher the content of organic matter of a soil, the lower is the mobility of a herbicide in that soil.

Dissipation and long-term activity of CGA 24705

The dissipation of the compound was tested by a standard method designed to determine the persistence of compounds under laboratory conditions. Samples taken after various time intervals are examined by bioassay which indicated the speed of dissipation under the conditions used: moisture content 50% field capacity, temperature 22°C, soil from Möhlin with 3.8% o.m., pH (KCl) 6.8, 14% clay, 22% silt, 64% sand. The results of this dissipation test are summarized in Table 2.

Table 2

Dissipation of CGA 24705 and alachlor in Möhlin soil in days

Herbicide	50% dissipation after days	75% dissipation after days
CGA 24705	26	55
Alachlor	8	22

The results of Table 2 show a markedly slower dissipation of CGA 24705 than of alachlor. However, the dissipation of CGA 24705 is considered rapid enough not to leave any residues which might cause carry-over problems in the field.

For comparison purposes, it may be added that under very similar test conditions, atrazine, trifluralin and diuron exhibited 50% dissipation in 60, 100 and 80 days respectively.

An additional experiment was laid down in the greenhouse to verify the relative long-term activites of CGA 24705 and alachlor. Herbicides were applied pre-emergence onto soil-filled seed trays and seeds of Setaria italica were sown after various time intervals. Plant fresh weights were recorded from each sowing after 4 weeks' growth. Test conditions were: 22°C, alternating soil moisture by watering as required, unsterilized Möhlin soil. The results shown in Table 3 demonstrate the longer-lasting effectiveness of CGA 24705 compared with alachlor under greenhouse conditions.

The dissipation times obtained in the two tests are not strictly comparable, since the test conditions were very different. In the first test, the compound was intimately mixed with the soil, whereas in the other test a normal pre-emergence application was made. In addition, in the first test the soil moisture was constant, in contrast to normal wetting and drying cycles in the second test. Thus the dissipation of both products was slower under the conditions of the second test.

Table 3

Duration of activity of CGA 24705 and alachlor indicated by growth inhibition of test plants sown at various intervals after herbicide application

Product	Rate kg a.i./ha	Growth as % of control when sown after weeks 0	1	2	3	4	5	6	7	8	9	10
CGA 24705	4	0	0	0	0	0	0	0	0	0	40	80
	2	0	0	0	0	0	0	10	10	40	75	95
	1	0	0	25	25	25	25	40	40	85	100	100
	0.5	10	10	40	40	40	45	90	100	100	100	100
Alachlor	4	0	0	10	25	25	40	65	100	100	100	100
	2	0	0	10	60	60	75	100	100	100	100	100
	1	0	10	10	100	100	100	100	100	100	100	100
	0.5	10	20	75	100	100	100	100	100	100	100	100

Site of uptake

Results of placement studies carried out according to the charcoal barrier method of Gray & Weierich (1969) have clearly shown that the shoot is the predominant site of uptake of CGA 24705 in the various grasses examined.

Grass weeds are highly sensitive to low concentrations of herbicides in the shoo zone while much higher concentrations in the root zone cause only limited stunting effects. The activity through shoot uptake is also much faster than that through roo uptake.

Cotton and soybean, however, show a contrary response to CGA 24705 placed in the shoot and root zones. Both crops are more sensitive to root exposure. This fact explains to some extent the selective effect of grasskillers in broadleaved crops. The cotyledons protect the emerging plant from contact with the herbicide. On the other hand, the selectivity in maize is due to the size of the germinating seed grain and the placement selectivity of the product as well as the ability of this species to metabolize the herbicide to a certain extent.

Effect of temperature and soil moisture on the activity

The temperature, as demonstrated in Table 4, influences the activity of CGA 2470 to a great extent.

Table 4

The effect of temperature on the activity of CGA 24705 against Setaria italica

Temperature °C	Dosage in kg a.i./ha causing 80% growth reduction
18	0.60
22	0.30
29	0.15

The general statement that herbicide activity increases with increasing soil moisture can also be accepted for CGA 24705. The dependence on soil moisture can clearly be seen, based on the results of Table 5. The herbicide was incorporated in a Möhlin soil (for composition see Table 1) and the concentration for 80% growth reduction was determined.

Table 5

Activity of CGA 24705 against Setaria italica at different moisture levels after incorporated treatments

Soil moisture as % of field capacity	Concentration of herbicide in ppm causing 80% growth reduction
45	2.6
65	2.0
90	0.92

FIELD RESULTS

Size of the test program

CGA 24705 has been tested during 2 seasons each in the northern and the southern hemispheres in a very widespread program which included 14 countries. The most important crops and weeds have been covered. Furthermore, the behaviour of CGA 24705 under adverse conditions in respect to soils and climate has also been investigated, so that the picture which can be drawn of its performance is quite a complete one.

Crop tolerance

Maize: Maize tolerated CGA 24705 alone in all types of soils, including very light ones, at the rate of 3 kg a.i./ha and more. However, some slight phytotoxicity has been observed in soils with low organic matter contents ($<0.5\%$) where high rainfall immediately after sowing was followed by extremely high temperatures. The standard acetanilide caused similar signs of phytotoxicity under these conditions.

Soybeans: Up to 4 kg a.i./ha and more of CGA 24705 have been well tolerated by soybeans. This rate is also safe in the extremely difficult conditions of light soils with high rainfall. The excellent performance and crop tolerance of CGA 24705 under these very adverse conditions demonstrate its high selectivity in soybeans.

Peanuts: The tolerance to this crop has been excellent up to 4 kg a.i./ha.

Crops still under investigation: sugarbeets, alfalfa, sunflowers, rape, various vegetables.

Cereals, rice, sorghum and cotton: In a number of tests in these crops, the compound has shown only marginal safety. Unless further tests under different conditions are completed, its use cannot be recommended.

Activity

The following list shows weed species and the rates needed to control them consistently in a medium soil. The rate for consistent control in light soils is lower, but the rate for very adsorptive soils (more than 6% o.m.) could be higher.

Table 6

Activity spectrum of CGA 24705

Grasses and sedges	kg a.i./ha
Cenchrus spp.	2.5 - 3.0
Echinochloa crus-galli	1.0 - 2.0
Eleusine indica	1.0
Digitaria spp.	1.0 - 2.0
Panicum dichotomiflorum	1.0 - 1.5
Panicum texanum	1.0 - 2.0
Setaria glauca	1.0 - 2.0
Setaria verticillata	1.25- 2.5
Setaria viridis	1.25- 2.0
Setaria faberii	1.25- 2.0
Cyperus esculentus	2.0 - 3.0
Cyperus rotundus	> 3.0
Broadleaved weeds	**kg a.i./ha**
Amaranthus retroflexus	2 - 4
Portulaca oleracea	2 - 4
Fumaria officinalis	2 - 4
Stellaria media	2 - 4
Mollugo verticillata	2 - 4
Polygonum spp.	> 3
Chenopodium album	3
Ipomoea spp.	> 4
Xanthium pensylvanicum	> 4
Ambrosia artemisiifolia	2 - 4
Abutilon theophrasti	2 - 4

The results of Table 6 show clearly that CGA 24705 as a germination inhibitor is specifically active against grasses, whereas the control of broadleaved weeds is not consistent and depends to a great extent on the climatic and soil conditions. Therefore, CGA 24705 needs in most cases a partner herbicide to complement its spectrum by controlling broadleaved weeds. Suitable herbicides for combinations are triazines or ureas, according to the crop.

A very important property of CGA 24705 is its duration of activity. This is clearly demonstrated by the practical examples in Table 7.

The results of Table 7 and many other results lead to the conclusion that the longer-lasting effect of CGA 24705 found under laboratory conditions can be confirmed under field conditions.

CGA 24705 has also performed very well against Cyperus esculentus. This difficult-to-control perennial weed can be controlled with rates of 2 kg a.i./ha or more. In light and medium mineral soils, 2 - 3 kg a.i./ha gives a good control, whereas in adsorptive soils (chernozems) 3 - 4 kg a.i./ha are needed. In favourable conditions CGA 24705 gives 100% control and complete eradication of Cyperus esculentus. That all the subsurface parts of this weed have been eliminated can be observed very often in the following year when no regrowth of shoots occurs in treated plots.

Table 7

Trial results and duration of activity in different countries and conditions. Score EWRC* system or % activity (Texas)

Product	Assessment	Months after application	kg a.i./ha 1	2	3	kg a.i./ha 1	2	Locality and conditions
				Digitaria sang.				
CGA 24705	1	1	-	6	4	-	-	Hoertendorf
	2	2.5	-	8	4	-	-	Austria
	3	4.5	-	8	4	-	-	Highly adsorptive
Alachlor	1	1	-	6	6	-	-	soil and
	2	2.5	-	9	7	-	-	dry conditions
	3	4.5	-	9	9	-	-	
				Echinochloa cg.		Panicum dich.		
CGA 24705	1	1.5	1	1	1	4	2	Mantova
	2	3	4	1	1	6	3	Italy
Alachlor	1	1.5	4	2	2	3	2	Sandy loam
	2	3	9	7	6	6	5	
				Setaria vert.				
CGA 24705	1	2	5	2	2	-	-	Neuvy en Beauce
	2	3.5	6	3	2	-	-	France
Alachlor	1	2	6	6	3	-	-	Silty clay loam
	2	3.5	8	8	6	-	-	
				Echinochloa cg.				
CGA 24705	1	1	80	100	-	-	-	Southern Texas
	2	1.5	85	95	-	-	-	USA
	3	2	77	92	-	-	-	
	4	3	80	92	-	-	-	Irrigated
Alachlor	1	1	93	100	-	-	-	condition
	2	1.5	70	90	-	-	-	sandy clay loam
	3	2	53	82	-	-	-	
	4	3	30	75	-	-	-	

* 1 = 100% activity, 9 = no control of weeds, 4 = sufficient control for practical purposes

OUTLOOK AND FUTURE PRACTICAL USE OF CGA 24705

CGA 24705, with its specific activity on grasses, will be used mainly in combination with products which are more active on broadleaves in the crops shown in Table 8.

Table 8

Combination partners for CGA 24705 in different crops

Crop	Rate of CGA 24705 in kg a.i./ha	Combination partner	Rate in kg a.i./ha
Maize	1 - 2	atrazine	0.75 - 1.5
Soybeans	1 - 2	chlorbromuron	1.5 - 2.0
		prometryne	0.75 - 1.0
Peanuts	1 - 2	terbutryne	1.5 - 2.0
Sunflower	1 - 2	prometryne	1.0 - 2.0

For the time being, ready-made formulations are available for maize in the form of flowables at ratios of atrazine to CGA 24705 of 1:1, 1:1.5 and 1:2. The other combinations have to be applied as tank mixes for the moment.

The choice of the optimum combination and ratio is determined by

- the soil type
- the differences in weed spectrum and the density of infestation
- the carry-over risks, especially with atrazine.

With the new combinations, the atrazine rate can be reduced to the level needed for broadleaved weed control. As a consequence, the risk of carry-over is eliminated.

CONCLUSIONS

The combinations of CGA 24705 with various herbicides are able to solve many different problems. Thus, in the combination with atrazine, the long duration of grass activity of CGA 24705, together with the crop competition, ensures season-long weed control. Grasses which germinate late in the season, e.g. Digitaria sanguinalis can be kept out.

Generally, CGA 24705 as a partner complements the spectrum of activity of the most important Ciba-Geigy herbicides and of some other herbicides. Its high grass activity combined with an ideal duration of activity enables CGA 24705 to be a universal partner for the herbicides in the aforementioned crops.

Acknowledgements

The authors are much indebted to Mr. K. Maag and Mr. C. Capponi for their contribution in the development of this compound and to all our colleagues in the Ciba-Geigy group companies. The help of Mr. D.H. Green in correcting the English translation is very much appreciated.

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EL-161, A NEW PRE-PLANT INCORPORATED HERBICIDE FOR CONTROL OF GRASS AND DICOTYLEDONOUS WEEDS IN COTTON

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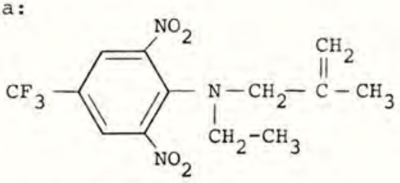
Summary Two years of field trials in Greece, Spain and Turkey have shown that EL-161 (N-ethyl-N-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoromethyl)benzenamine) pre-plant incorporated at 1.0 - 1.25 kg a.i./ha provides sufficient initial and residual control of several broad-leaf, including *Solanum nigrum*, and annual grass weeds At tne rates needed for weed control, EL-161 is sufficiently selective to cotton while a slight stand reduction can be associated with the use of higher rates.

INTRODUCTION

EL-161 is the Lilly Code Number for N-ethyl-N-(2-methyl-2-propenyl)-2,6-dinitro-4-(trifluoromethyl)benzenamine, a new selective pre-emergence herbicide developed by Eli Lilly and Company for weed control in cotton, soybeans and other crops. The generic name ethalfluralin has been proposed.

The chemical, physical and toxicological properties of this new compound are summarized below:

Structural formula:



Empirical formula: $C_{13}H_{14}F_3N_3O_4$ M.W. 333.26

Pure EL-161 is a yellow-orange crystalline solid which melts at 55-56°C. It is readily soluble in organic solvents and its solubility in water is 0.2 ppm at pH 7 and 25°C. EL-161 has a vapour pressure of 8.2 x 10^{-5} mm Hg when measured by jet effusion.

EL-161 is relatively safe for the user and, when applied as recommended, should result in no hazard to domestic animals or wildlife. The LD_{50} for mice and rats is greater than 10 g/kg and an LD_0 greater than 200 mg/kg for dogs and cats has been observed. Treatment with 2 g/kg on rabbit skin produced only very slight irritation without systemic effect. Rats appeared normal after exposure for 1 hour to inhalation at a concentration of 0.028 mg/litre of air. There appear to be no significant amounts of radioactivity translocated to crops grown in soil treated with ^{14}C-labelled EL-161.

In this paper results of two years of field trials with EL-161 for weed control in cotton are summarized.

METHOD AND MATERIALS

In 1973 twelve replicated small-scale experiments were established in Greece, Spain and Turkey. In 1974 26 small-scale replicated experiments were established in Greece, Spain, Syria and Turkey along with 96 large-scale field trials scattered throughout the main cotton areas in Greece and Spain.

Plots in small-scale replicated experiments ranged from 25 to 50m^2 and the treatments, laid down in a randomized block design, were replicated 4-6 times.

Plot size in large-scale field trials varied between approximately 1000 and 5000m^2 and treatments included in them were replicated twice.

A variety of equipment has been used to spray and incorporate the chemical in both small-scale experiments and large-scale trials.

Herbicidal efficacy as percent weed control was directly visually assessed in treated plots and related to weed counts in untreated controls. Selectivity to cotton was evaluated by stand counts and vigour ratings. Cotton yield measurement was carried out in 3 of the 1973 trials.

Duncan's multiple range test has been used in the statistical analysis of the data.

RESULTS AND DISCUSSION

Herbicidal efficacy

Early results from the 1973 small-scale replicated experiments indicate that, in the hot and dry climatic conditions usually prevailing in southern Europe in spring, incorporation of EL-161 is needed to secure sufficient herbicidal efficacy. This is clearly illustrated in Fig. 1.

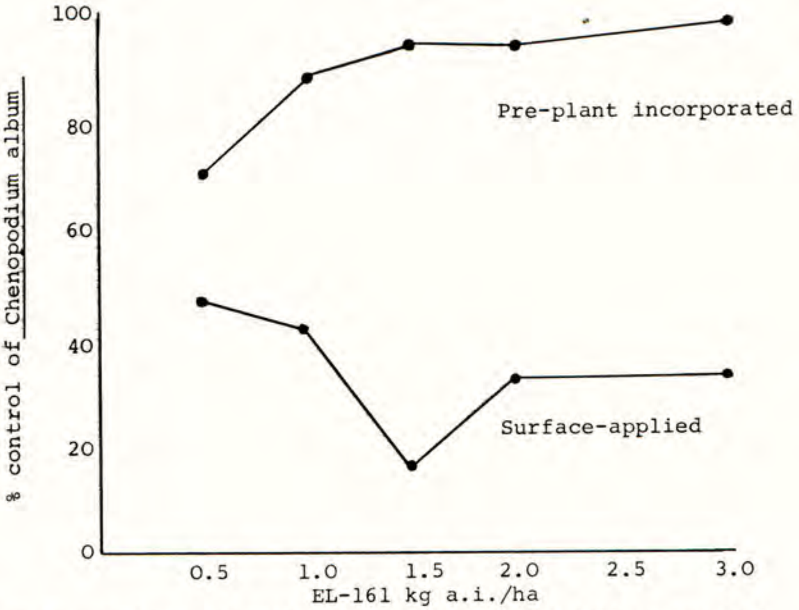


Fig. 1. Effect of soil incorporation of EL-161 on control of *Chenopodium album* (ave. of 4 experiments)

In Table 1 herbicidal efficacy data from both 1973 and 1974 are summarized. The data show that EL-161 at 1.0 kg a.i./ha provides very good to excellent control of several of the most important broadleaves and annual grasses occurring in cotton fields. More than 90% control was obtained of the annual grass species. Of the broadleaf species encountered, EL-161 provided in excess of 90% control of all species except for *Polygonum convolvulus*, *Ranunculus arvensis*, *Solanum nigrum* and *Tribulus terrestris*.

TABLE 1
Percent control of various species with EL-161 at 1 kg a.i./ha

	% control	Number of trials
Broadleaves:		
Amaranthus retroflexus	93	4
Amaranthus spp.	98	9
Chenopodium album	93	11
Chenopodium spp.	98	2
Polygonum convolvulus	68	3
Portulaca oleracea	98	4
Ranunculus arvensis	73	1
Solanum nigrum	86	75
Tribulus terrestris	78	1
Grasses:		
Echinochloa crusgalli	94	9
Setaria verticillata	90	1
Setaria spp.	99	2

Solanum nigrum has been the most prevalent weed species in the 1974 large-scale trials. Data summarized in Table 2 show that commercially acceptable control of this important species is secured in most cases with 1 kg a.i./ha of EL-161. However, an increase of the herbicide rate to 1.25 kg a.i./ha further increased the control level.

TABLE 2
Summarized data from large-scale trials for percent control of Solanum nigrum

EL-161 kg a.i./ha	Number of trials within range 60-80%	80-89%	90-100%	Total trials	Mean % control
1.0	9	16	24	49	85.5
1.25	3	10	37	50	91.7

The residual activity of EL-161 at 1.0 kg a.i./ha has proved sufficient for season-long control of susceptible weeds in cotton fields. Data presented in Fig. 2 show that the initially satisfactory control of *Echinochloa crusgalli* with 0.5 kg a.i./ha of EL-161 breaks down later in the season, however with rates of 1.0 kg a.i./ha and higher, control remained practically unimpaired throughout the season.

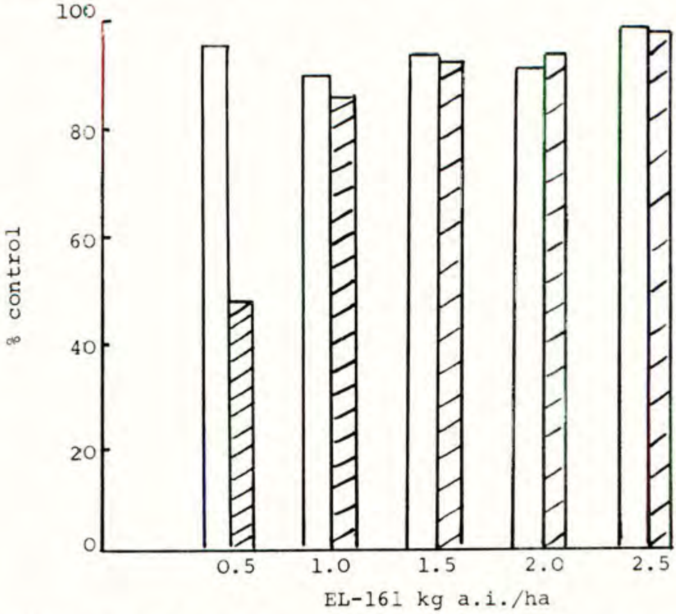


Fig. 2. Initial and residual control of *Echinochloa crusgalli* with EL-161 (ave. of 3 experiments). Open columns, assessed 18-27 days after treatment; hatched columns, 115-135 days after treatment.

In conclusion, herbicidal efficacy data show that when pre-plant incorporated at 1.0 - 1.25 kg a.i./ha, EL-161 provides satisfactory initial and residual control of several important weed species.

Selectivity to cotton

Summarized data of cotton stand counts in 16 small-scale replicated experiments are presented in Fig. 3. The data show that a slight reduction of cotton stand can be noticed at 1.5 kg a.i./ha of EL-161 and that this reduction increases almost linearly with EL-161 rates. Field observations have shown that the stand reduction was usually associated with rather severe damping-off caused by either *Rhizoctonia solani* or Phycomycetes.

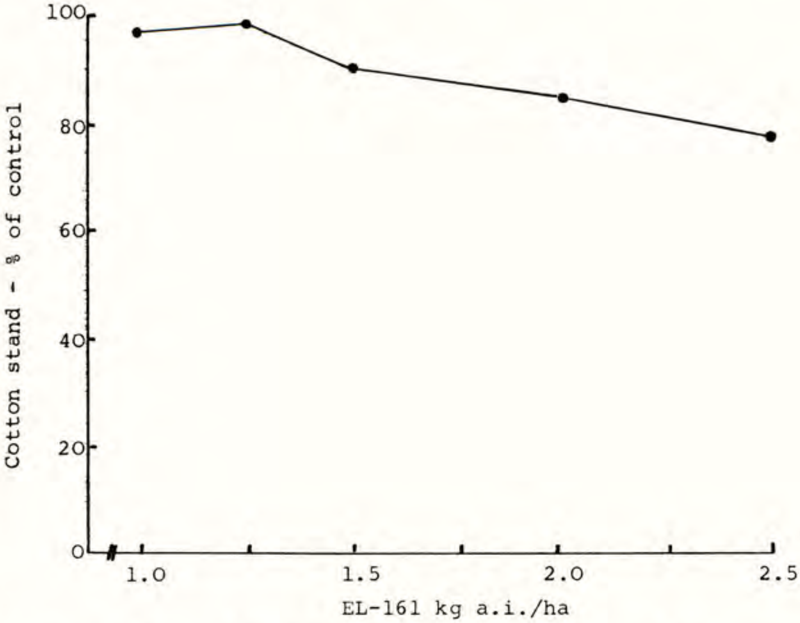


Fig. 3. Effect of EL-161 on cotton stand (ave. of 16 experiments)

Cotton vigour ratings made 30 - 40 days after cotton planting and grouped in Table 3 show that the growth of the crop is not significantly impaired by EL-161 even at rates much higher than those needed for adequate weed control.

TABLE 3
Grouped data for cotton vigour

EL-161 kg a.i./ha	Number of trials within vigour range			
	<80%	80-90%	>90%	Total
0.50	-	-	3	3
0.75	-	-	3	3
1.00	1	2	63	66
1.25	-	5	59	64
1.50	-	-	12	12
2.00	-	2	10	12
2.50	-	3	2	5
3.00	-	-	3	3
Total	1	12	155	168

Finally, yield data collected in 3 of the 1973 small-scale replicated experiments conducted in Turkey are presented in Table 4 and they show that no negative yield effect occurs even at high EL-161 rates.

TABLE 4
Yield of EL-161 treated cotton as % of yield in untreated controls from 1973 experiments in Turkey

EL-161 kg a.i./ha	Location and Soil Texture		
	IZMIR Sandy loam	MENEMEN clay loam	FOCA Sandy loam
0.5	109.3 ab*	101.5 bcde	88.7 e
1.0	115.8 ab	110.4 abc	116.4 bcd
1.5	125.1 a	114.1 ab	120.7 bcd
2.0	115.0 ab	122.5 a	127.0 abc
3.0	117.2 ab	113.5 ab	133.9 ab
Control (untreated)	100.0 b	100.0 cde	100.0 de

* Means followed by different letters differ significantly according to Duncan's multiple range test , at the 5% level.

In conclusion, selectivity data show that at rates needed to secure adequate weed control, EL-161 is sufficiently safe to cotton.

Proceedings 12th British Weed Control Conference (1974)

HERBICIDAL ACTIVITY AND THE PROSPECTS OF USE OF 23,465 RP, A NEW HERBICIDE IN THE GROUP OF UREIDOPHENYLOXADIAZOLONES

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Summary 23,465 RP or 2-tert butyl-4-[2-chloro-4-(3,3-dimethylureido) phenyl]1,3,4-oxadiazolin-5-one, is a new herbicide with pre- and post-emergence activity which has maximum effect under humid conditions. The more sensitive broad-leaved weeds (Galium aparine, Stellaria media) are controlled at doses of 500-750 g/ha. At 1 kg/ha, 23,465 RP is active against most annual dicotyledons, with the exception of a few cruciferous weeds, and on certain grasses. At 2 kg/ha, it controls temperate annual grasses, and, at 4 kg/ha, some perennial grasses. Because the field activity is very persistent at 4 kg/ha and above, it is envisaged that 23,465 RP may be used for total weed control.

The post-emergence selectivity of 23,465 RP towards different crops varies with dose: cereals tolerate 500-750 g/ha, lucerne, at the dormant stage, 750-1000 g/ha, and winter rape 750-1500 g/ha. At these doses, 23,465 RP does not give complete control of grasses, but on lucerne and winter rape a mixture of 23,465 RP and carbetamide has given very promising results as a complete herbicide.

23,465 RP is also well tolerated by plantation crops such as sugar cane and rubber which are unaffected by pre-emergence applications of 2 kg/ha and 4 kg/ha respectively.

Résumé Le 23,465 RP ou tertiobutyl-2[chloro-2 (diméthyl-3,3 uréîdo)-4 phényl]-4 oxadiazolone-1,3,4 one-5, est un nouvel herbicide actif en pré et post-levée des mauvaises herbes, qui donne son efficacité maximale en période humide (automne - hiver en Europe).

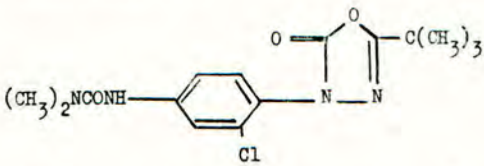
Son champ d'activité varie en fonction des doses : ainsi les dicotylédones les plus sensibles sont détruites dès la dose de 500 à 750 g/ha (Galium aparine, Stellaria media). A 1 kg/ha, le 23,465 RP est actif sur la plupart des dicotyledones annuelles, quelques crucifères exceptées, et sur certains graminées. A 2 kg/ha, il permet de maîtriser les graminées annuelles et à 4 kg/ha les graminées vivaces (Agropyron repens). C'est en raison de ce champ d'activité très étendu qu'il est envisagé d'utilider le 23,465 RP pour le desherbage total.

La sélectivité du 23,465 RP,en post-levée des différentes cultures, varie avec les doses : les céréa;es d'hiver tolèrent 500 à 750 g/ha, la luzerne, en repos végétatif, 750 à 1000 g/ha, le colza d'hiver 750 à 1500 g/ha. A ces doses, le 23,465 RP doit être complété par un graminicide : pour la luzerne et le colza d'hiver, l'association 23,465 RP + carbétamide a donné des résultats très prometteurs.

Le 23,465 RP est également bien toléré par un certain nombre de cultures tropicales notamment la canne à sucre qui résiste en pré-levée à la dose de 2 kg/ha, et l'hévéa qui supporte 4 kg/ha.

INTRODUCTION

Further studies on the oxadiazon family of compounds by the Research Group of Société des Usines Chimiques Rhône-Poulenc have led to the preparation of new derivatives, the ureidophenyloxadiazolones. The results of laboratory and greenhouse tests have recently been published (Desmoras, et al 1974) for the most interesting of these : 23,465 RP.



2-tert butyl-4-[2-chloro-4-(3,3-dimethylureido)phenyl]1,3,4-oxadiazolin-5-one.

The field evaluation of 23,465 RP started in 1970 and included multi-crop screening tests, in spring and autumn-sown crops. From these tests, several possible uses emerged and the following field studies have subsequently been carried out: weed control in winter cereals, winter-sown rapeseed, established lucerne and, more recently, industrial weed control and weed control in tropical plantation crops.

METHOD AND MATERIALS

The formulation used in all the field trials was a 50% w/w wettable powder and doses are given as g or kg/ha a.i.

Application volumes varied from 500 l/ha in field crops to 1000 l/ha for industrial weed control. Comparisons were made with existing herbicide treatments.

In the tests on winter wheat, selectivity was assessed by counting the numbers of seed heads per square metre and by taking grain yield, the results being expressed as percentages of the control.

The herbicidal activity on blackgrass (Alopecurus myosuroides) as well as on broad-leaved weeds was determined during May, i.e. about 5-6 months after the autumn treatments and 1-3 months after treatments at the end of winter or in spring.

Similarly, for winter rapeseed, weed control observations were carried out at the beginning of stem elongation of the rape. These observations, therefore, take account of the persistence, as well as the initial activity of 23,465 RP. For rapeseed, plant populations and yield are expressed as percentages of the control.

On lucerne, the fresh weight yields have been taken from three cuts and are reported as tonnes per hectare. Weed control assessments were limited to the first cut at the end of May.

In all the tests, the plots were arranged in randomised blocks, to allow for statistical analysis of the results.

For the industrial weed control trials activity and persistence were assessed by visual scores (0 = no control, 10 = complete kill). In other tests, the activity was recorded as coefficient of efficacy, calculated from the weight of weeds :

$$\text{coeff. effic.} = \frac{\text{control} - \text{treated}}{\text{control}} \times 100$$

RESULTS

Table 1

Susceptibility of weeds to 23,465 RP and 23,465 RP + carbetamide

	Pre-emergence 23,465 RP (g/ha)			Post-emergence 23,465 RP (g/ha)			23,465 RP + carbetamide (g/ha)	
	500	1000	2000	500	1000	2000	500 + 750	1000 + 1500
Agropyron repens (p)	R*	R	MR	R	R	MS	-	-
Alopecurus myosuroides	MR	MS	S	MR	MS	S	S	S
Apera spica-venti	-	-	-	MS	S	S	S	S
Avena fatua	R	R	MS	MR	MR	MS	MS	S
Hordeum sp.	R	MR	MS	R	MR	MS	MS	S
Lolium italicum	-	-	-	MR	MS	S	-	-
Poa annua	S	S	S	MS	S	S	S	S
Anagallis arvensis	-	-	-	S	S	S	-	-
Anthemis cotula	MS	S	S	R	MS	S	-	-
Capsella bursa-pastoris	MS	S	S	MS	S	S	MS	S
Fumaria officinalis	-	-	-	S	S	S	S	S
Galium aparine	MR	MS	S	MS	S	S	MS	S
Heracleum sphondylium (p)	R	R	R	R	R	R	-	-
Lamium amplexicaule	S	S	S	S	S	S	S	S
Lithospermum arvense	-	-	-	MR	S	S	MR	S
Matricaria inodora	R	S	S	MS	S	S	S	S
Myosotis sp.	MS	S	S	MS	S	S	MS	S
Papaver rhoeas	S	S	S	MS	S	S	MS	S
Petroselinum sativum	R	R	MR	R	MR	MS	-	-
Polygonum aviculare	S	S	S	S	S	S	-	-
Polygonum convolvulus	S	S	S	MR	MS	S	-	-
Polygonum persicaria	S	S	S	MS	S	S	-	-
Polygonum lapathifolium	-	-	-	MS	S	S	-	-
Raphanus raphanistrum	R	R	MR	R	MR	MR	-	-
Scleranthus annuus	S	S	S	MS	S	S	MS	S
Senecio vulgaris	MS	S	S	MR	S	S	MS	S
Sinapis arvensis	R	R	MR	R	MR	MS	MR	MS
Spergula arvensis	S	S	S	S	S	S	-	-
Stellaria media	MS	S	S	MR	MS	S	MS	S
Taraxacum officinale (p)	R	R	R	R	R	R	-	-
Veronica agrestis	S	S	S	S	S	S	S	S
Veronica hederifolia	S	S	S	S	S	S	S	S
Veronica persica	-	-	-	S	S	S	S	S
Viola tricolor	R	MS	MS	MS	S	S	MS	S

* R = Resistant; MR = Moderately resistant; MS = Moderately susceptible; S = Susceptible; -, No information; (p), perennials

Table 2

Effect of 23,465 RP applied pre- and post-emergence on winter wheat ears (No. as % of control) and yield (% of control) and on blackgrass and dicotyledons (% kill)

Location	Stage and date of treatment		23,465 RP (g/ha) 500	1000	2000	Chlortoluron (g/ha) 1200	2400	4800
La Queue-en-Brie	Pre	Wheat ears	99	27	4	116	104	97
(Val-de-Marne)	4/11	Blackgrass	100	100	100	100	100	100
France	1970	Dicotyledons	100	100	100	97	100	100
Champlein	Post	Wheat ears	111	107	93	110	126	126
sown 31/10/70	23/2	Blackgrass	98	98	100	97	100	100
	1971	Dicotyledons	77	100	100	82	100	100
Emerainville	Pre	Wheat ears	95	50	2	132	102	105
(Seine et Marne)	2/11	Blackgrass	81	90	100	90	97	99
France	1970	Dicotyledons	12	74	93	0	0	29
Cappelle	Post	Wheat ears	130	122	123	94	134	144
sown 2/11/70	8/2	Blackgrass	52	97	100	80	82	94
	1971	Dicotyledons	82	86	99	63	80	74
Emerainville	Pre	Wheat ears	95	53	8	0	90	0
(Seine et Marne)	26/11	Wheat yield	87	66	11	0	88	0
France	1970	Dicotyledons	52	72	89	0	20	0
Cappelle	Pre	Wheat ears	107	105	84	0	99	0
sown 26/11/70	26/11	Wheat yield	91	81	46	0	93	0
	1970	Dicotyledons	87	88	97	0	60	0

General herbicidal activity

The activity of 23,465 RP is summarised by species in Table 1, based on weeds occurring in the temperate crop trials and excluding those only on the non-crop sites. 23,465 RP is active both pre- and post-emergence and its activity and range of weeds controlled are directly proportional to dose rate.

At 500 g/ha, some dicotyledons are controlled; most broad-leaved weeds are killed at 1 kg/ha and some grasses are also susceptible at this dose rate. 2 kg/ha is required to obtain satisfactory activity on most annual and perennial grasses and particularly on self-sown cereals. *Raphanus raphanistrum* and *Sinapis arvensis* are two dicotyledons showing resistance to 23,465 RP, together with the deeper-rooted *Heracleum sphondylium* and *Taraxacum officinale*.

Weed control in winter wheat

Blackgrass (*Alopecurus myosuroides*) was shown to be susceptible to 1 kg/ha of 23,465 RP but this dose rate is phytotoxic to wheat, when applied pre-emergence (Table 2). The tolerance of wheat, post-emergence, is a little better although, even in this situation, the dose should be limited to about 500 g/ha.

Table 3

Effect of 23,465 RP alone and with carbetamide on the plant population and yield (% of control) of winter rapeseed and on grasses and dicotyledons (% kill)

Location	Stage and date of treatment		23,465 RP (g/ha)			23,465 RP + carbetamide (g/ha)			Propyzamide + diuron (g/ha)
			500	1000	1500	500 +750	1000 +1500	1500 +2250	500 +1600
St-Hilaire-le-Grand (Marne) France	Pre 11/9/72	Plant numbers	98	89	64	114	92	78	-
		Yield	106	112	106	111	113	117	-
		Grasses	0	15	48	36	50	84	-
		Dicotyledons	85	98	98	83	98	99	-
Major sown : 7/9/72	Post 23/11/72	Plant numbers	95	112	109	101	104	108	94
		Yield	113	114	110	106	104	97	106
		Grasses	31	29	83	85	100	100	100
		Dicotyledons	87	99	100	84	99	100	100
St-Cyr-les-Colons (Yonne) France	Pre 13/9/72	Plant numbers	93	91	96	99	88	99	-
		Yield	103	145	140	127	140	163	-
		Grasses	0	10	34	0	47	55	-
		Dicotyledons	42	96	99	65	91	98	-
Sarepta sown : 12/9/72	Post 15/12/72	Plant numbers	104	109	112	123	109	104	119
		Yield	120	130	150	177	190	183	181
		Grasses	32	42	60	89	99	100	99
		Dicotyledons	30	97	99	62	96	99	95
Berry-Bouy (Cher) France	Pre 14/9/72	Plant numbers	93	56	26	97	82	65	-
		Yield	101	100	99	100	103	90	-
		Grasses	13	71	97	65	91	88	-
		Dicotyledons	93	99	99	94	99	100	-
Major sown: 13/9/72	Post 26/10/72	Plant numbers	112	120	110	108	111	105	109
		Yield	94	105	105	100	104	99	103
		Grasses	8	78	89	86	98	100	100
		Dicotyledons	84	97	99	81	97	99	95

Weed control in rapeseed

Pre-emergence applications of 23,465 RP at 1 kg/ha have caused severe stand reduction and a check to growth, although this phytotoxicity seems to have little permanent effect on the crop. Post-emergence applications are far better tolerated from the 4-5 leaf stage, through to the full winter dormant stage. In this latter situation, weed control of dicotyledons is excellent, but activity on grasses is rather weak, and, for this reason, a mixture of 23,465 RP and carbetamide has been examined (Table 3).

Weed control in lucerne

Application of 23,465 RP at a dose of 1 kg/ha applied in the winter of the year of seeding has shown excellent selectivity. As with rapeseed, however, the addition of a grass herbicide, such as carbetamide, has improved the spectrum of weed control (Table 4).

Table 4

Effect of 23,465 RP with and without carbetamide on lucerne yield (t/ha≁) and weeds (% kill)

Location	Date of treatment		23,465 RP (g/ha)			23,465 RP + carbetamide (g/ha)			propyzamide + diuron (g/ha)	Untreated control
			500	1000	1500	500 +750	1000 +1500	1500 +2250	1000 +1600	
	Stage I 13/12/72	1st yield*	32.1	32.7	26.7	29.0	33.2	28.1	30.0	28.3
		2nd yield*	11.4	11.9	10.9	11.5	12.4	10.2	12.5	10.8
Pontillault		3rd yield*	7.4	6.1	6.5	6.2	5.7	5.8	6.0	5.9
(Seine et Marne)		Total Yield	50.9	50.7	44.1	46.7	51.3	44.1	48.5	45.0
France		% weed kill	4	39	72	53	83	95	93	-
Europe sown : 18/3/72	Stage II 15/2/73	1st yield*	30.2	29.1	26.3	29.1	30.2	27.5	29.9	28.3
		2nd yield*	10.9	11.5	11.8	11.4	12.1	10.9	11.2	10.8
		3rd yield*	7.5	5.3	5.4	6.7	5.0	5.3	6.7	5.9
		Total Yield	48.6	45.9	43.5	47.2	47.3	43.7	47.8	45.0
		% weed kill	42	67	95	62	89	96	100	-
	Stage I 11/12/72	1st yield*	24.6	24.4	25.7	30.0	28.0	27.2	27.2	21.0
Betheniville		2nd yield*	13.6	13.5	13.2	13.6	13.5	12.7	14.3	12.5
(Marne) France		3rd yield*	11.8	13.1	12.5	12.3	12.3	12.4	12.7	12.6
		Total Yield	50.0	51.0	51.4	55.9	53.8	52.3	54.2	46.1
Europe		% weed kill	0	77	91	79	100	100	100	-
sown: April 1972	Stage II 16/2/73	1st yield*	26.4	25.8	23.9	26.3	26.6	23.0	23.2	21.0
		2nd yield*	13.7	12.6	12.5	13.3	12.5	12.2	12.1	12.5
		3rd yield*	12.6	12.4	12.1	12.6	12.5	12.1	12.7	12.6
		Total Yield	52.7	50.8	48.5	52.2	51.6	47.3	48.0	46.1
		% weed kill	19	91	94	68	96	100	100	-

≁ t/ha = tonnes/hectare

* 1st, 2nd and 3rd yields are three consecutive cuts in 1 year to give the total yield for that year.

Table 5

Effect of 23,465 RP applied for industrial weed control

Location and date of treatment	Herbicide	kg/ha	Score (0, no activity - 10, complete kill) Months after treatment 1	2	6	12	18
St-Fons	23,465 RP	4	-	7.5	8.8	7.2	3.5
(Rhône) France	23,465 RP	8	-	7.6	10.0	9.7	6.0
23/3/72	Diuron	8	-	8.4	9.2	7.2	4.5
Feyzin	23,465 RP	4	5.6	-	5.5	-	-
(Rhône) France	23,465 RP	8	8.0	-	7.2	-	-
5/2/73	Diuron	8	4.3	-	4.2	-	-
St-Maurice-de-Beynost	23,465 RP	4	-	8.0	5.5	-	7.3*
(Ain) France	23,465 RP	8	-	9.0	8.9	-	9.1*
6/2/73, 13/1/74	Diuron	8	-	6.5	2.3	-	5.5*

* Results 18 months after first treatment and 5 months after second treatment.

Dose rates up to 8 kg/ha of 23,465 RP have shown excellent efficacy and persistence when compared with standard materials, such as diuron. In this situation, crucifers and legumes (sainfoin, vetch, etc.,) appear to be the most resistant species (Table 5).

Table 6

Relative tolerance of tropical crops to 23,465 RP

Crop	Pre-emergence (kg/ha) 0.5	1.0	2.0	4.0	6.0	Post-emergence (kg/ha) 0.5	1.0	2.0	4.0	6.0
Cotton	R	R	R	-	-	R	R	R	-	-
Soybean	R	R	R	-	-	R	R	-	-	-
Sorghum	-	-	-	-	-	R	R	-	-	-
Sunflower	MR	S	S	S	-	R	R	S	S	-
Sugar cane	R	R	R	R	-	R	R	R	S	-
Peanut	R	R	R	-	-	R	R	R	-	-
Rubber⁄	-	-	-	-	-	-	-	S	S	-
Oil Palm	-	-	-	-	-	R	R	MR	S	S
Rice	S	S	S	S	-	R	R	-	-	-

R, resistant; MR, some resistance when soil and local conditions are optimal; MS, high risk of crop damage; S, susceptible

⁄ Resistant to all rates up to 4 kg/ha with directed sprays.

Trials in the Caribbean and in Malaysia with 23,465 RP have shown that sugar cane tolerates doses of up to 4 kg/ha pre-emergence and 2 kg/ha post-emergence. At these doses, a wide range of tropical broad-leaved and grass weeds are controlled for periods of up to 6 months. Other crops, showing varying degrees of tolerance, include oil palm, rubber, cotton, peanuts and rice (Table 6) cocoa and tea.

DISCUSSION

One of the main criteria for effective herbicidal activity of 23,465 RP is the presence of adequate soil moisture; therefore, in Europe, its use in autumn-sown crops is of major interest. In the tropics, providing adequate soil moisture is present, from rainfall or irrigation, herbicidal activity is very good, especially under shade conditions.

In winter wheat, a dose of 500g/ha of 23,465 RP should not be exceeded. At this rate some important broad-leaved weeds are controlled, e.g. *Anagallis arvensis*, *Galium aparine* and *Veronica* spp., so that 23,465 RP may be used to complement grass herbicides which have little or no activity against these broad-leaved species.

In rapeseed, the mixture of 23,465 RP with carbetamide gives the advantages of flexibility in timing, from the 4-5 leaf stage through to the full winter dormant stage, as well as activity on both broad-leaved and grass weed species. Applications may be made either early in the dormant period (November-December) or may be delayed until February-March depending on the nature of the weeds. The mixture with carbetamide may be used in the same way on lucerne.

The use of 23,465 RP as an industrial herbicide at a dose of 4-8 kg/ha is at present being further evaluated, as is the use of the material in tropical situations.

From this review of results, 23,465 RP appears to be a herbicide of promising potential, in light of its differential activity and selectivity versus dose rate.

References

DESMORAS, J., AMBROSI, D. & BOESCH, R. (1974) Etudes au Laboratoire et en serre du 23,465 RP nouvel herbicide de la famille des ureidophenyl-oxadiazolones. *Phytiatrie-Phytopharmacie* (in the press).

BTS 30 843 - A NEW PRE-EMERGENCE GRASS HERBICIDE

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Summary BTS 30 843 is a novel pre- or very early post-emergence grass herbicide. Glasshouse data have shown that all important annual grassy weeds tested, including *Echinochloa crus-galli*, *Digitaria sanguinalis*, *Setaria* spp., *Panicum* spp. and *Alopecurus myosuroides* are controlled. Preliminary field evaluation in Europe, Australasia and the U.S.A. has shown that the compound shows promise in controlling all the major annual grassy weed problems in such diverse crops as soyabean, peanut, cotton, maize and small grains at rates of 1-2 kg/ha. Small seeded broad-leaved weeds are controlled by BTS 30 843, but only at relatively high rates of application.

The herbicidal effect is indicated by a failure of the weed to germinate, or a very severe twisting and stunting of the seedling. Early post-emergence sprays cause a complete cessation of growth of the seedling weed followed by a darkening of the colour, malformation of the leaves and eventual death.

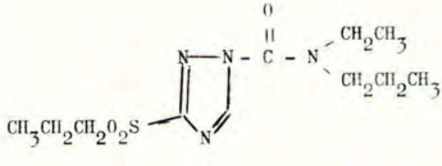
Résumé BTS 30 843 est un nouvel herbicide de pré ou post-levée très précoce. Les résultats obtenus en serre ont montré que toutes les adventices monocotylédones annuelles classiques y compris *Echinochloa*, *Digitaria*, *Setaria*, *Panicum* spp. et *Alopecurus* sont détruites. Les résultats préliminaires de plein champ en provenance d'Europe, d'Australasie et des Etats-Unis ont montré que ce produit etait porteur d'espérances en ce qui concerne la lutte contre la plupart des monocotylédones annuelles dans des cultures comme le soja, cacahuète, coton, maïs et autres cultures à petites graines à des doses de 1 à 2 kg/ha. Les dicotylédones à petites graines sont détruites par BTS 30 843, mais à des doses relativement élevées.

L'effet herbicide se caractérisait par un défaut de germination de l'adventice soit par une déformation accompagnée de crispation de la jeune plantule. Les applications de post-levée très précoce entraînent un arrêt complet de la croissance de la plantule d'adventice, suivi d'un assombrissement et de malformation des feuilles, pouvant se solder par la mort.

INTRODUCTION

In 1969 The Boots Company began an extensive synthetic programme around the general area of *N*-carbamoyl-1,2,4-triazoles. Many of these compounds showed a very high level of selective pre-emergence grass control. Work on a large number of active compounds has resulted in the selection of BTS 30 843 for commercial development for pre- or early post-emergence grass control in crops such as soyabean, peanut, cotton, maize and small grains.

The compound itself is chemically 1-(N-ethyl-N-propyl-carbamoyl)-3-propyl-sulphonyl-1 H-1,2,4-triazole (IUPAC) or N-ethyl-N-propyl-3-(propylsulfonyl)-1 H-1,2,4-triazole-1-carboxamide (Chemical Abstracts nomenclature), and its structure is as follows:



Empirical formula $C_{11}H_{20}N_4O_3S$ — Molecular weight 288

Physical form - white solid — Odour - odourless

Melting point - 51.0 - 51.6°C

Solubility - 25°C(mg/l.) -

Water	1.9×10^3	Acetone	1.0×10^6
Ethanol	1.7×10^5	Benzene	5.0×10^5
Chloroform	1.0×10^6	Ether	6.7×10^4
Kerosene	4.0×10^3	Xylene	3.3×10^5

Wiswesser line formula - T5NN DNJ AVN3&2 CSW3

The acute toxicity of BTS 30 843 in rats, mice and rabbits has been determined as follows:

Species	Route	LD50 mg/kg
Mouse	Oral	400-800
Rat	Oral	100-200
Rat	Dermal	> 2,000
Rabbit	Dermal	> 500

No obvious untoward effects were shown by male and female rats given doses of 8 and 20 mg/kg/day for 30 days.

METHOD AND MATERIALS

BTS 30 843 has been evaluated both under glass and in the field. Glasshouse studies were conducted initially on the four crops maize, cotton, soyabean and peanut and the four grass weeds Echinochloa crus-galli, Digitaria sanguinalis, Setaria glauca and Sorghum halepense pre-emergence. Spraying was conducted logarithmically with a maximum dose of 8 kg/ha reducing to 0.25 kg/ha used against the crops and a maximum dose of 2 kg/ha reducing to 0.06 kg/ha used against the weeds. Crop/weed selectivity can be conveniently defined with this procedure. Other glasshouse tests included a determination of persistence and efficacy on soils with varying clay and organic matter content.

Preliminary field evaluations were conducted at Lenton Research Station, Nottingham and Kooree Research Farm, Australia. Crops and weeds were precision drilled and BTS 30 843 was sprayed across the line of the drillings at rates of 4, 2, 1 and 0.5 kg/ha. Assessments were made 14, 21 and 35 days after spraying. All applications were made using a spray volume of 415 l/ha at a pressure of 2.81 kg/cm^2. The spray nozzles were Tee-Jets 8003. All small plot work was done with a small pusher sprayer giving a spray width of 90 cm. At least three replicates of each treatment were applied.

More detailed field evaluations have been conducted in the U.S.A. (soyabeans, peanuts, cotton and maize), in Australia (soyabeans, peanuts and maize) and in Europe (winter cereals and maize).

RESULTS

Glasshouse tests

Results from glasshouse evaluations show a very considerable effect on grass weeds and small-seeded broad-leaved weeds with little effect on large-seeded broad-leaved weeds and with a substantial margin of crop safety (Table 1).

Work involving the differential placement of chemical in relation to the weed seed has shown that BTS 30 843 is absorbed through the germinating seedling or through the root. Application of the compound to soil containing seedlings has given excellent weed control whereas foliar treatments are without effect. The symptoms associated with death suggest that the mode of action of this compound is associated with an inhibition of mitosis. This has yet to be substantiated by experimentation.

Table 1

Results of pre-emergence glasshouse tests with BTS 30 843

Species	Rate (g/a)*
Digitaria sanguinalis	0.6**
Echinochloa crus-galli	0.6
Poa annua	0.6
Setaria glauca	0.3
Sorghum halepense (seedling)	0.3
Alopecurus myosuroides	1.25
Avena fatua	5.0
Chenopodium album	0.6
Stellaria media	0.6
Portulaca oleracea	0.6
Brassica oleracea	5.0
Polygonum persicaria	5.0
Ipomoea purpurea	>2.0
Abutilon theophrasti	>2.0
Wheat	20**
Barley	20
Maize	10
Soyabean	>80
Peanut	>80
Cotton	20

* g/a is grams per are. Ten grams per are are equivalent to 1 kg/ha.
** The figure is the lowest rate required to control the weeds or the highest rate showing no effect on crops.

Further glasshouse evaluations examined the persistence of BTS 30 843 in a sandy loam soil. Two groups of 9 cm pots were sprayed with the compound at 1 kg/ha. One group was then stored dry and the other irrigated daily with the equivalent of 2.5 cm of rain. Successive plantings of Echinochloa crus-galli and visual assessment of the growth of the weed were used to indicate the persistence of BTS 30 843 (Table 2). As expected none of the activity was lost by decomposition or volatilization from the soil stored under dry conditions, and further, no significant diminution of effect was produced by simulated leaching.

These encouraging results stimulated examination of the performance of the compound in different soil types. Table 3 shows the results of three rates of BTS 30 843 sprayed onto a light sandy soil, a heavy clay soil and an organic fen soil. Each soil type was seeded with the four indicator grasses and assessed visually. Clearly, BTS 30 843 is less active on fen soil (14.3% o.m.) but excellent weed control has still been achieved by the very low rate of 0.63 g/are. This suggests that BTS 30 843 should be effective even on soils with a high organic matter content, unlike many other pre-emergence herbicides.

Table 2

Results of a glasshouse persistency test on BTS 30 843 bioassayed with Echinochloa crus-galli

Week sown	Soil stored dry	Soil irrigated daily
0	10*	10
1	9	10
3	10	8
5	10	8+
7	10	10

* Assessed on a scale 0-10 where 0 is no effect and 10 is complete kill.

Table 3

Activity of BTS 30 843 on three different soil types under glasshouse conditions

Soil type	Species	Rate (g/are) 1.25	0.63	0.32
Sandy loam	E. crus-galli	8+*	10	9+
	D. sanguinalis	10	10	10
	S. glauca	10	10	10
	S. halepense	10	10	9+
Clay loam	E. crus-galli	9+	9+	10
	D. sanguinalis	10	9+	10
	S. glauca	8	10	10
	S. halepense	9+	9+	10
Organic fen	E. crus-galli	10	10	7
	D. sanguinalis	10	9+	6+
	S. glauca	10	8	5
	S. halepense	10	10	10

* Assessed on a scale 0-10 where 0 is no effect and 10 is complete kill.

Field trials

Results from preliminary field trials are shown in Table 4. Again a very high level of pre-emergence grass control was confirmed with some activity against small-seeded broad-leaved weeds. Little control of large-seeded broad-leaved weeds was observed, but a considerable margin of crop safety was evident with many crops.

In the majority of agricultural situations a weed problem is seldom confined to either grass or broad-leaved weed infestations. For this reason it is essential to produce a product or a mixture which will give broad-spectrum weed control in a particular crop. It was towards this end that certain commercially available additives were assessed in admixture with BTS 30 843. These mixtures included BTS 30 843 + atrazine for maize, and BTS 30 843 + fluometuron for cotton.

Table 4

Results of preliminary field evaluations with BTS 30 843

Species	Lenton(kg/ha)	Kooree(kg/ha)
Avena fatua	4*	-
Alopecurus myosuroides	1	-
Poa annua	0.5	-
Chenopodium album	2	-
Chrysanthemum segetum	4	-
Stellaria media	2	-
Anthemis arvensis	2	-
Galium aparine	4	-
Barley	4	-
Wheat	4	-
Carrot	2	-
Sugarbeet	2	-
Bean (Phaseolus vulgaris)	4	-
Flax	4	-
Potato	4	-
Pea	4	-
Digitaria sanguinalis	0.75	1.0
Eleusine indica	-	0.5
Echinochloa crus-galli	0.75	0.5
Setaria glauca	1.5	1.0
Panicum maximum	0.75	1.0
Amaranthus retroflexus	1.5	4.0
Abutilon theophrasti	1.5	4.0
Ipomoea purpurea	1.5	4.0
Portulaca oleracea	-	2.0
Maize	1.5 **	2.0
Cotton	-	2.0
Soyabean	1.5 **	2.0
Peanut	-	4.0

* Lowest rate to control weeds, highest rate safe to the crop.
** The highest rate applied.

Results from replicated trials in the U.S.A. with BTS 30 843 alone and in mixture on a variety of crops are shown in Tables 5-8.

Table 5

Results of field evaluations in maize with BTS 30 843 - Florida, U.S.A.

Treatment	Rate (kg/ha)	Digitaria sanguinalis	Eleusine indica	Amaranthus retroflexus	Crop Injury
BTS 30 843	0.5	6*	6	-	0
BTS 30 843	0.75	9	8	-	0
BTS 30 843	1.0	10	10	-	0
BTS 30 843	1.5	8	8	-	0
BTS 30 843	2.0	10	10	4	4
BTS 30 843 + atrazine	1.0 1.0	9	8	9+	0
Atrazine	2.0	2	2	10	0

* Assessed on a scale 0-10 where 0 is no effect and 10 is complete kill. A score of 2 is taken as unacceptable crop damage.

Very similar data were obtained in field trials in maize in Europe and in Australia.

Table 6

Results of field evaluations in soyabeans with BTS 30 843 - South Carolina, U.S.A.

Treatment	Rate (kg/ha)	Eleusine indica	Chenopodium album	Mollugo verticillata	Crop Injury
BTS 30 843	0.5	6.0*	4.0	6.0	0
BTS 30 843	0.75	7.5	4.0	-	0
BTS 30 843	1.0	9.0	5.0	-	0
BTS 30 843	1.5	10.0	7.0	9.0	0
BTS 30 843	2.0	10.0	8.0	-	0
Alachlor	3.0	10.0	7.0	-	0

* Assessed on a scale 0-10 where 0 is no effect and 10 is complete control. A score of 2 is taken as unacceptable crop damage.

Table 7

Results of field evaluations in peanuts - Georgia, U.S.A.

Treatment	Rate (kg/ha)	Grass**	Acanthospermum hispidum	Richardia scabra	Crop Injury
BTS 30 843	0.5	4.0*	2.0	-	0
BTS 30 843	0.75	4.0	4.0	-	0
BTS 30 843	1.0	8.0	7.0	-	0
BTS 30 843	1.5	8.5	7.0	7.0	0
BTS 30 843	2.0	9.5	8.0	9.5	0
Alachlor	3.0	8.5	6.0	10.0	0

* Assessed on a scale 0-10 where 0 is no effect and 10 is complete kill. A score of 2 is taken as unacceptable crop damage.
** Grass weed was Digitaria sanguinalis and Dactyloctenium aegyptium.

Table 8

Results of field evaluations in cotton with BTS 30 843 - South Carolina, U.S.A.

Treatment	Rate (kg/ha)	Grass**	*Portulaca oleracea*	Crop Injury
BTS 30 843	1.0	10*	10	0
BTS 30 843	1.25	10	10	0
BTS 30 843	1.5	10	10	1
BTS 30 843	1.75	10	10	1
BTS 30 843	2.0	10	10	3.5
BTS 30 843 + fluometuron	1.0 1.0	10	10	0
Fluometuron	2.0	8	10	0

* Assessed on a scale 0-10 where 0 is no effect and 10 is complete kill. A score of 2 is taken as unacceptable crop damage.
** Grass weed was predominantly *Eleusine indica* and *Dactyloctenium aegyptium*.

DISCUSSION

These field trial data show very clearly that excellent grass weed control can be obtained with BTS 30 843 at rates of 0.75 - 1.5 kg/ha. A high degree of crop tolerance was indicated in soyabean and peanuts. Some damage was seen in cotton and maize with the higher rates of application, but at dosages which gave effective weed control a margin of crop safety was still evident. The addition of commercially available broad-leaved herbicides for selected crops has been shown to give excellent control of all weeds with no damage to the crops. Examples of this have been shown with BTS 30 843 + atrazine (1.0 kg/ha + 1.0 kg/ha) in maize and with BTS 30 843 + fluometuron (1.0 kg/ha + 1.0 kg/ha) in cotton.

Further work in progress at Lenton has shown that BTS 30 843 can be successfully applied to emerged grasses up to the three-leaved stage. If these data are confirmed in off-station trials, then this will allow BTS 30 843 to be applied to a crop both pre- and early post-emergence giving greater flexibility on timing of sprays. Preliminary observations on mode of action indicate that BTS 30 843 is effective by root uptake from the soil and has no contact activity.

CONCLUSION

BTS 30 843 has shown excellent grass weed control in a number of crops in the U.S.A., Europe and Australia. The flexibility in application timing will allow for treatment of the field when conditions are ideal for weed control. Good selectivity has been shown in soyabean and peanut, but cotton and maize are damaged by high rates. Nevertheless a margin of safety exists between the concentration required for weed control and that which damages the crop.

Acknowledgements

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NOTES

Proceedings 12th British Weed Control Conference (1974)

WL 29226 - A NEW SELECTIVE HERBICIDE FOR USE IN CEREALS

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Summary WL 29226 (2,6-dichlorobenzyl(2,2-dimethyl-4-ethyl-dioxolan-4-yl)methyl ether) has been field tested in winter-sown wheat as a pre-emergence herbicide. At a dose of 1 kg/ha a.i. it has given excellent control of Alopecurus myosuroides together with other annual grass weeds (Poa, Lolium, Phalaris spp.) and has shown a very high level of control of a wide range of annual broad-leaved weeds (including Stellaria, Veronica, Matricaria and Papaver spp.). No effects on crop yield have been recorded following 2 years of field evaluation in the U.K. WL 29226 appears to be a useful herbicide for broad-spectrum weed control in wheat.

Résumé Des essais en plein champ furent entrepris pour évaluer l'activité des applications en pré-levée du WL 29226 (2,6-dichlorobenzyl (2,2-diméthyl-4-éthyl-dioxolan-4-yl)methyl ether) sur blé d'hiver. A la dose de 1 kg/ha (m.a.) on obtien une tres bonne efficacité contre Alopecurus myosuroides ainsi que contre des autres graminées annuelles (Poa, Lolium, Phalaris spp.). En plus, ce produit fut montré très actif contre nombreuses dicotylédones annuelles (y compris Stellaria, Veronica, Matricaria, Papaver spp.). Aucun effet sur le rendement du blé ne fut constaté pendant deux années d'experimentation en Grande Bretagne. Le WL 29226 parait tres intéressant pour lutter contre un spectre large des mauvaises herbes dans le blé.

INTRODUCTION

A survey conducted during 1972 showed that of the 3.3 million hectares of cereals grown in the U.K. at least 1.6 million hectares were infested with grass weeds (Anon., 1974). The main grass weeds found were wild oats (Avena fatua, A. ludoviciana), blackgrass (Alopecurus myosuroides) and couch (Agropyron repens).

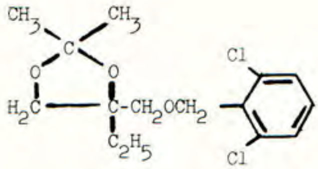
The discovery of selective herbicides to control these grass weeds in cereal crops has been an objective of the Woodstock laboratory. This programme of research has already resulted in the introduction of benzoylprop ethyl (Chapman et al., 1969) and flamprop isopropyl (Mouillac et al., 1973) for the control of wild oats in wheat and barley respectively. This paper is concerned with the control of blackgrass and annual broad-leaved weeds in cereals using WL 29226, a representative of a novel class of herbicides presently being studied at the Woodstock Laboratory.

PHYSICAL AND CHEMICAL PROPERTIES

Chemical name: 2,6-Dichlorobenzyl(2,2-dimethyl-4-ethyl-dioxolan-4-yl) methyl ether

Common name (proposed): Benzglycereth

Chemical structure:



Appearance: White crystalline powder

Odour: Slight chemical

Melting point: 42-44°C

Solubility: Soluble in all organic solvents examined (e.g. alcohol, acetone, chloroform, benzene). Insoluble in water. Can be recrystallized from cold petroleum spirit.

Stability: Technical WL 29226 is stable on storage under normal conditions. It is stable under alkaline conditions but will decompose when treated with acid.

Formulation: 400g/litre emulsifiable concentrate.

TOXICOLOGY

WL 29226 as the technical material has the following acute toxicity when administered as a single oral dose:

Species	LD_{50} (mg/kg)
Rat	3000 - 4000
Mouse	650 - 800

BIOLOGICAL PROPERTIES

In glasshouse screening tests WL 29226 showed a high level of pre-emergence activity against a range of annual grasses. Crop species showing tolerance to pre-emergence treatments included cotton, wheat, soyabean and sugar beet. Foliar spray tests show a low level of activity with little evident selectivity. Field screens confirmed the selectivity pattern shown for annual weeds, particularly in cotton and wheat.

WL 29226 does not inhibit seed germination of susceptible species but acts at a subsequent stage of development. Monocotyledons germinated on filter paper treated with solutions of the compound show severe inhibition of shoot growth after emergence of the coleoptile from the seed. Initial root elongation is little affected but subsequently root tip necrosis and cessation of growth occur. In dicotyledons the root growth is similarly inhibited although shoot growth is relatively unaffected. Further studies on the mode of action of WL 29226 are continuing.

FIELD PERFORMANCE

The field testing of WL 29226 is in progress in Austria, Belgium, Denmark, Holland, France, Germany, Spain, the U.K. and the U.S.A. This report details the results from the U.K. where 38 field trials in wheat were conducted during the 1972/73 and 1973/74 seasons. All treatments were made pre-emergence to winter-sown wheat on fields where natural infestations of blackgrass and annual broad-leaved weeds were expected to occur. WL 29226 was applied at doses from 0.25 to 3.0 kg/ha and compared with other pre-emergence herbicides including chlortoluron, nitrofen and terbutryne. The results are shown in the Tables 1, 2 and 3 for the control of Alopecurus myosuroides, annual broad-leaved weeds and crop yields.

Table 1 shows the level of control of A. myosuroides found with WL 29226. In general the 1.0 kg/ha dose of WL 29226 gives the same level of blackgrass control as do the standard treatments of chlortoluron and terbutryne. At doses less than 1.0 kg/ha then WL 29226 can often provide excellent weed control but sometimes this control is poor and on average such doses are inferior to the standard treatments. It is interesting to note that the activity of WL 29226 appears to be independent of soil type within the range of soils tested (Table 1) as blackgrass control can be obtained on soils with 24-48% clay and 2.4-5.0 % organic matter. The data tabulated include results from the 1972/73 and 1973/74 seasons, which were very different in their autumn rainfall patterns, and thus WL 29226 appears to be an effective herbicide under both dry and wet soil conditions.

The results in Table 2 show the response of several annual broad-leaved weeds to pre-emergence treatments with WL 29226. The important broad-leaved weeds of wheat are controlled by 1.0 kg/ha WL 29226. In addition to the weeds recorded in Table 2 the results from trials in N. Europe and Spain indicate that other broad-leaved weeds are controlled at 1.0 kg/ha including Anthemis sp., Capsella bursa-pastoris, Diplotaxis muralis, Lamium sp. and Thlaspi arvense. Where weeds have an extended period of germination or are autumn- and spring-germinating species (e.g. Fumaria officinalis) then doses greater than 1.0 kg/ha may be required for good weed control of the spring-germinating weeds.

The yield results from the trial series are shown in Table 3 and demonstrate no yield losses at doses of 1.0 and 2.0 kg/ha. WL 29226 has been tested on most of the important British and European wheat varieties (Bouquet, Brennus, Cappelle-Desprez, Capitole, Champlein, Clement, Hardy, Maris Huntsman, M. Nimrod, M. Ranger, M. Widgeon, Promesse, Talent, Top) and no varietal susceptibility has yet been found.

WL 29226 controls other grass weeds and results from field trials are presented in Table 4. The annual grass weeds Lolium spp., Poa spp. and Phalaris are controlled by 1.0 kg/ha of WL 29226 whilst the perennial species Agrostis stolonifera shows only a slight reduction from a 2.0 kg/ha application. The activity on Avena spp. is interesting and further investigation on this aspect of the performance of WL 29226 is being conducted.

WL 29226 is also being evaluated on other cereal crops including winter-sown barley and spring-sown barley and wheat and results to date look promising. The compound does show a useful level of activity on Echinochloa crus-galli with selectivity in paddy rice and this work is continuing in Japan. Field evaluation in other crops including maize, cotton and sugar cane is planned.

It appears that WL 29226 is a valuable addition to the present range of cereal herbicides showing a high herbicidal activity on annual grasses and annual broad-leaved weeds. This is coupled with a useful selectivity margin in cereals, especially in winter-sown wheat.

Acknowledgements

We wish to thank our many colleagues who have helped in the development of WL 29226.

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Table 1

Control of Alopecurus myosuroides in winter-sown wheat
(% reduction in numbers of panicles)

Soil		Herbicide and dose (kg/ha)							Untreated control (panicles/ m^2)
Clay (%)	o.m. (%)	WL 29226 0.25	0.5	1.0	2.0	Chlortoluron 2.0	Nitrofen 2.25	Terbutryne 2.5	
24	2.8	88	89	97	99	99	-	84	78
27	3.8	-	82	91	90	-	-	-	71
28	2.8	28	84	100	97	100	-	100	8
28	3.2	-	97	99	100	98	-	93	66
29	2.4	65	79	71	93	98	-	98	122
30	2.6	79	84	90	90	93	-	100	70
30	3.8	-	-	98	100	-	68	78	135
30	2.6	69	76	91	96	98	-	98	220
30	3.6	-	-	100	100	-	92	75	49
32	2.6	58	86	75	93	82	-	70	103
32	3.0	-	-	74	88	-	77	77	433
34	2.7	51	72	82	95	91	-	99	337
35	3.5	63	79	92	97	100	-	86	201
37	3.1	-	-	84	95	70	89	65	439
37	3.4	61	76	86	95	66	-	84	202
38	4.0	-	45	89	90	82	-	90	68
39	3.4	31	82	93	98	55	-	89	1376
46	5.0	-	59	91	92	94	-	77	895
48	3.5	87	68	84	86	47	-	50	34

Table 2

Control of annual broad-leaved weeds in winter-sown wheat
(Mean values expressed as % reduction in the numbers of plants)

No. trials meaned	Weed spp.	Herbicide and dose (kg/ha)						
		WL 29226				Chlortoluron	Nitrofen	Terbutryne
		0.25	0.5	1.0	2.0	2.00	2.25	2.5
12	Stellaria media	89	80	94	98	93	25	99
12	Veronica[(1)] spp.	77	61	92	97	92	85	100
4	Matricaria[(2)] spp.	-	92	96	99	100	39	88
4	Sinapis[(3)] and Raphanus	-	73	93	93	-	80	85
3	Papaver rhoeas	-	-	98	100	-	42	100
3	Polygonum aviculare	-	-	44	80	-	38	93
1	Galium aparine	-	42	75	83	58	-	59
5	Aphanes arvensis	33	60	78	95	100	22	92
2	Myosotis arvensis	-	100	100	100	98	-	100
2	Spergula arvensis	-	-	94	80	-	65	83
3	Viola tricolor	-	90	92	100	0	92	87
3	Centaurea[(4)] cyanus	-	59	89	93	82	-	98

Notes: (1) Veronica persica and V. hederifolia
(2) Matricaria recutita and Tripleurospermum maritimum sp. inodorum
(3) Sinapis arvensis, Raphanus raphanistrum
(4) data from N. France

Table 3

Grain yield
(as % of untreated control)

Herbicide and dose (kg/ha)							Untreated control (t/ha at 15% moisture	*Alopecurus* (panicles/m²)
WL 29226				Chlortoluron	Nitrofen	Terbutryne		
.25	0.5	1.0	2.0	2.0	2.25	2.5		
-	95	102	99	-	-	-	4.4	0
-	103	103	104	-	-	-	4.7	0
-	-	104	101	-	100	95	5.0	3
91	102	98	94	103	-	104	8.1	8
-	-	152	151	-	129	149	2.5	49*
-	112	101	105	111	-	105	5.7	66
98	95	91	89	98	-	100	7.4	70
-	97	98	99	-	-	-	5.9	71
-	-	103	106	-	97	104	4.8	135
107	109	106	101	105	-	113	5.4	202
105	105	108	107	107	-	103	6.6	202
-	-	125	122	-	125	125	4.4	433
-	-	116	114	-	106	99	3.3	439
-	205	287	298	294	-	268	1.7	895

*this trial had an infestation of *Lolium* sp. (173/m^2) which contributed to the improved yields

Table 4

Control of grass weeds in winter-sown wheat
(% reduction in numbers of plants)

No. trials meaned	Weed spp.	Herbicide and dose (kg/ha)						
		WL 29226				Chlortoluron	Nitrofen	Terbutryne
		0.25	0.5	1.0	2.0	2.00	2.25	2.50
1	*Avena ludoviciana*	-	-	54	76	-	23	0
1	*Avena fatua*	-	-	26	95	-	40	59
1	*Agrostis stolonifera*	-	-	0	63	-	9	82
2	*Lolium* spp.	-	-	100	100	-	98	90
4	*Phalaris paradoxa**	-	70	85	95	30	-	95
4	*Poa* spp.		-	94	100	-	94	100

*including in one trial some *P. brachystachys*

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AC 92,553, A SELECTIVE HERBICIDE FOR WEED CONTROL IN CEREALS AND OTHER CROPS

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Summary AC 92,553, N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine, is a new herbicide which has provided excellent control of annual grasses and many broadleaved weeds. In experimental tests as a preplant incorporated application at 0.6 to 1.5 kg a.i./ha, excellent weed control was obtained in cotton, soybeans, peanuts and other crops. AC 92,553 can also be applied pre-emergence, and with this method rates of 1.0 to 2.0 kg a.i./ha have controlled most grasses and certain broadleaved weeds in maize, wheat and rice. Combinations of AC 92,553 with other herbicides are being tested to increase the spectrum of weed control.

INTRODUCTION

Annual grasses are a very important weed problem in many areas of the world. Blackgrass (*Alopecurus myosuroides*) infests a significant percentage of the cereal acreage in the United Kingdom (Phillipson, 1974). In Taiwan, Chang (1973) has reported that *Echinochloa crusgalli* is one of the most competitive of the major weeds in rice. In the United States, certain annual grasses, such as *Panicum dichotomiflorum* and *Digitaria* spp., have become dominant weed problems in maize as a result of using herbicides which do not adequately control these species (Harvey & Doersch, 1974). However, field testing of AC 92,553 in a number of crops indicates that this compound offers promising control of many economically important grass species and a number of broadleaved weeds, particularly the small-seeded species.

MATERIALS AND METHODS

AC 92,553 has the chemical name N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine and a proposed common name of penoxyn. Technical AC 92,553 is an orange crystal with low water solubility (0.3 ppm at 20°C) and a melting point of 56° to 57°C. The compound is stable under both acidic and alkaline conditions. Several formulations of AC 92,553 are being tested, including an emulsifiable concentrate containing 330 g a.i./l. (330-E), a wettable powder containing 50% a.i. w/w (50-WP) and granular formulations containing 5% a.i. w/w (5-G) or 3% a.i. w/w (3-G).

The compound has a low acute and chronic mammalian toxicity. The acute oral LD50 values in male albino rats for AC 92,553 technical grade and AC 92,553 330-E are 1250 mg/kg and 2930 mg/kg, respectively. The acute dermal LD50 values in albino rabbits of the technical and the AC 92,553 330-E formulation are >5000 mg/kg and 6870 mg/kg, respectively. In addition, the standard chronic toxicity studies further document its safety. To evaluate the compound's safety to the environment, other studies, including soil leaching, fish toxicity and bird toxicity, were undertaken.

Following extensive greenhouse testing in which AC 92,553 showed promising activity, the compound was field tested on various crops at many locations throughout the world. AC 92,553 was applied both pre-emergence and preplant incorporated using standard techniques. The size of the replicated plots usually was at least 30 m^2, and sprays were applied with CO_2 plot sprayers while granules were spread by hand. The crops were planted and grown under conditions representative of good local cultural practices. Weed control was evaluated by visual rating or by actual weed counts. Crop phytotoxicity was assessed by various methods, using visual ratings, counting tillers and measuring crop height and yield. The environmental conditions of each trial were recorded.

RESULTS

Field tests - preplant incorporated treatment

AC 92,553 can be used either pre-emergence or preplant incorporated. Under most conditions, however, more consistent weed control is obtained if the herbicide is shallowly incorporated.

In soybean trials in the United States good control of small-seeded broadleaved weeds and annual grasses has been obtained with AC 92,553 applied either pre-emergence or preplant incorporated. In one representative trial where the soil was 70% sand, the rates of the preplant incorporated treatments used were somewhat lower than normal because of the soil composition. As shown in Table 1, after 55 days AC 92,553 at 0.6 kg a.i./ha controlled 87% and 88%, respectively, of *Amaranthus retroflexus* and *Digitaria sanguinalis*. Control of these two species was very similar to that obtained in other plots where an equal rate of trifluralin was used.

Table 1

Effect of AC 92,553 on weeds in soybeans in Louisiana, 1974

Treatment	Dose (kg a.i./ha)	% Weed control (after 8 weeks)† Amaranthus retroflexus	Ipomoea spp.	Digitaria sanguinalis
AC 92,553	0.6	87 bcd	53 b	88 a
	0.8	95 a	45 c	82 ab
AC 92,553 + metribuzin	0.6 + 0.3	92 abc	75 a	88 a
Trifluralin	0.6	80 d	37 d	80 bc
Trifluralin + metribuzin	0.6 + 0.3	93 ab	73 a	85 ab
Control	-	0 e	0 e	0 d

†Means within a column followed by similar letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

Other soybean tests in the southern U.S. have demonstrated that higher rates of AC 92,553 are needed if the soil contains 2% or more organic matter. For most soils in the northern soybean growing area of the United States, where organic matter is 4% or higher, AC 92,553 is used at rates ranging from 1.1 to 1.4 kg a.i./ha.

Although most annual grasses and small-seeded broadleaved weeds which infest soybeans are readily controlled with AC 92,553, this herbicide provides only partial control of many of the large-seeded broadleaved weeds, such as Ipomoea spp. In these cases, combinations of AC 92,553 with metribuzin and other compounds have usually improved the spectrum of broadleaved weed control. This point is illustrated in Table 1 where AC 92,553 + metribuzin gave a significantly better control of morning glory (Ipomoea spp.) than AC 92,553 alone.

In addition to soybeans, crop selectivity is good with preplant incorporated treatments on a number of other crops such as cotton, peanuts, rape, cauliflower and swede.

Field tests - pre-emergence treatment

AC 92,553 has been used pre-emergence in a number of crops, including maize, barley, wheat, carrot, chickpea (Cicer arietinum) and transplanted rice. With this method crop selectivity is achieved through placement of the herbicide above the crop seed. Due to its low solubility in water, AC 92,553 does not leach readily. Results from field trials in Italy, including information on weed control and selectivity of AC 92,553 in cereals, will be presented by Professor Kovacs in another section of this conference. The following is summarized from tests in the United States and Taiwan.

In maize, pre-emergence application of AC 92,553 at 1.7 to 2.2 kg a.i./ha usually provides good control of annual grasses (Table 2). In addition, the compound will control many annual broadleaved weeds and will provide partial control of velvetleaf (Abutilon theophrasti), a major weed problem in maize in the U.S. AC 92,553 at 2.2 kg a.i./ha usually provides better control than indicated in Table 2.

Table 2

Effect of AC 92,553 alone and in combination with atrazine on weeds and maize in Illinois

Treatment	Dose (kg a.i./ha)	% Weed control (after 4 weeks)† Setaria faberi	Abutilon theophrasti	Yield (kg/ha)
AC 92,553	1.7	93 a	88 ab	10,302
	2.2	91 a	70 b	9,607
AC 92,553 + atrazine	1.7 + 1.7	96 a	94 ab	10,786
Alachlor	2.2	98 a	5 c	9,450
Alachlor + atrazine	1.7 + 1.7	98 a	97 a	10,268
Control	-	0 b	0 c	8,318

† Means within a column followed by similar letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

Atrazine at rates of 3 kg a.i./ha and higher provides good control of velvetleaf in maize. However, since maize is often grown ahead of soybeans, a crop sensitive to triazine residues in the soil, most farmers use a lower rate of atrazine combined with a herbicide for grass control to prevent soybean damage from the atrazine residues. Thus, Abutilon theophrasti is usually poorly controlled because low rates of atrazine provide only partial control and most grass herbicides provide little control at recommended rates. However, combinations of AC 92,553 and atrazine provide good control of velvetleaf as shown in the work summarized in Table 2, where yields were very similar following application of combinations of atrazine + AC 92,553 at 1.7 + 1.7 kg a.i./ha and atrazine + alachlor at 1.7 + 1.7 kg a.i./ha. The treatment alachlor + atrazine at 1.7 + 1.7 kg a.i./ha provided better velvetleaf control than usually expected. The combination of AC 92,553 + cyanazine also provided excellent broad-spectrum weed control.

Under most test conditions, AC 92,553 has not caused injury to maize planted from 3 to 6 cm deep. In several tests, no crop injury was observed following application of rates as high as 6.7 kg a.i./ha.

AC 92,553 is also being tested for pre-emergence use on transplanted and upland rice. In one test in Taiwan (Table 3), the rice plants were transplanted on March 25, 1973; herbicide treatments were applied six days after transplanting; and the crop was grown under representative cultural conditions for flooded rice. AC 92,553 and the two standard herbicides, butachlor and benthiocarb, gave excellent control of Echinochloa crusgalli. AC 92,553 at 1.5 kg a.i./ha gave better control of Monochoria vaginalis than butachlor at 1.5 kg a.i./ha or benthiocarb at 3.0 kg a.i./ha. On Cyperus difformis, butachlor and benthiocarb both provided better control than either rate of AC 92,553. At the 2.0 kg a.i./ha rate, AC 92,553 controlled 89% of Cyperus difformis. Although not included in the tabular summary, other annual broadleaved weeds, such as Rotala spp., Elatine spp. and Lindernia spp., were also adequately controlled by AC 92,553.

Table 3

Effect of AC 92,553 and two standard herbicides on several weed species in transplanted rice (Taiwan)

Treatment†	Dose (kg a.i./ha)	Weed density (weeds/m²)‡ Echinochloa crusgalli	Monochoria vaginalis	Cyperus difformis
AC 92,553	1.5	0 b	4.0 c	13.3 b
	2.0	0.3 b	2.7 c	5.7 b
Butachlor	1.5	0.7 b	21.3 bc	0.0 b
Benthiocarb	3.0	0.3 b	51.3 b	1.0 b
Hand-weeded control	-	0.7 b	23.0 bc	13.0 b
Weedy control	-	44.0 a	130.0 a	128.3 a

† The herbicides were applied 6 days after transplanting. The weed counts were taken 35 days after transplanting.

‡ Means within a column followed by similar letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

After widespread testing, it was found that AC 92,553 does not control perennial broadleaved and perennial sedge species found in flooded rice. To obtain a wider spectrum of weed control, AC 92,553 is being tested in combination with other rice herbicides.

Although toxic to direct-seeded rice, AC 92,553 appears to be relatively safe in transplanted rice. Under conditions where the rice seedlings are very young and the weather cool, a slight yellowing of the crop plant may occur but disappears rapidly. This early injury does not appear to influence yield. The results in Table 4 show that AC 92,553 at the proposed use rates has no detrimental effect on plant height, tillering or final yield when compared to the hand-weeded control or the other standard treatments. This representative test shows that AC 92,553 has good selectivity and provides control of many of the economically important weeds in transplanted rice.

Table 4

The effect of AC 92,553 and other herbicides on the height, tillering, and yield of transplanted rice in Taiwan

Treatment†	Dose (kg a.i./ha)	Height (cm/plant)	No. of tillers‡ (tillers/10 plants)	Yield (kg/ha)
AC 92,553	1.5	55.6	26.5 b	3,537 a
	2.0	55.5	25.6 bc	3,537 a
Butachlor	1.5	55.0	26.7 b	3,443 a
Benthiocarb	3.0	56.8	29.6 a	3,450 a
Hand-weeded control	-	57.2	26.6 b	3,533 a
Weedy control	-	57.7	23.6 c	2,973 b
		n.s.		

†The herbicides were applied 6 days after transplanting; the height and number of tillers were measured at 35 days after transplanting; yields were taken 119 days after planting.

‡Means within a column followed by similar letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

Pre-emergence application of AC 92,553 has also been found effective in a variety of vegetable crops including lettuce, carrot, kale and tomato.

Metabolism and residues

The results from field and toxicology studies were sufficiently promising to warrant metabolism studies and the development of residue methods for maize, rice, cotton and several other crops. At present, the data show no apparent residues in grain or seed above the validated sensitivity of the methods used (0.05 ppm). Field studies have shown that this herbicide degrades in the soil and does not accumulate even after reapplication of AC 92,553. Follow crops, such as soybeans, cotton, corn, wheat and red beets, grown the year after maize or cotton do not contain residues.

DISCUSSION

AC 92,553 is a selective herbicide which has unique properties. Alone or in combination with metribuzin, AC 92,553 provides broad-spectrum weed control in soybeans, a warm-season crop. For cool-season crops, selectivity is achieved by placing the herbicide above the seed. Thus, pre-emergence treatments of this herbicide can be used for weed control in maize, barley, rye and other cereals. AC 92,553 alone or in combination with atrazine or cyanazine controls most annual grass and broadleaved weeds in maize without leaving soil residues to damage follow crops. Tests in Europe have shown that AC 92,553 controls many important annual grasses and most broadleaved weeds in barley and rye. The compound also has utility for control of many weeds in transplanted rice.

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DIFENZOQUAT, A NEW POST-EMERGENCE WILD OAT HERBICIDE FOR WHEAT AND BARLEY

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Summary AC 84,777 is the code number used for a new selective post-emergence herbicide for control of wild oats (Avena spp.) in wheat and barley. The chemical name is 1,2-dimethyl-3,5-diphenyl-1H-pyrazolium methyl sulfate. Difenzoquat is the approved common name. A brief description of toxicity, formulations, application techniques, selectivity and results of world-wide performance tests is given. Good to excellent control of several species of wild oats including Avena fatua, A. ludoviciana and A. sterilis was reported at application rates of 0.6 to 1.2 kg a.i./ha. Crop tolerance was good with no injury up to 5.0 kg a.i./ha in barley and up to 2.4 kg a.i./ha in winter wheat. Spring wheat was injured in some trials and possible factors are suggested.

INTRODUCTION

Grass weeds remain the single most important weed problem in temperate zone cereal crop production. Several weed species are important depending upon climate, geographical area and cultural practices. These include wild oats (Avena spp.), blackgrass (Alopecurus myosuroides), cheatgrass (Bromus spp.), Lolium species, Apera spica-venti and others. However, on a world basis the different species of wild oats are perhaps more widespread and cause greater crop loss than the other grass weeds. In Australia wild oats is described as the worst weed in wheat causing between 30 and 50 million dollars loss each year (McNamara, 1972).

According to Pfeiffer (1968) the increased importance of the grass weed problem has resulted from many interrelated factors, some technological and some economic. More recently Phillipson (1974) reported results of a survey on the presence of wild oats and blackgrass in the United Kingdom. It was estimated that not less than 2 1/4 million acres of wheat and barley were infested with wild oats and 1/2 million acres with blackgrass.

METHODS AND MATERIALS

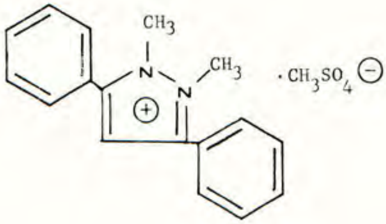
Chemistry

Difenzoquat was selected for commercial development from a large series of related compounds synthesized and tested at the Princeton Agricultural Center of American Cyanamid Company. The technical grade material is an off-white crystalline powder of 97%-98% purity having a melting point of 151°-153°C and a water solubility of approximately 70% at 25°C. It is relatively insoluble in non-polar solvents.

Chemical name

1,2-dimethyl-3,5-diphenyl-1H-pyrazolium methyl sulfate has been assigned by Chemical Abstracts Service, Columbus, Ohio. The common name difenzoquat has been approved by the American National Standards Institute and the terminology committee of the Weed Science Society of America. Difenzoquat is also designated as AVENGE or FINAVEN, trademarks of American Cyanamid Company.

Chemical structure



Formulations

Difenzoquat has been tested primarily in liquid formulations containing 200, 250 or 400 g a.i./l. Soluble powder formulations containing 33%, 39% and 40% have also been tested.

Toxicity

The acute mammalian toxicity of technical grade difenzoquat and a standard liquid formulation is given below:

		LD50 mg/kg	
Species	Route	Technical	Formulation 250 g a.i./l.
Albino rat	Oral	470	422
Rabbit	Dermal	3540	>10,000
Rabbit	Eye irritation	Negative	Positive
Rabbit	Skin irritation	Negative	Negative

Greenhouse tests

Initial screening tests were performed on *Avena fatua* grown in flats under greenhouse conditions using a single overhead automatic traverse flat-fan nozzle that delivered 800 l./ha spray volume. Data were recorded 15 days and 5 weeks after application. Other flats containing additional weed species and several crops were also treated simultaneously and data recorded. Following the first promising results several months of detailed studies were conducted to define activity/structure relationships, dosage, timing, selectivity, formulation and weed spectrum parameters.

Field trials

Based on information developed in the greenhouse, an extensive field evaluation program was carried out in Europe, Mexico, Australia, Canada and the U.S. Experimental protocols employed standard field plot designs in cereal crops with a majority of the trials using 2 x 10 m plots with three or four replications. Several locations utilized log/dose applications and crop screen techniques. Uniform experimental protocols were utilized to provide detailed information on the following factors:

1. Dosage (exclusive of log trials): 0.3, 0.6, 0.9, 1.2 and 2.4 kg a.i./ha

2. Growth stage (wild oat): 2- to 3-leaf
   3- to 6-leaf
   fully tillered/stem elongation

3. Spray volumes: 25-50 l./ha (aircraft)
   100-800 l./ha (ground)

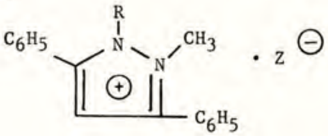
4. Crop selectivity: spring and winter wheat
   spring and winter barley
   rape
   sugar beet
   flax

5. Wetting agent: 0.05, 0.2 and 0.5% v/v
   ionic type
   solids vs. liquid

6. Growth conditions

RESULTS

Extensive structure activity studies were carried out to fully explore this interesting chemical series. The effect of N-substituents is clearly shown in the following series:



	R	Kg/ha to control wild oats
	H	>11
Difenzoquat	CH_3	0.14
	C_2H_5	1.1
	n-C_3H_7	4.5
	$CH_2CH{=}CH_2$	>11
	$CH_2C{\equiv}CH$	>11
	$CH_2CO_2C_2H_5$	11
	C_6H_5	>11
	$CH_2C_6H_5$	>11

Similar monosubstituents were also made on each phenyl group as well as an extensive screening of various salts. These studies led to the selection of difenzoquat as the compound of choice.

Typical data obtained from greenhouse studies is presented in Table 1. Treatments were made when the wild oats had 3 to 4 leaves and were rated 5 weeks after application using a 0 to 9 scale where 0 = no effect and 9 = complete kill. All treatments were made with 0.5% wetting agent added on a volume basis. The marked reduction in fresh weight of the wild oats treated with difenzoquat is indicative of a rather dramatic interruption of growth. By contrast the wheat and barley were essentially unaffected.

Table 1

Effects of difenzoquat on Avena fatua in wheat and barley in greenhouse studies - Princeton, N. J.

Difenzoquat (kg a.i./ha)	Avena fatua Herbicide index[1]	% Reduction fresh weight	Phytotoxicity index[1] Wheat	Barley
4.48	9.0	96	1	0
1.12	9.0	96	0	0
0.56	8.5	92	0	0
0.28	9.0	96	0	0
0.14	7.5	80	0	0

1. Herbicide and phytotoxicity index, 0 = no effect, 9 = complete kill.

The field evaluation program has been carried out on an international basis and covers the period from 1971 through 1974. Detailed reports on performance from certain European countries will appear elsewhere under Sections 2a and 3a of this Conference. From perhaps less than six field tests in 1971, the following list of trials by country shows the extent of the 1972 program:

Australia	(4)	France	(20)	Israel	(3)	Sweden	(5)
Belgium	(4)	W. Germany	(4)	Italy	(3)	Turkey	(2)
Canada	(20)	Greece	(2)	Mexico	(4)	United Kingdom	(20)
Denmark	(4)	Holland	(6)	Spain	(6)	United States	(14)
						Yugoslavia	(1)

Based on results of these tests expanded field trial programs were carried out during 1973 and 1974 in most countries where Avena spp. are a significant problem in cereal production. More than 500 replicated field trials were conducted during each of these last two years. From this wide-ranging program certain conclusions can be drawn.

Dosage - Depending upon wild oat infestation, growing conditions, crop density and competitiveness difenzoquat has given good to excellent control of wild oats at rates of 0.6 to 1.5 kg a.i./ha. The standard rate will be 1.0 kg a.i./ha in spring and winter barley and winter wheat and 0.75 kg a.i./ha in spring wheat. Representative results showing dosage and growth stage effects are given in Table 2.

Growth stage - At 1 kg a.i./ha difenzoquat effectively controls wild oats when applied at all growth stages from 2- to 3-leaf stage through early stem elongation. Optimum growth stage for application appears to be the 3- to 6-leaf stage.

Spray volume - As shown in Tables 3 and 4 good results may be obtained with spray applications ranging from 50 up to 400 l. of water/ha by ground sprayer. Similar results have been obtained with 25 to 50 l./ha by aircraft.

Crop selectivity - At 1 kg a.i./ha good crop selectivity has been obtained in the following crops:

barley (spring and winter)
wheat (winter)
rape (with variety exceptions)
flax
vetch

Spring wheat varieties are more sensitive to difenzoquat and special studies are needed before final recommendations can be made. Sugar beet is also sensitive at application rates required for wild oat control.

Table 2

Control of *Avena fatua* and *A. ludoviciana* in spring barley - Spain, 1972

Trial site I var. Pallas

Treatments[1]	Dosage (kg a.i./ha)	Wild oat control 3-4 leaf stage[2]	Crop injury[2]
Difenzoquat	1.25	7.0	0
	2.5	8.5	0
	5.0	9.0	0

Trial site II var. Pallas

Treatments[1]	Dosage (kg a.i./ha)	Wild oat control		Crop injury
		3-leaf[3]	5-7 leaf	
Difenzoquat	0.2	0	2.0	0
	0.3	0	4.0	0
	0.6	4.0	6.0	0
	0.8	5.0	7.0	0

Trial site III var. Toledo

Treatments[1]	Dosage (kg a.i./ha)	Wild oat control		Crop injury
		3-4 leaf	5-7 leaf[4]	
Difenzoquat	0.3	4.0	3.0	0
	0.6	8.0	6.0	0
Metoxuron	4.8	3.0	2.0	0
Benzoylprop ethyl	1.2	8.0	7.0	3

1. Spray volume, 500 l./ha.
2. Herbicide and crop injury index, 0 = no effect, 9 = complete kill.
3. Cold, dry and windy 3 weeks after application.
4. Cold weather after application.

Wetting agents - As with most post-emergence herbicides the spray solution must have special sticking, spreading and penetrating action to obtain acceptable herbicidal action. This is especially important with difenzoquat in the control of wild oats. Extensive studies in greenhouse and replicated field trials have confirmed the importance of ionic type and quantity of surfactant on wild oat control, crop selectivity and compatibility. The effect of adding different concentrations of two non-ionic wetting agents is shown in Table 5. Significant improvements in wild oat control can be noted with increasing concentration of wetting agent. Only normal variations between wetting agents are apparent. In this trial, doubling the spray volume by increasing spray pressure resulted in a significant improvement in wild oat control.

Growth conditions - The interaction of growth stage and growing conditions is shown in Table 2 where weather effects dominated growth-stage effects.

Table 3

Control of *Avena fatua* in barley with difenzoquat 250-AS liquid formulation at four spray volumes - Salamanca, Mexico, 1973

Difenzoquat (kg a.i./ha)	Spray volume (l./ha)	Wild oat control[1]
(Wild oats at 2-6 leaf stage)		
0.5	50	8.22 a
1.0	50	9.00 a
0.5	100	8.33 a
1.0	100	8.22 a
0.5	200	5.56 b
1.0	200	8.00 a
0.5	400	4.67 b
1.0	400	8.05 a
0	-	0.00 c

Coefficient of variation, 11.6%.
1. Herbicide index scale, 0 = no effect, 9 = complete kill based on wild oat spikelets.
Means with common letters are not significantly different at P=0.05, using Duncan's Multiple Range Test.

Table 4

Control of *Avena fatua* in wheat with difenzoquat 250-AS liquid formulation at four spray volumes - Pueblo Nuevo, Mexico, 1973

Difenzoquat (kg a.i./ha)	Spray volume (l./ha)	Wild oat control[1]
(Wild oats at 3-6 leaf stage)		
0.5	50	8.00 a
1.0	50	8.33 a
0.5	100	7.67 a
1.0	100	8.00 a
0.5	200	7.22 ab
1.0	200	8.00 a
0.5	400	6.22 c
1.0	400	8.22 a
0	-	0.00 d

Coefficient of variation, 8.4%
1. Herbicide index scale, 0 = no effect, 9 = complete kill based on wild oat spikelets.
Means with common letters are not significantly different at P=0.05, using Duncan's Multiple Range Test.

Table 5

Effect of wetting agents on Avena fatua control in spring barley with difenzoquat at 0.6 kg a.i./ha - United Kingdom, 1972

Treatments	% v/v in spray solution	Surviving spikelets % of untreated[1]	Wild oat control, %
In 200 l. water/ha			
Untreated		100 ($1644/m^2$)	
Agral	0.05	52.1 e	47.9
	0.2	27.9 cd	72.1
	0.5	13.0 b	87.0
Tergitol TMN	0.05	43.8 de	56.2
	0.2	30.2 cd	69.8
	0.5	19.6 bc	80.4
In 400 l. water/ha			
Tergitol TMN	0.5	4.4 a	93.6

1. Means with common letters are not significantly different at P=0.05, using Duncan's Multiple Range Test.

DISCUSSION

Based on the "tagged-plant technique," difenzoquat effectively controlled wild oats at all growth stages from 2- to 3-leaf through early stem elongation. Avena fatua, A. ludoviciana and A. sterilis appeared to be equally susceptible to foliar sprays with this compound. Under optimum growing conditions and good crop competition, 0.6 kg a.i./ha gave good control on 3- to 4-leaf stage wild oats, whereas 0.9 to 1.2 kg a.i./ha was needed with late applications or during cold dry weather conditions. Selectivity in spring and winter barley was excellent at all growth stages even at dosages up to 5.0 kg a.i./ha. Some transient leaf spotting was noted a few days after application, but crop development was normal through harvest. Winter wheat showed good tolerance of the herbicide but spring wheat was more sensitive with marked differences between varieties. Sugar beet was also sensitive as were certain varieties of spring rape.

The basis of herbicidal action and selectivity is not know but the compound is very specific on wild oat species and its lack of activity on other weed grasses is interesting. Visible symptoms of herbicidal action such as yellowing develop slowly, frequently requiring three to four weeks. However, there is evidence of rapid growth suppression which frequently results in treated wild oat plants having a dark green rosette appearance and many arrested tillers. As symptoms develop further there is progressive yellowing of leaves and stems which first appears at the leaf collar.

Frequently there is swelling, yellowing and necrosis of the basal stem area, all of which suggest chemical translocation to meristematic sites. The arrested growth and lateral proliferation of basal tissues are indicative that there has been a chemical influence on cell division and elongation. The tissue yellowing and necrosis would indicate an effect on some other vital physiological function. Similar symptoms have not been observed in wheat and barley but evidence of absorption and movement has been clearly shown with ^{14}C-labelled compound. Further studies are needed for a better understanding of the specific mode of action in wild oats in contrast to that in wheat, barley and other crops.

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Acknowledgement

Grateful acknowledgement is hereby given to all those involved in the stud referred to in this report.

BIFENOX: A SELECTIVE WEED KILLER

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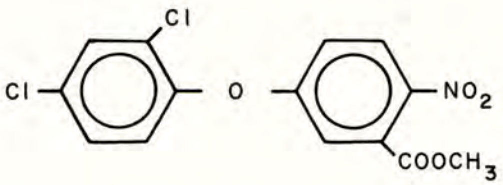
Summary Bifenox is the common name of a new pre-emergence herbicide, methyl 5-(2',4'-dichlorophenoxy)-2-nitrobenzoate. This herbicide, whose tradename is MODOWN™, has been tested world-wide under the code MC-4379. Dosage rates of 1.68 to 2.24 kg/ha are effective to control many annual dicotyledonous weeds and certain annual monocotyledonous weeds over a wide range of soil types and organic matter contents and under a variety of climatic conditions. Potential economic crop uses include soybeans, corn (*Zea mays*), grain sorghum, sunflower, safflower, barley, oats, wheat and rice. Bifenox is non-persistent, readily metabolized, possesses low mammalian toxicity, and is environmentally non-hazardous. Bifenox is a selective herbicide whose mode of action is principally through interference with the photosynthetic process.

INTRODUCTION

For the past four years, Mobil Chemical Company, a Division of Mobil Oil Corporation, has been developing bifenox herbicide (Figure 1), the American National Standards Institute's approved common name for methyl 5-(2',4'-dichlorophenoxy)-2-nitrobenzoate.

Figure 1

Chemical structure of bifenox



Methyl 5-(2',4'-dichlorophenoxy)-2-nitrobenzoate

The extensive field data that have thus far been compiled clearly show that this new herbicide is significantly effective in controlling many important annual broadleaf weeds and certain annual grasses in such crops as soybeans, corn (Zea mays), grain sorghum, sunflower, safflower, barley, oats, wheat and rice. Bifenox is available as an 80% wettable powder and an emulsifiable concentrate containing 908g/3.79l. active ingredient, under the trademark MODOWN™ herbicide (formerly coded as MC-4379).

This presentation will include toxicology, mode of action, metabolism and fate, residue, crop tolerance, weed control and label registration.

TOXICOLOGY

Acute toxicology

Table 1 summarizes the toxicity data which establish that bifenox offers a relatively low hazard to man and animals.

Table 1

Acute toxicology of bifenox

Test	Technical	908g/3.79l. e.c.	80% w.p.
Acute oral LD_{50} (Rat):	>6400 mg/kg	>1630 mg/kg	>10000 mg/kg
Acute oral LD_{50} (Mouse):	4556 mg/kg		
Acute dermal LD_{50} (Rabbit):	>20000 mg/kg	>20000 mg/kg	>10000 mg/kg
Acute inhalation LC_{50} (Rat):	>200 mg/l.	>200 mg/l.	>200 mg/l.
Primary eye irritant (Rabbit):	Negative	Positive	Negative
Primary skin irritant (Rabbit):	Negative	Negative	Positive (Mild)
Eight-day LC_{50} (Duck):	>5000 ppm		
Eight-day LC_{50} (Pheasant):	>5000 ppm		
Four-day TL_{50} (Trout):	0.87 ppm	2.55 ppm	
Four-day TL_{50} (Bluegill):	0.64 ppm	1.8 ppm	
Crayfish (Procambarus blandingi):	>1000 ppm	5 ppm	>1000 ppm

Chronic toxicology

Rats and dogs fed diets containing as much as 500 ppm bifenox technical for 90 days did not differ from the control animals in any of the following:

Body weights	Blood chemistry studies
Food consumption	Urine analyses
Behavioral reactions	Organ weights
Mortality	Gross pathologic studies
Hematologic studies	Histopathologic studies

Teratogenic studies at 100 ppm and mutagenic studies at 500 ppm in rats and mice respectively were negative.

MODE OF ACTION

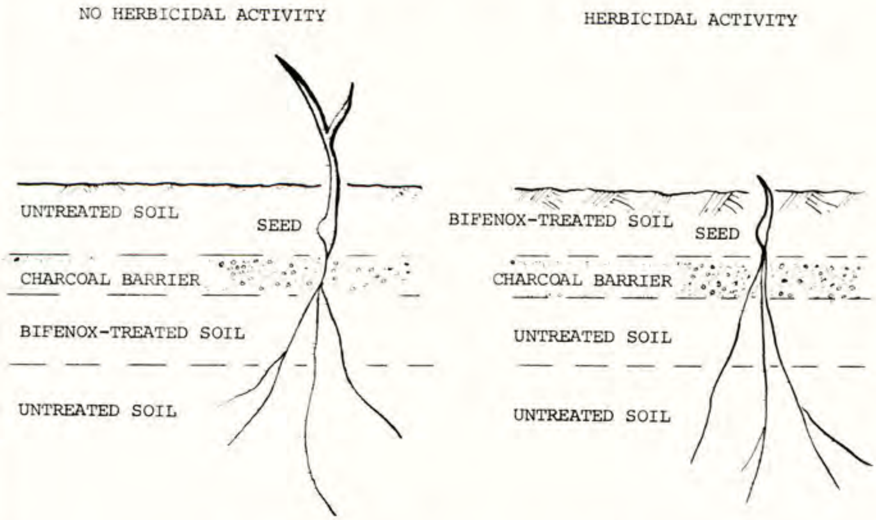
Bifenox herbicide can act by inhibition of either photosynthesis or plant respiration. Using test methods described in earlier work on the mode of action of herbicides (Moreland et al., 1970), at the Agricultural Research Service, U. S. D. A. Raleigh, North Carolina, found bifenox a strong inhibitor of electron transport in a mitochondrial system. The I_{50} value for state 3 respiration inhibition with maleate as substrate is 2.3×10^{-5} M. The value for inhibition of noncyclic electron transport and coupled photophosphorylation in isolated chloroplasts is estimated to be approximately 1.5×10^{-5} M.

In a laboratory experiment, Digitaria sanguinalis (large crabgrass) was grown in soil treated pre-emergence at 1.68 kg/ha. Plants kept in the dark for 4 days were tolerant to bifenox; plants kept in a comparable flat exposed to sunlight for 4 days in the greenhouse died.

Bifenox is absorbed by the weed seedlings as they grow through it. Activity through root absorption is minimal. Experiments similar to that illustrated in Figure 2 demonstrated that when exposure of Digitaria sanguinalis to bifenox was restricted to the roots of the plant through the use of a charcoal barrier, the plant was not injured. However, when the plant shoot passed through bifenox on the soil surface, adsorption on the shoot or hypocotyl killed the weed.

Figure 2

Response of crabgrass following selective exposure of roots and shoots to bifenox-treated soil



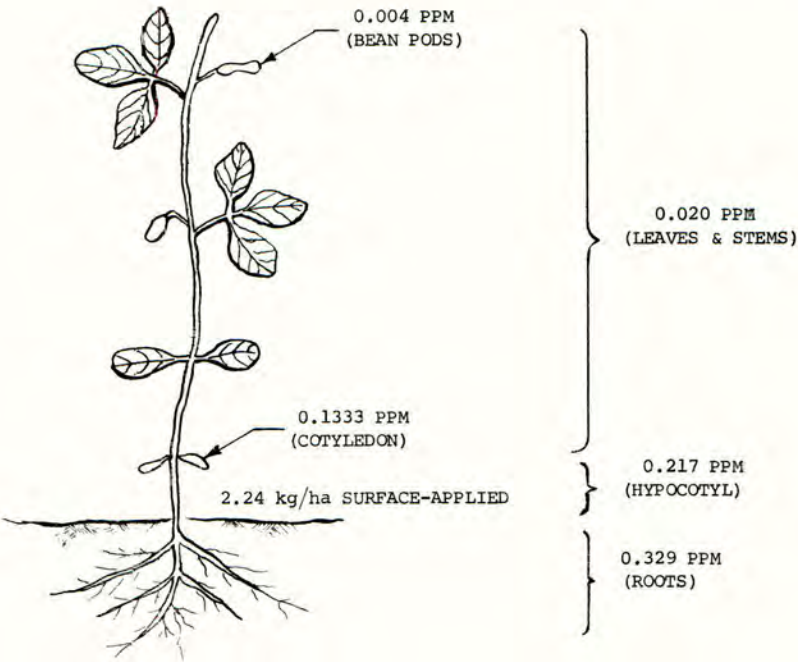
METABOLISM AND FATE IN PLANTS AND SOIL

In laboratory studies with radioactive bifenox, the compound had a half-life of 5 to 7 days in the soil. Nutrient solution studies on soybean with the compound radio-labelled in three parts of the molecule showed little translocation from the roots of corn and soybean.

Figure 3 shows a typical distribution of radioactivity when soybeans are grown in soil surface-treated with 2.24 kg/ha of bifenox. This study confirms the nutrient solution observations. Thin-layer chromatography indicates that the radioactivity is largely in plant conjugate form, bound to the roots and unable to translocate. The distribution of radioactivity is closely correlated to the period of intimacy of the parts of the plant to the bifenox layer on the soil.

Figure 3

Distribution of radioactivity after 63 days in soybean treated at 2.24 kg/ha surface-applied



Field and laboratory data show that bifenox is not a persistent or easily leached chemical. The chemical's half-life in field studies is between 7 and 14 days under conditions favourable for biological processes. As a result the herbicide effectiveness is 7 to 8 weeks. Leaching is not a factor in reducing the residue of the chemical in the soil. The water solubility of bifenox is 0.35 ppm at 25°C. Bifenox is relatively stable to ultraviolet light (290 - 400 nm), and in aqueous solutions under medium acidic to slightly basic conditions at room temperatures. Chemical and microbiological factors are responsible for loss of the chemical.

RESIDUE STUDIES

Over 750 soybean, corn, grain sorghum, sunflower, safflower, wheat, oats, barley and rice crop samples were analysed for bifenox residues using gas chromatography. No residues of bifenox or its four principal metabolites were found in the seeds of soybean, corn (Zea mays), grain sorghum, sunflower, safflower, barley, oats, wheat or rice using a method sensitive to 0.05 ppm (Melnizek, 1972). More than 50% of these samples were from excess rate treatments as high as 4X. A temporary negligible tolerance of 0.05 ppm for bifenox in and on soybean and corn has been established by the United States Environmental Protection Agency. This 0.05 ppm level will be adequate to cover residues which might result from the use of bifenox. Radiotracer studies have shown that total radioactive residues are of the order of 0.02 - 0.03 ppm.

CROP TOLERANCE

General pre-emergence use rates have been determined for the tolerant crops listed in Table 2.

Table 2

Recommended dose rates of bifenox for tolerant crops

Crops	Active ingredient rate (kg/ha)
Soybeans, Corn, Sorghum, Sunflower, Safflower	1.68 - 2.24 pre-emergence
Small grains	1.12 - 1.68 pre-emergence 0.28 - 0.84 post-emergence
Rice	1.68 - 3.36 pre-emergence 1.12 - 2.24 post-emergence

Heavy rainfall soon after crop emergence may cause temporary crop injury on soybeans, corn and sorghum. This occurs usually as a result of splashing treated soil onto the lower leaves of newly emerged plants. Temporary stunting may occur. In soybeans, there may be leaf crinkling while in corn and sorghum a transverse chlorotic band may appear on the lower leaves. This effect is temporary and the crop soon grows out of it. Yields are not adversely affected. No significant varietal differences in tolerance to bifenox have been found in tests with soybeans, corn, sorghum and rice. Table 3 shows crops which have very marginal tolerance or are susceptible to bifenox.

Table 3

Susceptible crops

Sugar beets	Leafy vegetables
Cucurbits	Tobacco
Cotton	Tomatoes
Cole crops	Potatoes

WEED CONTROL

During 1974, Mobil has worked with well over 150 co-operators in thirty-five countries. In addition, MODOWN herbicide was used commercially under an experimental permit in 18 states on soybeans and field corn in the U. S. during 1974. Efficacy data received from these trials show excellent pre-emergence activity from surface applications on many important annual broadleaf weeds (Table 4) and good control of certain annual grasses Table 5.

Table 4

Susceptible broadleaf weeds

Abutilon theophrasti	velvetleaf
Alisma plantago-aquatica	waterplantain
Alternanthera philoxeroides	alligatorweed
Amaranthus spp.	pigweed
Argemone mexicana	Mexican pricklepoppy
Baptisia tinctoria	wild indigo
Brassica spp.	mustard
Chenopodium album	lambsquarters
Commelina communis	dayflower
Datura stramonium	jimsonweed
Fumaria officinalis	fumitory
Heteranthera spp.	ducksalad
Ipomoea hederacea	ivyleaf morningglory
Kochia scoparia	kochia
Ludwigia spp.	false loosetrife
Malva neglecta	common mallow
Polygonum aviculare	prostrate knotweed
Polygonum pensylvanicum	pennsylvania smartweed
Portulaca spp.	purslane
Sagittaria spp.	arrowhead
Sesbania exaltata	hemp sesbania
Sida spinosa	prickly sida
Solanum nigrum	black nightshade
Sphenoclea zeylanica	gooseweed
Vernonia spp.	ironweed
Xanthium spp.	cocklebur

Table 5

Susceptible sedges and grasses

Brachiaria platyphylla	broadleaf signalgrass
Cyperus iria	rice flatsedge
Cyperus spp.	sedge
Digitaria spp.	crabgrass
Echinochloa colonum	jungle-rice
Eleocharis acicularis	slender spikerush
Eriochloa gracilis	cupgrass
Eragrostis pilosa	India lovegrass
Echinochloa crus-galli	barnyard grass
Leptochloa uninervia	Mexican sprangletop
Leptochloa filiformis	red sprangletop
Panicum dichotomiflorum	fall panicum

Since it is not necessary for moisture to move bifenox into the soil where it can be taken up by root absorption, performance is less affected by weather conditions than that of most pre-emergence herbicides. Moisture, however, is essential in the treated soil surface as weeds grow through it. Bifenox provides effective weed control on soils of varying organic matter and texture. Residual activity appears to be shorter under tropical conditions than under temperate conditions. Persistence of activity ranges from 5 - 8 weeks. Surface applications give better results than soil incorporation. Combinations with effective grass herbicides such as alachlor and trifluralin increase the spectrum of weed control activity.

U. S. LABEL REGISTRATION STATUS

In the fall of 1973, the U. S. Environmental Protection Agency granted Mobil an experimental permit for the use of bifenox as a pre-emergence broadleaf weed herbicide for use in soybeans and field corn. The 80% wettable powder and 908g/3.791. emulsifiable concentrate formulations of MODOWN herbicide were included in the permit. MODOWN herbicide was sold under the temporary permit during 1974. Full registration is expected on soybeans and corn prior to the 1975 season. Temporary permits have been requested for the use of bifenox on grain sorghum, rice and small grains (oats, wheat and barley). These additional experimental permits are also expected prior to the 1975 season. Registrations are pending as well in countries outside the U. S.

Acknowledgements

Appreciation is expressed to Mobil Chemical Research personnel who assisted in accumulation of these data, including A. J. Huvar, W. A. Embry and J. Garlick and to Dr. D. E. Moreland for the use of his unpublished data.

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NOTES

CHARACTERISTICS AND FIELD PERFORMANCE OF A NEW SELECTIVE HERBICIDE FOR WEED CONTROL IN SUGARCANE

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Summary Tebuthiuron, N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea, has been widely tested during the past four years in the United States, Brazil, Australia and the Philippines. Commercially acceptable control of a broad spectrum of annual broadleaf and grassy weeds was observed when an 80% wettable powder formulation was diluted and applied as a spray either pre-emergence or early post-emergence to weeds in the 2-3 leaf stage. The effective dosage range was found to be between 1.0 and 2.0 kg a.i./ha depending on soil texture and geographical area. Tebuthiuron has demonstrated longer residual control than many commonly used pre-emergence herbicides under conditions of high rainfall and temperature.

INTRODUCTION

Tebuthiuron, a new pre-emergence herbicide for sugarcane, has been field tested in a number of major sugarcane growing areas of the world over the past four years by Eli Lilly and Company scientists. Tebuthiuron is chemically N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea and has been tested under the code EL-103.

This paper is a summary of the characteristics and field trial results obtained to date.

Technical tebuthiuron is a white solid with a melting point of 159-161°C. It is light-stable and non-corrosive to metal, polyethylene and spray equipment. The solubility of tebuthiuron in various solvents at 25°C is as follows:

Solvent	Solubility (mg/ml)
Acetone	70
Acetonitrile	60
Benzene	3.7
Chloroform	250
Ethylacetate	20
Hexane	6.1
Methyl alcohol	170
Methyl cellosolve	60
Water pH 7	2.5

Data available on the toxicology of EL-103 technical material are as follows:

Oral Acute-Mouse:	LD_{50} 600 mg/kg
Rat:	LD_{50} 600 mg/kg
Dog:	LD_0 >500 mg/kg
Cat:	LD_0 >500 mg/kg
Chicken, quail, duck:	LD_0 >500 mg/kg
Trout:	TL_{50} 144 ppm
Bluegill:	TL_{50} 112 ppm
Dermal-Rabbit:	200 mg/kg, no dermal irritation
Eye-Rabbit:	71 mg/eye produced no significant effects

Oral Subacute-3 Months:

Rat:	No effect level-1000 ppm
Dog:	No effect level-1000 ppm

30 Days:

Chicken:	No detectable signs of toxicity when fed at a level of 1000 ppm

Rats, rabbits, dogs, mallard ducks and fish rapidly absorb, metabolize and excrete tebuthiuron through the kidneys. There is no major binding of tebuthiuron or its metabolites in animal tissues. Tebuthiuron was non-teratogenic in the rat when fed at a dose of 1800 ppm, which was the highest concentration tested. The toxicity of tebuthiuron when formulated as an 80% wettable powder was similar to that of technical tebuthiuron.

MATERIALS AND METHODS

Field trials were established with tebuthiuron on both plant and ratoon sugarcane in the United States, Brazil, Australia and the Philippines. Tebuthiuron was formulated as an 80% wettable powder and applied as a surface spray both pre-emergence and post-emergence to sugarcane and weeds. Trials were conducted over a wide range of sugarcane varieties and soil textures.

The experiments were of a randomized block design with three or four replications and a plot size of 50 m^2 or more. All herbicide applications were made with research-type application equipment.

RESULTS

Brazil

A total of 24 replicated experiments was conducted by Van der Schans et al. (1974) in Brazil during 1971-1973 involving application of tebuthiuron to both plant and ratoon sugarcane. Tebuthiuron was applied as a broadcast application at doses of 0.6, 0.8, 1.0, 1.2, 2.4 and 4.8 kg a.i./ha. Currently used herbicides were included as reference standards at the doses recommended by the manufacturer.

Commercially acceptable control of all annual grass and broadleaf weeds found in the trials was achieved in both plant and ratoon sugarcane under conditions where soil moisture was adequate to activate a surface-applied herbicide. The dose required was found to be 1 kg/ha on soils of medium texture and 1.2 kg/ha on heavy soils.

Under conditions of low rainfall where some weeds germinated following application, a mechanical cultivation was used successfully to remove the weeds present and activate tebuthiuron so that the expected duration of weed control was achieved. The duration of weed control observed with tebuthiuron was consistently longer than that obtained with 2,4-D amine, diuron, atrazine, ametryne and alachlor.

Perennial Cyperus species were not controlled in any of the trials by tebuthiuron. Tebuthiuron gave commercially acceptable control of all annual weeds found in the trials as an early post-emergence application up to the 2-3 leaf stage.

Plant sugarcane was observed to be tolerant to twice to three times the dose required to give commercially acceptable weed control. Typical evidence of photosynthetic inhibition was occasionally observed in trials where 4.8 kg a.i./ha had been applied to plant sugarcane. No evidence of phytotoxicity was observed at any dose in any of the ratoon sugarcane trials.

Australia

Eleven experiments have been conducted in the eastern Queensland sugarcane growing areas in Australia by Guse et al. (1974). The results to date have been very similar to those reported for Brazil. One difference is that there is a late-season weed problem caused by blue billygoat weed (Ageratum houstonianum) which interferes with the burn in the sugarcane fields at harvest time. Tebuthiuron has controlled this weed successfully at harvest time by pre-emergence applications of 1-1.5 kg a.i./ha.

The Philippine Islands

Ten replicated field trials have been conducted on the island of Negros in the Philippine islands by Bandong et al. (1974) with tebuthiuron on plant and ratoon sugarcane. Commercially acceptable control of a broad spectrum of annual grasses and broadleaf weeds has been obtained consistently with 1.2 kg a.i./ha. No phytotoxicity to sugarcane has been observed either in plant cane or ratoon cane from applications of tebuthiuron up to 4.8 kg/ha.

United States

A total of 13 replicated field trials has been conducted in Louisiana by Pafford (1974) on plant and ratoon sugarcane, treating a 76-cm band according to local practice. In plant cane, single spraying treatments were compared with a split application of a fall and spring treatment. Commercially acceptable weed control was achieved when tebuthiuron was applied at the following doses, expressed as kg/ha on a broadcast basis:

Soil texture	Plant cane Spring & fall	Plant or ratoon cane Spring only
Light	0.5 + 0.5-0.75	0.75-1
Medium	0.75 + 0.75-1	1-1.5
Heavy	1 + 1-1.25	1.5-2

DISCUSSION

Tebuthiuron appears to offer a major advantage over many other pre-emergence herbicides where longer residual weed control is desired. However, the long residual activity of tebuthiuron and the lack of selectivity exhibited by most row crops make this herbicide unsuitable for use in cane fields where inter-cropping is planned. It is also apparent that cultivation and subsequent treatments with 2,4-D or other herbicides will be required when tebuthiuron is used in areas infested with perennial *Cyperus* species.

Tebuthiuron appears to be readily absorbed through the root system, and plant toxicity symptoms suggest that it is an inhibitor of photosynthesis. Vertical leaching studies conducted under field conditions indicate that tebuthiuron leaches very slowly with most of the chemical remaining in the top 15 cm of soil. C^{14} studies conducted to date are indicative of microbial degradation as the main means of dissipation from soil. The pattern of degradation in soil is relatively slow compared to other substituted urea herbicides. Further research is under way to establish the rate of degradation under conditions in the major areas of expected commercial use.

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Proceedings 12th British Weed Control Conference (1974)

CYPERQUAT, 1-METHYL-4-PHENYLPYRIDINIUM CHLORIDE, FOR THE CONTROL OF NUTSEDGE (CYPERUS SPP.)

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Summary Cyperquat (formerly S-21634), 1-methyl-4-phenylpyridinium chloride, is a new post-emergence herbicide discovered and developed by Gulf Oil Chemicals Company. Cyperquat specifically controls both purple (C. rotundus) and yellow nutsedge (C. esculentus). Foliar sprays at the 6-9 leaf stage and at rates of 2-4 lb/ac in at least 20 gal of water are effective in causing top kill and inhibiting regrowth from the tubers. Growing conditions determine the optimum rate. Combinations with other herbicides such as 2,4-D, 2,4-DB or fenoprop (silvex) improve the downward translocation and thus the effectiveness. Species showing the most tolerance to cyperquat are peanuts, soybeans, rice, potatoes, strawberries, various turf grasses and some ornamental crops. Cyperquat has not been tested on other Cyperus spp., and consistent control of weeds other than nutsedge has not been observed. There is no pre-emergence activity.

Résumé Le cyperquat (antérieurement S-21634), chlorure de 1-méthyl-4-phénylpyridinium, est un nouvel herbicide de post-émergence découvert et mis au point par la Cie Gulf Oil Chemicals. Le cyperquat est spécifique pour la répression du souchet pourpre (C. rotundus) et du souchet comestible (C. esculentus). Des applications foliaires au stade de la 6e à la 9e feuille et à des doses de 2.2 à 4.4 kg dans au moins 225 litres d'eau par ha, ont tué le feuillage et empêché la germination des bulbilles. Les conditions de croissance déterminent les doses optimales. Des mélanges avec d'autres herbicides tels le 2,4-D, le 2,4-DB ou ce fenoprop (silvex) ont amélioré la translocation vers les racines et par consequent l'efficacité. Les cultures démonstrant le plus de tolérance envers le S-21634 sont: les arachides, le soya, le riz, les pommes de terre, les fraises, diverses espèces de graminées à gazon et quelques plantes ornementales. Le cyperquat n'a pas été essayé sur d'autres espèces de Cyperus. On n'a pas observé une répression persistante d'autres adventices que le souchet. Il n'y a pas d'activité de pré-émergence.

INTRODUCTION

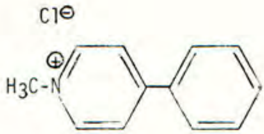
Cyperus spp. are increasing as a weed problem in most states of the United States in addition to being considered by some as the world's worst weed.

In 1971 during the screening of new chemicals for their herbicidal activity we discovered that yellow and purple nutsedge (Cyperus esculentus and C. rotundus) were susceptible to post-emergence treatments of cyperquat. Succeeding tests in the greenhouse and field have shown its utility and selectivity in being specific for nutsedge species.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical structure

(British Patent 1,341,802)



1-methyl-4-phenylpyridinium chloride

Formulation

3 lb a.i./U.S. gal emulsifiable concentrate

Solubility of technical material (% w/w)

Water	infinite	Acetone	0.12
Ethanol	34.25	Benzene	0.03

Handling characteristics

Aqueous formulation - no known handling difficulties.

Special precautions

Avoid contact by ingestion, inhalation or skin absorption since this material may be poisonous through these methods of contact. Protective measures should include protective clothing, goggles, respirator and rubber gloves. Wash skin thoroughly following application of this material.

TOXICOLOGY

Toxicity of cyperquat technical

Acute oral LD_{50} in albino rats	35.1 mg/kg
Acute dermal LD_{50} in albino rabbits	23.7 mg/kg
Acute dermal LD_{50} in albino rats	2025 mg/kg
Acute dermal LD_{50} in monkeys	>3038 mg/kg
Acute aerosol inhalation	
Median lethal concentration in rats	34.9 mg/l. (air)
Eye irritation in rabbits 17.0/110.0 - mildly irritating	
Primary skin irritation in rabbits 4.5/8.0 - moderately irritating	
96-hr TL_{50} in rainbow trout	50.9 ppm
96-hr TL_{50} in bluegill	12.7 ppm
8-Day dietary LC_{50} in bobwhite quail	312.5 ppm
8-Day dietary LC_{50} in mallard ducks	1350 ppm

Toxicity of formulation (3 lb cyperquat/U.S. gal)

Acute dermal LD_{50} in albino rabbits	267 mg/kg

GREENHOUSE TRIALS

On actively growing nutsedge chlorosis develops at the base of the leaves in 3-5 days after spraying. Subsequently, chlorosis moves toward the leaf tip and necrosis follows within 2-4 weeks. Weed control evaluations are more meaningful when made at 4 or more weeks after treatment.

Growth from tubers connected by stolons or rhizomes to the sprayed plant may be severely retarded and may or may not appear above ground depending on moisture and other environmental factors. It should be noted that connected tubers that are "dormant", i.e. have no shoots, may emerge under favorable conditions. Tubers which are not connected to the sprayed plant are not affected.

We have conducted many greenhouse and growth chamber experiments to study the various factors affecting the performance of cyperquat.

Nutsedge was sprayed at different stages of growth in several experiments and results showed that treatment in the 6-9 leaf stage with 3-6 lb/ac of cyperquat gives total kill. Higher rates were needed when sprayed past this stage. Total kill of nutsedge plants when sprayed before the 6-9 leaf stage was not as good, even though top growth could be killed with as little as 1 lb/ac of cyperquat. We interpret these latter results to indicate that there is a certain minimum leaf area or absorbing surface required, along with sufficient plant development, to allow for optimum translocation, in order to achieve total kill of nutsedge.

Another factor studied biologically was the rapidity of cyperquat absorption. This was shown by spraying a series of nutsedge plants in the 6-9 leaf stage with 2 lb/ac of cyperquat. Different lots of the sprayed plants were then subjected to simulated rainfall immediately, and at 1, 2, 4, 8 and 16 h after treatment. The results showed that, if there was no rainfall washing off the chemical within 4 h, acceptable kill was obtained.

Once the spray solution comes in contact with the soil it becomes inactive biologically and consequently there is no pre-emergence activity.

To study translocation a series of nutsedge plants in the 6-9 leaf stage were sprayed at 2 lb/ac. Immediately thereafter, and at 1, 2, 4 and 8 days, the foliage of different lots of the treated plants was cut off at the soil surface. Lack of regrowth indicated that a lethal dose of cyperquat had translocated from the foliage to the tubers prior to removal of the above-ground portion. On the basis of these results, under this one set of growing conditions, it took about 8 days for translocation of a lethal dose to the tubers.

Growth chamber tests were conducted in which temperature, light intensity and relative humidity conditions were varied in growing nutsedge which had been sprayed with cyperquat. Results showed that nutsedge grown at a temperature of 80° F or above, under high light intensity, a relative humidity of 70% or greater, and a constant supply of adequate soil moisture was the easiest to kill with cyperquat. All these conditions are necessary for nutsedge to have active growth and this is when best control can be realized. On the other hand, nutsedge plants reared under conditions of low temperature, low light intensity, and low relative humidity were more difficult to kill at equivalent rates.

Equally effective activity was observed at spray volume dilutions from 10 to 160 gal/ac of water. In a few cases more regrowth occurred at 10 gal/ac.

A listing of response of weed and crop species to post-emergence applications of cyperquat appears in Table 1.

Combinations with herbicides or growth regulators which translocate downward to the tubers, such as 2,4-D, 2,4-DB or fenoprop usually improve the effectiveness of cyperquat. Nutsedge plants cut off at the soil surface within 4 days after treatment may not be controlled. Heavy rains within 4 h after treatment may also reduce control. Control is enhanced by covering treated plants with soil.

Table 1

Response of weed and crop species to post-emergence application of cyperquat

Plant species		Response*	
Common name	Scientific name	3 lb/ac	1 lb/ac
Weeds:			
Pigweed	*Amaranthus retroflexus*	1	0
Lambsquarter	*Chenopodium album*	1	0
Wild buckwheat	*Polygonum convolvulus*	3	2
Wild mustard	*Brassica kaber*	1	0
Cocklebur	*Xanthium pensylvanicum*	1	0
Morningglory	*Ipomoea purpurea*	1	0
Crabgrass	*Digitaria sanguinalis*	2	1
Downy brome	*Bromus tectorum*	0	0
Giant foxtail	*Setaria faberii*	1	0
Barnyardgrass	*Echinochloa crusgalli*	2	0
Green foxtail	*Setaria viridis*	2	0
Wild cane	*Sorghum bicolor*	1	0
Wild oats	*Avena fatua*	0	0
Purple nutsedge	*Cyperus rotundus*	4	4
Yellow nutsedge	*Cyperus esculentus*	4	4
Agronomic crops:			
Cotton	*Gossypium herbaceum*	2	1
Peanuts	*Arachis hypogaea*	0	0
Tomato	*Lycopersicum esculentum*	2	1
Sugar beets	*Beta vulgaris*	1	1
Soybean	*Glycine max*	1	0
Alfalfa	*Medicago sativa*	1	0
Strawberry	*Fragaria chiloensis*	0	0
Corn	*Zea mays*	1	0
Grain sorghum	*Sorghum vulgare*	1	0
Wheat	*Triticum aestivum*	0	0
Rice	*Oryza sativa*	0	0
Ornamental crops:			
Andora juniper	*Juniperus communis*	0	0
California privet	*Ligustrum ovalifolium*	0	0
Forsythia	*Forsythia suspensa*	0	0
Japanese holly	*Ilex crenata*	0	0
Japanese yew (Cottage garden)	*Taxus sp.*	0	0
Timber crops:			
Loblolly pine seedlings	*Pinus taeda*	1	0

*0 = no injury; 4 = complete control

FIELD WORK

Replicated field plot studies were conducted during 1972 and 1973 in corn, cotton, peanuts, turf and a limited number of ornamental species throughout the U.S. and Canada. Many other unreplicated tests were also conducted on a total of 31 additional crops.

Tests in field corn throughout midwestern U.S. showed that acceptable nutsedge control was achieved at 2-4 lb/ac. The lower rate was just as effective as the higher rate at those locations where the nutsedge was in the proper stage of growth and where growing conditions were optimum at the time of treatment. The higher rate was required where the nutsedge was in an advanced stage of growth and/or where growing conditions at the time of treatment were less than optimal. At one location the broadcast method of application resulted in a slight but significant improvement in nutsedge control as compared to the directed method.

In only one experiment out of six did the broadcast method cause statistically significant corn injury as compared to a directed spray, and in this case there was no adverse effect on yields.

Results in soybeans were similar to those in corn where excellent nutsedge control was obtained at 2-4 lb/ac, and in one of two tests temporary soybean injury was seen as a result of a broadcast treatment. Directed and broadcast sprays were equivalent in effectiveness, and there was no effect on yields.

Tests in cotton in southeastern U.S. showed 2-6 lb/ac of cyperquat were necessary for control, because of the advanced stage of growth of the nutsedge at the time of treatment.

Younger cotton was more sensitive to cyperquat than older cotton. However, there was no relation between the degree of injury and the method of application (i.e., broadcast vs. directed sprays).

In twelve experiments conducted with peanuts, eleven at 4 lb/ac, cyperquat gave excellent control of nutsedge. Variations in spray volume did not significantly influence the degree of control.

Inclusion of the herbicide 2,4-DB or the fungicide Bravo (chlorothalonil) in the treatment neither enhanced nor decreased the activity as compared to that of each of the components alone. Compatibility of the mixtures was thereby demonstrated.

In all experiments the lack of injury to peanuts plus the yield data support the conclusion that cyperquat at rates up to 6 lb/ac a.i. is non-phytotoxic to peanuts.

Work conducted by co-operators throughout the U.S. and Canada using cyperquat at rates of 2 to 6 lb/ac active ingredient revealed the following information. In one-half of all of the tests, acceptable weed control was obtained at 3 lb/ac and in 80% of the trials acceptable control was obtained at 4 lb/ac. These trial results represent all testing, including those tests when spraying was not made at the optimum time. Most of the crops showed tolerance to cyperquat. A listing of the relative tolerance of crops to rates of cyperquat necessary for nutsedge control is given in Table 2.

Table 2

Relative tolerance of crops to rates of cyperquat necessary for nutsedge control

	Good	
alfalfa	oats	rice
barley	onions	rye
bromegrass	peanuts	strawberries
field corn	pine seedlings	turf grasses
sweet corn	potatoes	wheat
	Moderate	
carrots	lettuce	peas
cotton	green beans	soybeans
	Poor	
cucumbers	squash	sunflower
grain sorghum	sudan grass	tomatoes
melon	sugar beets	

Turf grasses in tests throughout the United States were shown to be tolerant to a single application of up to 5 lb/ac or a split application totalling 6 lb/ac. Grasses which were tolerant were common bermuda, Tifgreen bermuda, Ormand bermuda, FB-137 bermuda (*Cynodon dactylon*), Emerald and Meyer zoysiagrass (*Zoysia tenuifolia*), tall fescue (*Festuca arundinacea*), common and Merion Kentucky bluegrass (*Poa pratensis*), St. Augustinegrass (*Stenotaphrum secundatum*), and centipedegrass (*Eremochloa ephiruroides*).