SESSION 7C

APPLIED ASPECTS OF WEED CONTROL

SESSION
ORGANISER MR J. D. FORREST

RESEARCH REPORTS
(Poster papers) 7C-26 to 7C-38

BAS 517H:A NEW POST-EMERGENCE HERBICIDE FOR ANNUAL AND PERENNIAL GRASS WEED CONTROL IN BROAD-LEAVED CROPS - UK TRIALS RESULTS

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ABSTRACT

BAS 517H is a new post-emergence graminicide with excellent selectivity in broad leaved crops. Two years of UK trials have shown high levels of activity against the annual and perennial grass weeds Avena fatua, Alopecurus myosuroides, Lolium perenne,volunteer cereals, Agrostis gigantea, and Elymus repens. Optimum control of annual grass weeds was achieved with BAS 517H at 0.15kg a.i./ha, although under colder conditions, increasing the rate to 0.2kg a.i./ha has resulted in a slightly increased speed of activity.

A rate of 0.5kg a.i./ha gave good control of perennial grass weeds, although particularly severe infestations of E. repens required a second application.

Increasing the rate of adjuvant resulted in an increased speed of activity, though final levels of weed control remained constant.

INTRODUCTION

BAS 517H is a new systemic graminicide currently being developed by BASF worldwide. The product has mainly post-emergence activity, although some effects from pre-emergence application have been seen in pot experiments. However, no pre-emergence activity has been detected in UK field trials.

The product has shown excellent activity against annual and perennial grass weeds with a high degree of selectivity to broad leaved crops. This paper reports on the results from 41 field trials performed in the UK over a period of two seasons.

METHODS AND MATERIALS

Trial design:

All finite plot trials employed a randomised block design with 3 replicates and a plot size of $17m^2$. Treatments in logarithmic dilution trials were applied as strips replicated twice with a plot size of $80m^2$.

Application:

The treatments were applied using a Van der Weij knapsack sprayer. Water volumes of 250 l/ha and 80 l/ha were achieved using Birchmeir Hellico Sapphire 6673a and Spraying Systems Tee Jet TX3 hollow cone nozzles respectively. All treatments were applied in a water volume of 250 l/ha except where stated, and at a nozzle pressure of 2.5 bars. The trial to examine varying rates of adjuvants was applied using the logarithmic dilution technique.

Assessments:

Weed control was assessed as a percentage reduction in green tissue relative to the untreated plots.

Materials

Material	Concentration
BAS 517H	0.2kg a.i./l
Fluazifop-p-butyl	0.125kg a.i./l
Quizalofop-ethyl	0.5kg a.i./l
Sethoxydim	0.193kg a.i./l
Alkylarylpolyglycol ether	99-100%
Mineral oil	97%
Di-l-p-methene	96%
Alkylphenol	90%
Emulsifiable paraffinic oil	99%

The chemical and physical properties and toxicology data of BAS 517H are given elsewhere in these proceedings. (Meyer N, et al 1985)

Adjuvants:

In trials to examine biological efficacy all BAS 517H treatments were applied with a 97% mineral oil as 0.8% of the total spray volume with the exception of the trial to examine adjuvants, whilst standard treatments were applied with the appropriate recommended adjuvant. In trials to examine selectivity, rates of adjuvant were increased proportionally to the rate of graminicide.

Crops and cultivars in the trials

Crops	Cultivars		
Sugar beet	Monoire	Regina	Amethyst
	Salohill	Novogeno	Samson
	Nomo	Julia	
Potatoes	Wilja	Estima	
	Crown	Maris Piper	
Swedes	Ruta Otofte		
Oilseed rape	Rafal	Bienvenu	
Peas	Birte	Belinda	Miranda
	Progreta	Scout	Maro
	Sprite	Imposant	Dark Skinned Perfection
	Rigel	Hurst Beagle	Stehgolt
	Vedette	Solara	Bikini
	Consort	Finale	Markana
	Palla	Waverex	

RESULTS

Selectivity

BAS 517H + mineral oil was shown to be selective in sugar beet, peas and potatoes at rates of at least twice that required to achieve effective control of perennial grass weeds in UK trials. Further rate increases in peas occasionally resulted in a slight de-waxing of the foliage. This effect, which was probably due to the excessive rate of oil in the treatment, was soon outgrown by the crop. Triple rate (1.5kg a.i./ha) applied to peas at flowering was safe on all cultivars tested.

Adjuvants

The rate of selected adjuvants required for maximum control of A.fatua in combination with BAS 517H at 0.2 kg a.i./ha 3 weeks after application can be seen in Figure 1. Substantial variation with rates was apparent at this assessment, although 6 weeks after application, 100% weed control was achieved with all rates of adjuvant.

Annual grass weed control

Table 1:
% control of annual grass weeds in oilseed rape

		Volunteer barley		Volunteer wheat		A.myosuroides		A.fatua	
No.of sites		1		1		1		1	
Assessment time:		a	b	a	b	a	b	a	b
% grass weed cover on untreated		17	13	15	9	25	50	32	13
Chemical	Rate (kg a.i./ha)								
BAS 517H	0.1	79	97	85	94	94	100	96	100
BAS 517H	0.15	98	99	91	100	94	100	97	100
BAS 517H	0.2	99	100	91	100	97	100	98	100
Fluazifop-p-butyl	0.125	99	100			90	99	93	99
Fluazifop-p-butyl	0.188			96	100				
Quizalofop-ethyl	0.075			94	100	91	100	95	99
Sethoxydim	0.24	87	98			94	100	94	100
Sethoxydim	0.29			86	98				

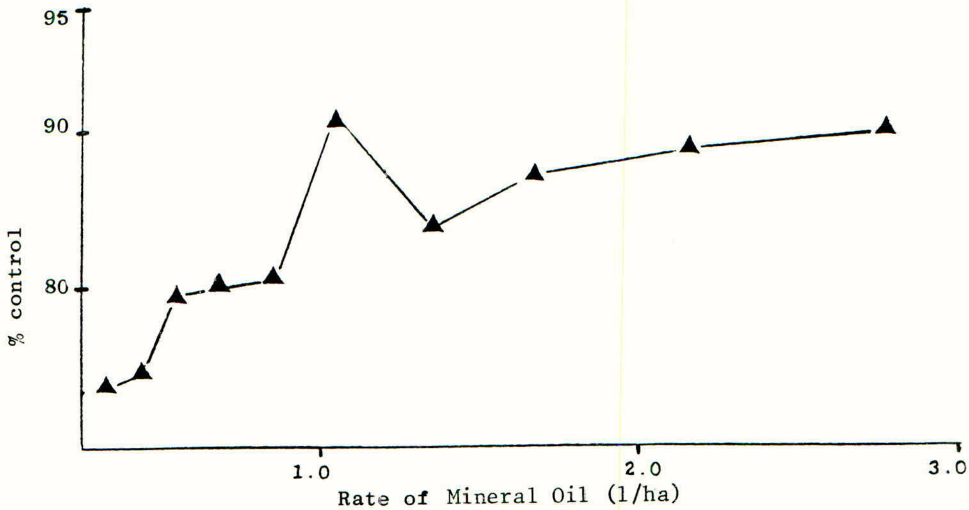
Weed growth stage at application: Zadoks 13-21
Time of assessment: a) At the end of autumn growth
b) At the commencement of spring growth

An autumn application of BAS 517H at 0.15kg a.i./ha in oilseed rape gave excellent control of A.myosuroides, A.fatua and volunteer cereals when assessed at the commencement of spring growth. However an earlier assessment had shown that increasing the rate from 0.1 to 0.2 kg a.i./ha gave increased weed control, suggesting a greater speed of activity from the higher rates. (Table 1)

The timing of autumn applications of BAS 517H in oilseed rape did not effect the levels of weed control assessed at the commencement of spring growth.(Table 2). Applications made as late as December were however much slower to take effect due mainly to the cold conditions which prevail at this time of the year.

A.fatua, A.myosuroides ,and cover crops of cultivated oats and barley were well controlled in spring sown crops by BAS 517H at 0.15kg a.i./ha 3 weeks after application. No benefit occurred from the use of higher rates of active ingredient. (Table 3). No reduction in weed control was seen with an application using a lower (80 l/ha) water volume.

Figure 1: The effect of different rates of adjuvants in combination with BAS 517H at 0.2kg a.i./ha on the control of A.fatua, in logarithmic dilution trials, assessed 3 weeks after application.



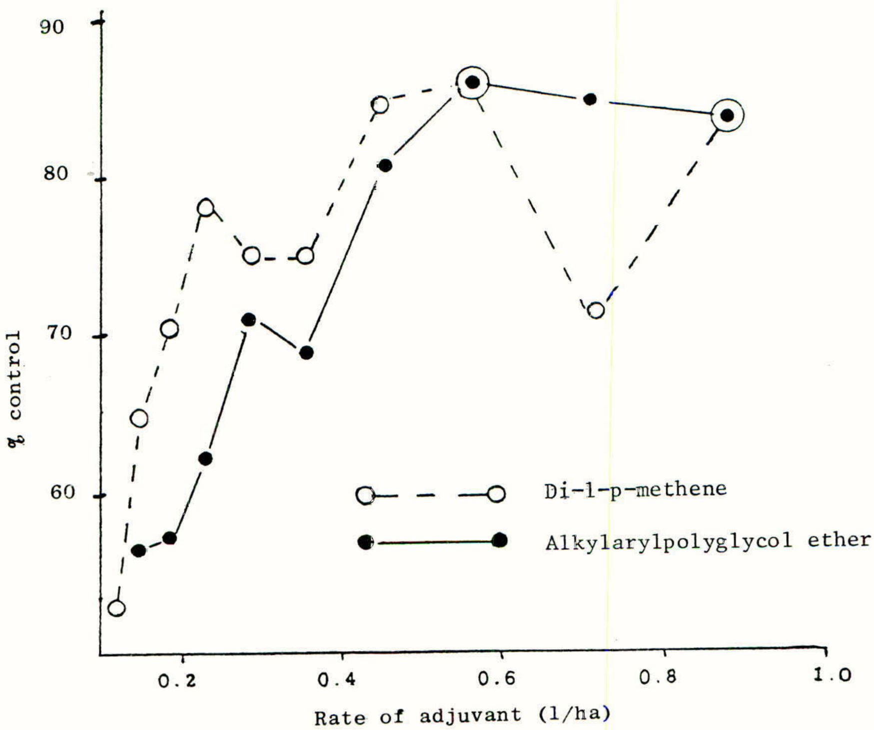


Table 2:

The effect of application timing and weed growth stage on % annual grass weed control in oilseed rape

		Avena fatua	Alopecurus myosuroides	Avena fatua	Alopecurus myosuroides	Avena fatua	Alopecurus myosuroides	Volunteer wheat
Assessment time		18 D.A.T.		30 days after December treatment		At the spring	commencement of growth	
% grass weed cover on untreated		37	7	82	32	10	27	6
Chemical rate (kg a.i./ha)	Application timing:							
BAS 517H 0.1]	Zadoks	91	86	99	99	99	100	100
BAS 517H 0.2]	13-15	94	88	99	99	99	99	100
BAS 517H 0.1]	Zadoks			99	99	99	100	100
BAS 517H 0.2]	21-25			100	99	100	100	100
BAS 517H 0.1]	Zadoks			43	40	100	100	100
BAS 517H 0.2]	25-29			50	47	100	100	100

Zadoks 13-15 - Early October
Zadoks 21-25 - Late October
Zadoks 25-29 - Early December

Table 3:
% control of annual grass weeds in sugar beet, potatoes and peas

		1984	1985			
		A.fatua	A.fatua	A.myosuroides	cover crops oats	cover crops barley
No of trials		9	2	1	1	2
% grass weed cover on untreated		30	85	65	90	35
Chemical	Rate (kg a.i./ha)					
BAS 517H	0.1	95	99	94	96	98
BAS 517H	0.15	96	99	100	97	99
BAS 517H	0.2	96	99	100	97	99
BAS 517H	0.2*		99	100	98	99
Fluazifop-p-butyl	0.125		99			100
Fluazifop-p-butyl	0.188			100		
Fluazifop-p-butyl	0.25				96	
Quizalofop-ethyl	0.125		99	100	86	98

Weed growth stage at application: Zadoks 13-21
* Applied in 80 l/ha water
Assessment time: 3 weeks after treatment

Perennial grass weed control

Table 4:
% control of perennial grass weeds in sugar beet, swedes and potatoes from a single application

		1984	1985		
		E.repens	A.gigantea	E.repens	
No of trials		7	2	3	3
% grass weed cover on untreated		41	44	72	41
Chemical	Rate (kg a.i./ha)				
BAS 517H	0.3	85	97	92	87
BAS 517H	0.4	88	98	92	91
BAS 517H	0.5	89	99	94	92
BAS 517H	0.6		99	94	
Fluazifop-p-butyl	0.375	84	98	93	92
Quizalofop-ethyl	0.375		99	95	

Grass weeds 15-20cm in height at application
Assessment time: 3-6 weeks after application

The results of perennial grass weed control in sugar beet, swedes and potatoes can be seen in Table 4. Excellent control of A.gigantea was given by BAS 517H at 0.5kg a.i./ha when assessed 3-6 weeks after treatment. E.repens proved more difficult to control and severe infestation often required a follow-up application to control regrowth. (Table 5).

Table 5
% control of E. repens from two applications of graminicide

Crop			Potatoes	Sugar beet
No of trials			1	1
% grass weed cover on untreated			100	65
Chemical	Rate (kg a.i./ha)	Timing		
BAS 517H	0.4	T1 +]	94	98
BAS 517H	0.3	T2]		
BAS 517H	0.5	T1 +]	96	99
BAS 517H	0.2	T2]		
Fluazifop-p-butyl	0.375	T1 +]	93	99
Fluazifop-p-butyl	0.188	T2]		
Quizalofop-ethyl	0.375	T1		94

Assessment time: 3 weeks after T2
T1 - grass weeds 15-20cm height
T2 - regrowth at 3-4 leaf stage

DISCUSSION

BAS 517H has shown good activity against a range of commonly occurring grass weeds in UK agriculture with good selectivity in broad leaved crops tested.

Final levels of annual grass weed control were the same irrespective of the weed growth stage or the timing of application. However late autumn applications resulted in retarded weed control due to colder conditions. The resulting competition may adversely affect the crop, making earlier applications preferable. Perennial grass weeds were initially well controlled by a single application of BAS 517H, although where a severe infestation of E.repens occurred, a second application was often necessary to control regrowth. Where applied, follow up applications have resulted in high levels of weed control.

The results demonstrate the importance of using the optimum rate of adjuvant with BAS 517H, in order to achieve maximum levels of weed control in a short period of time.

Both annual and perennial grass weed control compared favourably with the standard treatments.

ACKNOWLEDGEMENTS

Thanks are due to all the farmers who provided trial sites, and to all BASF (UK) staff who conducted the trials work.

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PRE-EMERGENCE R-40244 FOR EARLY WEED CONTROL IN POTATOES AND CARROTS

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ABSTRACT

Data from five years of trials in potatoes and four years of trials in carrots show R-40244 (3-chloro-4-chloromethyl-1-(α,α,α-trifluoro-m-tolyl)-2-pyrrolidone) at 0.75 kg ai/ha to be a highly effective pre-emergence herbicide with activity against a wide spectrum of broad-leaved weeds including problem species such as *Reseda lutea* and *Echium vulgare*.

Good selectivity in both crops was afforded at this rate. However, in carrots grown on lighter soils the lower rate of 0.5 kg ai/ha gave equally good weed control while providing a wider margin of crop safety.

Substantial increases in yield compared to the untreated control were recorded in both crops at dose rates between 0.5 kg ai/ha and 1.5 kg ai/ha reflecting the excellent weed control and crop safety of R-40244.

INTRODUCTION

R-40244 (3-chloro-4-chloromethyl-1-(α,α,α-trifluoro-m-tolyl)-2-pyrrolidone, proposed common name fluorochloridone) is a novel herbicide discovered by Stauffer Chemical Company. The physical and chemical properties of R-40244 have been previously described (Pereiro *et al*. 1982), and the product is now formulated as an emulsifiable concentrate and marketed in Europe as 'Racer'*.

R-40244 is thought to block β-carotene synthesis in plants which leads to the photodegradation of chlorophyll (Devlin *et al*. 1979, Lay & Niland 1983). Thus, the visual symptoms of herbicidal treatment with R-40244 are bleaching of green plant tissue. Lay & Niland (1983) suggest that the uptake of R-40244 applied pre-emergence is mainly via root absorbtion, though uptake by the emerging shoot is also possible.

Selectivity in carrots was first demonstrated in the UK in trials at the National Vegetable Research Station (Roberts *et al*. 1978). This selectivity is thought to be due to a reduced rate of translocation of R-40244 from root to shoot allied to a higher endogenous level of carotenoids (Lay & Niland 1983). Susceptible species were shown to translocate R-40244 more readily to the shoot.

* Registered trade mark of Stauffer Chemical Europe SA

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Selectivity in potatoes has been shown in several countries (Pereiro et al. 1982), and the mechanism is thought to be based on mechanical separation of the tuber from the chemical.

Data presented in this paper summarise 26 small plot replicated trials and 25 large scale grower trials in potatoes, and 15 replicated and 9 grower trials in carrots, carried out between 1981 and 1985.

MATERIALS AND METHODS

Replicated small plot trials

All replicated trials were of randomised block design with 3 or 4 replicates. Plot sizes were 15-18m^2 in potatoes and 20-22.5m^2 in carrots. R-40244 (an emulsifiable concentrate containing 250 g/l of active ingredient) was applied pre-emergence soon after planting at dose rates of 0.5 to 1.5 kg ai/ha in both crops. Where potatoes were re-ridged after planting R-40244 was applied immediately after re-ridging. R-40244 was compared in potatoes to pre-emergence metribuzin and in carrots to pre-emergence linuron followed by metoxuron or chlorbromuron post-emergence. Standard herbicides were applied at manufacturers' recommended rates. All treatments were applied overall using an Oxford Precision Sprayer fitted with Teejet 11002 nozzles delivering a spray volume of 200 litres/ha at 840 mm Hg.

Replicated trials were carried out on commercial crops located in England and Scotland (Fig 1.) covering a range of soil types from loamy coarse sand to silty clay loam in potatoes and from sand to fine sandy loam in carrots. In 1985 three trials were set up in carrots specifically to investigate the activity of lower rates (0.5 kg ai/ha and 0.625 kg ai/ha) of R-40244 on very light soils. Soil types were sand, coarse sandy loam and loamy fine sand.

All major cultivars of potatoes and carrots were covered in this trial series.

Potato crops were mainly planted in April with three crops planted in March. In 1983 bad weather delayed planting of three crops until late May and early June. Carrot crops were drilled over a wider period from March to July.

Weed control was assessed by counting individual species in 6-10 x 0.125 m^2 quadrats per plot or by an estimated percentage ground cover in untreated plots and by quadrat counts (6-10 x 0.125 m^2) or by visual estimates of percentage control in treated plots.

Crop tolerance was assessed by scoring each plot for the degree of leaf bleaching on a 0-5 scale (where 0 = no effect, 5 = every plant severely bleached) at 28-42 DAT and by recording an estimated percentage reduction in vigour for each treated plot relative to the untreated at this time and 28 days later.

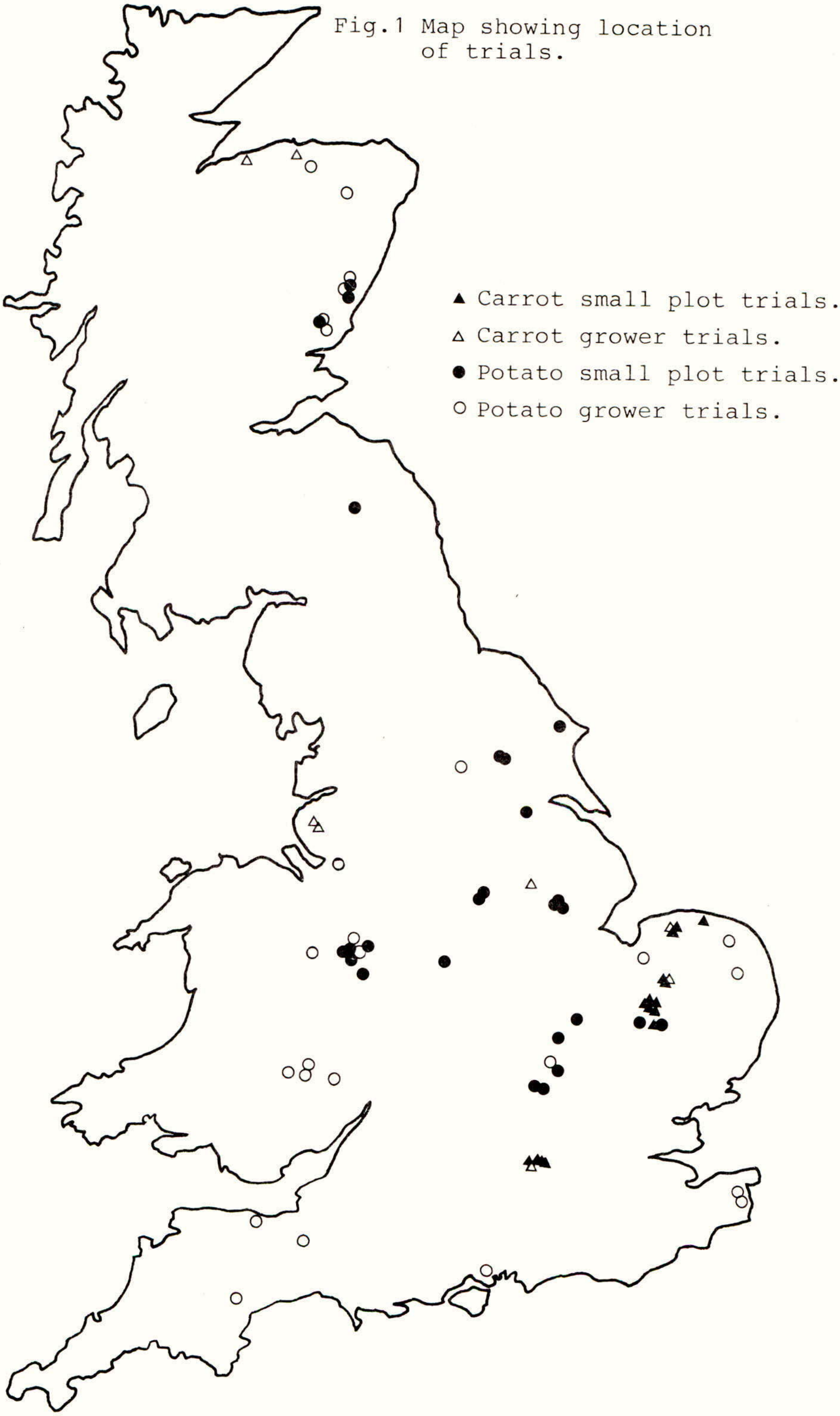

Fig.1 Map showing location of trials.

Trials were harvested with the field crop and yields were assessed by recording the total weight of potato tubers or carrot roots from 2 x 5m rows per plot.

Grower trials

In 1983 34 grower trials were set up at 25 sites on potatoes and 9 sites on carrots, located in England and Scotland (Fig 1.) Carrot sites covered a range of light and very light soils and potato sites covered a wide range of soil types from loamy coarse sand to sandy clay loam.

R-40244 was applied by growers to a 1 ha plot using their own sprayers at 0.75 kg ai/ha in most cases. Growers were requested to leave a small area unsprayed and to compare R-40244 with their normal herbicide programme. In potatoes the growers standard was generally a single spray application either pre- or post-emergence, but in carrots most growers used a sequential programme of pre-planting incorporated or pre-emergence herbicide followed by a post-emergence application. Crops were planted in March, April and May and covered all major cultivars of potatoes and carrots.

Weed assessments were carried out by taking quadrat counts in the untreated area (8 x 0.125 m^2) and by visual estimate of percentage control in the areas treated with R-40244 and the grower's standard herbicide.

Crop tolerance was assessed in the same way as in the replicated trials. Yields were not assessed in the grower trials.

RESULTS

A wide spectrum of broad-leaved weed species was encountered in trials in both crops. Table 1. shows mean levels of control achieved in replicated trials by R-40244 at 0.5 kg ai/ha and 0.75 kg ai/ha for 20 species of broad-leaved weeds and *Poa annua*. Weed populations varied considerably between trials and between years, but all species in Table 1 showed mean populations of greater than $5/m^2$. In 34 grower trials carried out in 1983 these levels of control were confirmed and the following additional species were shown to be susceptible (>90% control) to R-40244 at 0.75 kg ai/ha : *Aphanes arvensis*, *Arenaria serpyllifolia*, *Capsella bursa-pastoris*, *Geranium sp*., *Papaver rhoeas*, *Reseda lutea*, *Sinapis arvensis*, *Sonchus asper*, *Spergula arvensis*. Observations subsequent to the initial assessment revealed that a single application of R-40244 pre-emergence maintained these levels of weed control through the growing season of both crops.

In 1985, three trials carried out in carrots grown on very light soils indicated that the dosage rate of R-40244 could be reduced to 0.5 kg ai/ha and still maintain a high level of weed control, comparable to that at higher rates (Table 2).

Crop symptoms in potatoes and carrots were seen as leaf bleaching soon after emergence, usually on the leaf tips only,

TABLE 1

R-40244 pre-emergence weed control in potatoes and carrots (Summary of 45 trials)

Weed species : Dosage (kg ai/ha):	R-40244 0.5	R-40244 0.75	Metribuzin 0.7	Linuron + chlorbromuron 0.55+0.55/0.85	Linuron + metoxuron 0.55+2.75
			% control		
Aethusa cynapium	13 (1)	23 (5)	-	-	73 (1)
Anagallis arvensis	100 (2)	100 (3)	-	92 (2)	-
Anchusa arvensis	100 (1)	100 (2)	-	100 (1)	-
Atriplex patula	99 (1)	100 (1)	-	87 (1)	-
Bilderdykia convolvulus	75 (7)	78 (14)	57 (6)	93 (2)	100 (2)
Chenopodium album	94 (15)	93 (21)	73 (9)	99 (4)	100 (2)
Cirsium arvense	62 (2)	85 (2)	-	66 (2)	-
Echium vulgare	97 (2)	98 (2)	-	67 (2)	-
Fumaria officinalis	100 (2)	100 (3)	83 (1)	100 (1)	100 (1)
Lamium amplexicaule	87 (3)	100 (3)	38 (3)	-	-
Matricaria perforata	82 (9)	86 (14)	93 (6)	91 (2)	-
Myosotis arvensis	70 (3)	94 (6)	-	-	100 (1)
Poa annua	91 (9)	93 (11)	79 (6)	84 (4)	-
Polygonum aviculare	91 (12)	94 (17)	68 (8)	79 (2)	100 (2)
Polygonum lapathifolium	75 (3)	72 (3)	93 (1)	30 (2)	-
Polygonum persicaria	74 (10)	77 (12)	88 (5)	49 (2)	85 (2)
Senecio vulgaris	80 (4)	90 (13)	99 (1)	-	93 (3)
Stellaria media	84 (10)	91 (16)	96 (6)	100 (3)	100 (1)
Urtica urens	89 (3)	97 (9)	67 (3)	-	-
Veronica persica	94 (7)	100 (9)	94 (1)	100 (1)	100 (1)
Viola arvensis	63 (10)	73 (13)	75 (7)	73 (2)	100 (1)

Figures in parenthesis indicate number of trials from which the mean is derived.

though occasionally whole plants were affected. In potatoes more severe effects generally coincided with small seed potatoes planted close to the soil surface.

TABLE 2

R-40244 pre-emergence weed control in carrots grown on lighter soils

Weed species	Treatment :	R-40244			Linuron + chlorbromuron
	Dosage kg ai/ha:	0.5	0.625	0.75	0.55+0.55/0.85
		% control			
A. arvensis	(2)	100	100	100	92
C. album	(3)	100	100	100	96
E. vulgare	(2)	97	96	98	67
M. perforata	(1)	100	100	100	100
P. annua	(3)	99	100	100	94
P. aviculare	(2)	100	100	100	79
P. persicaria	(1)	84	82	88	85
S. media	(2)	100	100	100	98
V. arvensis	(2)	99	100	100	73

Figures in parenthesis indicate number of trials from which means for each species are derived.

TABLE 3

The effect of treatments on crop tolerance in potatoes (Summary of 26 Trials)

Treatment (kg ai.ha)		Bleaching score (0-5 scale) 28-42 DAT	% reduction in vigour 28-42 DAT	56-70 DAT
R-40244	0.5	0.8	0	0.5
R-40244	0.75	1.3	0	1.0
R-40244	1.0	2.1	0	3.0
R-40244	1.5	2.3	2.0	5.0
Metribuzin	0.7	0.6	0	0

It was observed that the appearance of bleaching in potatoes and carrots was related to the interval between application of R-40244 and emergence of the crop. The frequency and degree of bleaching was greater where this interval was less than 14 days though bleaching was transient in both crops and rarely seen on later leaves. Bleaching levels at 28-42 DAT were generally slightly higher on potatoes than on carrots (Tables 3 and 4). Assessments of crop vigour (Tables 3 and 4) indicated that carrots were affected more than potatoes though effects on both crops were usually very slight up to

TABLE 4

The effect of treatments on crop tolerance in carrots (Summary of 15 trials)

Treatment (kg ai/ha)		Bleaching score (0-5 scale) 28-42 DAT	% reduction in vigour 28-42 DAT	56-70 DAT
R-40244	0.5	0.6	0	0
R-40244	0.75	0.5	5.0	2.0
R-40244	1.0	1.2	2.0	0.5
R-40244	1.5	1.4	14.0	9.0
Linuron + chlorbromuron	0.55 + 0.55/0.85	0	0	0
Linuron + metoxuron	0.55 + 2.75	0	17.0	-

TABLE 5

The effect of treatments on mean yield of potatoes 1981-1984

Treatments (kg ai/ha)	Year: No of trials:	1981 3	1982 7	1983 2	1984 2
		t/ha			
Untreated		19.4	37.0	25.9	37.2
R-40244	0.5	29.1	43.0	-	-
R-40244	0.75	31.8	43.2	30.6	48.5
R-40244	1.0	34.6	42.7	-	-
R-40244	1.5	33.6	43.3	32.7	41.3
Metribuzin	0.7	35.0	41.1	-	43.4
SED		2.62	1.45	1.52	7.20

TABLE 6

The effect of treatments on mean yield of carrots 1982-1985

Treatments (kg ai/ha)	Year: No of trials:	1982 4	1983 3	1984 2	1985 1
		t/ha			
Untreated		22.2	32.9	15.1	24.5
R-40244	0.5	33.7	-	-	34.3
R-40244	0.75	38.2	56.9	18.9	34.3
R-40244	1.0	36.5	-	-	33.4
R-40244	1.5	38.4	54.9	17.2	32.1
Linuron + metoxuron	0.55 2.75	38.6	-	-	-
Linuron + chlorbromuron	0.55 0.55/0.85	-	-	-	36.9
SED		6.72	12.73	3.44	1.55

1.0 kg ai/ha. The standard treatment of linuron 0.55 kg ai/ha pre-emergence followed by metoxuron 2.75 kg ai/ha post-emergence caused a greater reduction in vigour than R-40244.

Results in Table 5 and 6 indicate that such crop effects did not lead to a loss in yield, indeed R-40244 substantially increased yield compared to untreated giving yields comparable to standard treatments.

DISCUSSION

These trials have demonstrated that R-40244 at 0.75 kg ai/ha gives excellent control of a wide range of broad-leaved weeds. Control of some other species tended to be variable though under favourable conditions even high populations of these were well controlled.

Most carrot crops in Norfolk and Suffolk are grown in soils in the lighter categories. On these soils and on the fine tilths achieved in carrot seedbeds a reduced rate of 0.5kg ai/ha proved sufficient to maintain a high level of weed control and also gained a greater margin of crop safety.

The early application, broad spectrum and long persistence of R-40244 resulted in crops free of weed competition from planting to harvest. In carrots, a single application of R-40244 gave equivalent results to a two spray programme.

Visual symptoms of R-40244 treatment were seen on both crops but proved to be short-lived and substantial yield increases were recorded from all dose rates.

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EVALUATION OF NEW RESIDUAL HERBICIDES FOR USE IN SEED POTATO CROPS

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ABSTRACT

Pendimethalin, 3 - chloro - 4 - chloromethyl - 1 - (*a*,*a*,*a* - trifluoro - m - tolyl) - 2 - pyrrolidone (as R-40244) and aclonifen were evaluated for crop safety against terbutryne + terbuthylazine and untreated controls in weed-free crops of potato cv Maris Piper grown for seed. Application of the four herbicides shortly after planting, at recommended rates, had no adverse effects on crop growth or yield, although slight bleaching of emerging shoots was noted with R-40244 in the dry spring of 1984. When applied at 10% crop emergence this herbicide caused extensive bleaching and slight necrosis of emerging shoots and foliage, but had no adverse effect on yield. All other herbicides, especially aclonifen, significantly reduced total tuber yields when sprayed at 10% emergence in the wet spring of 1983, but not in the dry spring of 1984. In both years the later application of pendimethalin caused leaf curling and malformation on emerged and emerging shoots which resembled or could have masked virus infection.

INTRODUCTION

Seed potato crops are more vulnerable to herbicide injury than ware crops, since they have a shorter growing season, and foliar symptoms produced by herbicide treatment may mask or be mistaken for virus infection during inspection for certification. This paper reports experiments on weed-free crops of cv Maris Piper with three herbicides new to the potato crop. Pendimethalin (Cyanamid of Great Britain Ltd), 3 - chloro - 4 - chloromethyl - 1 - (*a*,*a*,*a* - trifluoro - m - tolyl) - 2 - pyrrolidone or R-40244 (Stauffer Chemical Ltd) and aclonifen or CME127 (Cela-Merck Ltd) are all residual pre-emergence herbicides with a wide range of activity on annual weeds and with sufficient persistence in the soil to permit application considerably earlier than crop emergence in potato without loss of efficacy (Pereiro, Ballaux & Beraud, 1982; Winfield, Taylor, Gardner & Fletcher, 1978; Richardson & West, 1984).

These herbicides, together with a standard treatment, terbutryne + terbuthylazine, were applied either shortly after planting or at 10% crop emergence and evaluated for possible effects on crop growth or yield which might influence their suitability for use in seed potato crops.

MATERIALS AND METHODS

Two experiments were carried out on sandy loam soils (6 - 8% o.m. by loss on ignition) at Invergowrie in crops of cv Maris Piper grown for seed production. Plots consisted of two rows each of 27 plants, plus shared guard rows. Tubers (45 - 55 mm diameter) were planted at 30 cm spacing in rows 70 cm apart, giving a plot size of 8.1 m by 2.1 m. Treatments were arranged in randomised blocks and replicated three times. Two sets of untreated plots were included in each replicate.

The herbicides were applied by Oxford Precision Sprayer in a water volume of 500 l/ha either shortly after planting and final ridging or when 10% of the planted tubers had emerged shoots. Terbutryne + terbuthylazine, (Ciba-Geigy Agrochemicals) was used as the standard, at the rate recommended for the local soil type. The other herbicides were applied at rates suggested by the manufacturers as potentially suitable for use in potatoes, as follows:

Herbicide	Dose kg a.i./ha
Terbutryne + terbuthylazine	1.0 + 0.4
Pendimethalin	2.0
R-40244	0.75
Aclonifen	2.1

Potato haulm was cut and removed by hand when the majority of the tubers were of seed size (35 - 55 mm diameter). Tubers were harvested and graded and samples were assessed for internal vascular browning, skin set, disease incidence and dry matter content. Seed-size tubers were stored in trays until mid February in the dark at 2^{o}C and then submitted to a chitting regime of 12 h light and 12 h dark, both at 15^{o}C, until late April. Records were taken of sprout numbers and growth on 10 tubers/plot.

Routine applications of insecticides and fungicides were made to the field crops as and when necessary for protection against aphids and potato blight. The crops were not irrigated. A contact herbicide was applied overall well before crop emergence to control seedling weeds. Any weeds surviving this and/or experimental treatments were removed by hand. Dates of relevant operations were as follows:

	Expt I	Expt II
	1983-84	1984-85
Tubers planted	5 April	16 April
Treatments applied		
post-planting	15 April	19 April
10% emergence	26 May	25 May
Haulm cut	30 August	28 August
Tubers harvested	25 October	4 October
Chitting started	14 February	8 February

RESULTS

Expt I - field records

Prolonged wet weather between planting and crop emergence in spring 1983 together with impeded drainage resulted in a period of water-logging on experimental plots. Crop emergence was uneven and protracted. Nevertheless none of the post-planting treatments had any adverse effect on emerging shoots or on the subsequent growth and yield of the crop (Table 1).

TABLE 1

Expt I 1983 Field and harvest records

Herbicide	F.wt haulm t/ha	F.wt tubers t/ha Total	Seed[‡]	No. tubers/ plot	% d.m. tubers
Untreated	13.6	39.6	30.6	967	23.2
S.E. mean ±	0.68	1.08	1.01	36.3	0.31
Post-plant (15 April)					
Terbutryne + terbuthylazine	12.8	36.9	28.8	928	23.5
Pendimethalin	12.1	36.8	28.8	921	23.2
R-40244	15.1	38.9	29.8	883	23.1
Aclonifen	12.3	36.5	29.3	998	23.3
10% emergence (26 May)					
Terbutryne + terbuthylazine	12.6	35.3*	27.5	964	24.0
Pendimethalin	13.0	34.3**	27.1	883	23.7
R-40244	13.9	37.1	28.8	989	23.1
Aclonifen	11.4	31.2***	24.1	730***	23.7
S.E. mean ±	0.95	1.52	1.43	51.3	0.44

*, **, *** Significantly different from Untreated at the 5%, 1% or 0.1% level.

‡ 35 - 55 mm diameter.

Treatment at 10% emergence with terbutryne + terbuthylazine and, to a much greater extent, aclonifen caused yellowing of leaves and marginal necrosis, but only on emerged shoots. New growth was unaffected, but plots treated with aclonifen were generally slower to develop a crop canopy than untreated plots. R-40244 bleached all emerged shoots and foliage and also affected shoots emerging over the next few days. Pendimethalin caused leaf curling, thickening and malformation of treated foliage and on shoots emerging over the next few days. It had a similar but less marked effect on the first sets of new leaves produced by treated shoots. Crop canopy development on these plots was much slower than on untreated plots. The relatively light growth of haulm overall reflected the poor growing conditions early in the season, aggravated by early summer drought. In late August there were no significant differences in fresh weight of haulm recorded on treated as compared with untreated plots (Table 1).

No post-planting treatment had any significant adverse effect on tuber yield and quality, but all herbicides applied at 10% emergence, except R-40244, significantly reduced total yield of tubers, mainly by reducing tuber size. Plots treated with aclonifen also had many fewer tubers than untreated plots. Internal vascular browning and disease incidence were very low in harvested tubers and showed no relationship with experimental treatments, nor were there significant differences in skin set or in percentage dry matter of tubers.

TABLE 2

Expt II 1984 Field and harvest records

Herbicide	F.wt. haulm t/ha	F.wt tubers t/ha Total	Seed[‡]	No. tubers/ plot	% d.m. tubers
Untreated	26.4	48.5	39.6	887	23.1
S.E. mean ±	1.10	1.42	0.98	17.5	0.30
Post-plant (19 April)					
Terbutryne + terbuthylazine	25.5	47.6	38.8	897	23.3
Pendimethalin	25.1	48.8	38.8	905	22.6
R-40244	27.6	49.4	40.0	901	22.3
Aclonifen	28.3	51.3	41.3	902	22.5
10% emergence (25 May)					
Terbutryne + terbuthylazine	23.8	46.9	39.2	928	23.8
Pendimethalin	25.4	47.7	37.8	910	23.3
R-40244	26.2	49.8	41.4	943	22.9
Aclonifen	30.0	53.4	40.7	918	22.0*
S.E. mean ±	1.55	2.00	1.39	24.8	0.43

* Significantly different from Untreated at the 5% level.

‡ 35 - 55 mm diameter.

Expt II - field records

The 1984 experiment was planted in dry soil conditions and this was followed by a prolonged spell of fine, mainly dry weather which lasted until early September. Crop emergence occurred over a very short period of time and haulm growth generally was vigorous. Of the post-planting treatments, only R-40244 had any visible effect, causing bleaching of emerging shoots. This was rapidly outgrown. The bleaching effect resulting from treatment with this herbicide at 10% emergence was more severe than in 1983 and some leaf necrosis occurred. Subsequent growth was unaffected, but canopy development was slightly delayed in comparison with untreated plots. Aclonifen and pendimethalin produced similar but less severe effects than when applied at 10% emergence in 1983, but there was no foliar effect of terbutryne + terbuthylazine.

No treatment, whether applied post-planting or at 10% emergence, had any significant influence on foliage or tuber weights and numbers (Table 2). The incidence of internal vascular browning and tuber disease in this experiment was negligible. Tubers from plants treated with aclonifen at 10% emergence had a slightly lower dry matter content, possibly reflecting delayed maturity, than those from untreated plots. There were no differences between treatments in relation to skin set.

TABLE 3

Expts I and II - Chitting records/10 tubers

Herbicide	Expt. I 1984		Expt. II 1985	
	A 15 March	B 25 April	A 8 March	B 30 April
Untreated	14.0	15.2	12.8	20.3
S.E. mean ±	0.44	0.66	0.26	1.06
Post-plant				
Terbutryne + terbuthylazine	15.1	15.9	13.1	19.2
Pendimethalin	14.0	15.2	12.7	20.4
R-40244	13.8	13.2	12.5	16.5
Aclonifen	14.2	16.9	13.1	20.6
10% emergence				
Terbutryne + terbuthylazine	13.5	15.8	12.9	19.1
Pendimethalin	13.8	16.7	13.2	19.3
R-40244	15.5	15.9	12.9	23.3
Aclonifen	14.4	16.2	13.2	18.7
S.E. mean ±	0.62	0.93	0.37	1.50

A - Mean length (mm) longest sprout.
B - Fresh wt sprouts g/10 tubers.

Expts I and II - Chitting records

There was no indication that herbicide treatments in the field had any effect on sprout numbers, shape, colour or on early growth during chitting in either experiment (Table 3).

DISCUSSION

In the prolonged wet soil conditions of spring 1983 crop injury in response to application of residual herbicides was not unexpected. Label recommendations for the use of terbutryne + terbuthylazine at up to 10% emergence warn of yellowing of foliage and a check to crop growth if heavy rain falls shortly after application. Post-planting treatments caused no problems despite the adverse conditions, while only with aclonifen were yield reductions resulting from application at 10% emergence much worse than those caused by the standard herbicide treatment. R-40244 was safer than terbutryne + terbuthylazine in this situation, while pendimethalin had a marginally greater depressing effect on yield.

With virtually no rain from planting until well after crop emergence in 1984 the chances of herbicides reducing yields were much less and no herbicide caused a significant loss with either application date.

In terms of tuber yields, therefore, all herbicide treatments were safe when applied shortly after planting but, with the exception of R-40244, not when applied at 10% emergence in wet conditions. No treatment at either growth stage showed any residual effect on chitting performance. There is, however, a further factor to be considered in respect of seed potato crops. While minor foliar scorch and a slight check to growth in wet seasons should not present problems to a potato certification inspector, the leaf-curling and malformation caused by treatment with pendimethalin at 10% crop emergence were of much greater importance. They were still visible in June/July, and their resemblance to virus infection symptoms, which they could be confused with or mask, would have been unacceptable in a crop presented for certification (Hall, 1984). The bleaching effect of R-40244 was considered less likely to cause problems of this type, but it was of concern that this should have appeared in emerging foliage some five weeks after post-planting treatment in 1984. R-40244 has shown good selectivity in a wide range of potato cultivars grown for ware production (Pereiro et al, 1982). The bleaching effect appears to be common to all cultivars and most likely to occur with applications made shortly before emergence. It does not normally have any adverse effect on crop yield.

Our experimental treatments were applied only at the rates recommended and provided no evidence on margins of safety of seed crops to accidental overdosing with R-40244, pendimethalin or aclonifen. Further work is needed to examine these factors in relation to post-planting treatments. However, our results clearly indicated that application of all three herbicides, even at the recommended rate, at and around the time of crop emergence could create undesirable problems in crops grown for seed and should therefore be avoided.

R-40244 and pendimethalin were both test-marketed for use on ware potato crops in 1985 in the United Kingdom. In both cases recommendations are for application at or shortly after planting. These may also prove suitable for use in seed crops. Aclonifen is at present still in the development phase.

ACKNOWLEDGEMENTS

Thanks are due to R Wilson and Mrs G Wright for technical assistance and to the chemical companies who supplied the experimental samples.

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TOLERANCE OF POTATO CROPS TO GLUFOSINATE-AMMONIUM APPLIED AS AN EARLY POST-EMERGENCE HERBICIDE

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ABSTRACT

The crop safety of glufosinate-ammonium (HOE 39866) at 0.6 kg a.i./ha was compared with that of paraquat, when applied as an early post-emergence treatment for weed control in potatoes. It produced more severe initial effects on emerged shoots and delayed canopy development more than did the standard herbicide. In crops grown for seed, glufosinate-ammonium was more likely to reduce tuber yield if applied to emerged plants. In ware crops, no differences in final yield were found between the herbicide treatments or in comparison with an untreated control. There was no evidence of residual effects of glufosinate-ammonium or paraquat on the growth or performance of daughter tubers in store or in the field. It is suggested that the maximum emergence levels recommended for spray application to different types of potato crop should be somewhat lower for glufosinate-ammonium than those currently recommended for paraquat.

INTRODUCTION

Glufosinate-ammonium (HOE 39866) is a new non-selective herbicide with a wide range of potential uses. It acts primarily as a contact herbicide, but does have some limited systemic activity (Schwerdtle, Bieringer & Finke, 1981). This paper reports experiments carried out in Eastern Scotland to establish the relative safety of glufosinate-ammonium when applied early post-emergence to potatoes, as an alternative to paraquat.

MATERIALS AND METHODS

Seed crops

Two experiments were carried out at the Scottish Crop Research Institute (SCRI) Invergowrie on cv. Maris Piper. Plots consisted of two rows each of 27 plants, plus shared guard rows. Tubers (45-55 mm diameter) were planted at 30 cm spacing in rows 70 cm apart, giving a plot size of 8.1 m x 2.1 m. Treatments were arranged in randomised blocks and replicated three times. Two sets of untreated plots were included in each replicate. Paraquat at 1.1 kg a.i./ha and glufosinate-ammonium at 0.6 kg a.i./ha were applied at two stages of crop emergence by Oxford Precision Sprayer in a water volume of 300 l/ha. In 1982 treatment was made when 20% and 80% of the planting sites had emerged shoots, while in 1983, the figures were 35% and 80%. Plants with emerged shoots at treatment were tagged and the tubers harvested separately from the rest of the plot.

Potato haulm was cut and removed by hand when the majority of tubers were of 'seed' size (35-55 mm diameter). Tubers were harvested and graded and samples were assessed for internal vascular browning, skin set, disease incidence, specific gravity and sugar content. Evenly-graded seed-size tubers (10/plot in 1982 and 20/plot in 1983) were stored in trays until mid February in the dark at 2°C and then submitted to a chitting regime of 12 h light and 12 h dark, both at 15°C, until late April. Records were taken of sprout numbers and growth. Half of the tubers then had their sprouts removed and weighed; the remainder were planted out in the field, using a hand bulb-planter to ensure even depth of planting and to avoid injury to the chitted sprouts. Records were taken of shoot emergence, foliage development and tuber yield.

Routine application of insecticides and fungicides were made to both generations of field crops as and when necessary for protection against aphids and potato blight. The crops were not irrigated. In the original field crops weeds were removed by regular hand-weeding, while in the replanted crops, they were controlled by an application of terbutryne + terbuthylazine (1.0+0.4 kg a.i./ha) and a contact herbicide well before crop emergence. Dates of relevant operations were as follows:-

	Expt I	Expt II
	1982-83	1983-84
Tubers planted	20 April	25 April
First emergence	17 May	23 May
Treatments applied		
early	21 May	30 May
late	26 May	6 June
Haulm cut	10 Aug.	30 Aug.
Tubers harvested	28 Oct.	25 Oct.
Chitting started	15 Feb.	14 Feb.
Daughter tubers planted	26 April	27 April
Haulm cut	10 Aug.	15 Aug.
Tubers harvested	15 Aug.	17 Sept.

Ware crops

Two experiments were carried out by the East of Scotland College of Agriculture (ESCA) in 1983 in commercial crops grown for ware. Plots comprised four rows of plants 8 m long, with records being taken on 6 m lengths of the two centre rows (approximately 40 plants). Treatments were arranged in randomised blocks and replicated three times. Paraquat and glufosinate-ammonium were both applied at 0.6 kg a.i./ha in these experiments, by AZO knapsack sprayer in a water volume of 200 l/ha. Records were taken of crop canopy development, senescence and yield and size distribution of tubers.

All plots received the standard fungicide and insecticide treatments given to the rest of the field. Weeds were very sparse at both sites and offered no competition to crop growth.

Details of individual trials were as follows:-

Site	Coupar Angus	Penicuik
Cultivar	Pentland Crown	Maris Piper
Planting date	14 May	24 May
Treatment date	17 June	27 June
% plants with shoots emerged	95	55
Haulm desiccated	15 Sept.	1 Oct.
Tubers harvested	12 Oct.	16 Nov.

RESULTS

SCRI Expts - First year records

In Expt I, treatments were applied in calm dry conditions. Showery weather occurred between the application dates, but no rain fell during the week after the later application. Thereafter a prolonged dry spell of weather occurred until mid August. Paraquat scorched emerged shoots, but recovery took place rapidly. Glufosinate-ammonium caused leaf desiccation, followed by death of the treated stem and affected plants took longer than those treated with paraquat to recover. New growth was normal. The check to crop growth was more severe after the later date of application. Haulm weights on 10 August indicated no continuing adverse effect of either application of paraquat (Table 1). Plots treated with glufosinate-ammonium at either date had less haulm than those treated with paraquat; the overall effect was highly significant. Whole-plot records on tubers showed a 17% reduction in total yield following the later application of glufosinate-ammonium. Otherwise no individual treatment significantly affected yield of tubers, however glufosinate-ammonium produced lower total and seed tuber yields than paraquat at both dates, the overall effect being significant for both records. Tagged plant yields also showed this effect, plus a major yield reduction with late as compared with early application. Despite these treatment differences, tuber dry matter content was unaffected.

In Expt II continuous heavy rain after planting resulted in water-logging and crop emergence was slow and erratic. Adverse spraying conditions delayed the first application until 35% emergence rather than the intended 20% stage. The later application was made on time and a period of prolonged dry weather occurred thereafter. Each herbicide had similar effects on the crop to those reported for Expt I. Haulm growth generally was much less than in the previous experiment and very uneven (Table 1); there were no significant effects of herbicide or date of treatment. Application of either herbicide at 80% emergence caused significant reductions in total yield of tubers (whole plot), but there was no such effect from the earlier applications. Seed yields were similarly affected. However, records on tagged (emerged) plants showed marked reductions in yield with both application dates, with glufosinate-ammonium again significantly more severe overall than paraquat. Tuber dry matter percentage was unaffected by herbicide treatment. In neither experiment were there any effects of herbicide treatment on internal vascular browning, skin set, disease incidence on tubers, or total and soluble sugar content.

TABLE 1

SCRI Expts First year crop records

Herbicide	kg a.i./ha	F.wt haulm t/ha	F.wt tubers t/ha Total	F.wt tubers t/ha Seed size	% d.m. tubers	F.wt tubers g/tagged plant
Expt I						
Untreated		25.7	42.1	31.4	22.7	902
S.E. mean ±		0.75	1.52	1.31	0.36	50.1
20% emergence						
Paraquat	1.1	27.2	43.0	33.9	23.1	1151**
Glufosinate	0.6	22.3*	40.0	32.3	23.0	989
80% emergence						
Paraquat	1.1	26.5	40.6	34.5	22.6	860
Glufosinate	0.6	23.6	34.8**	28.2	22.3	705*
S.E. mean ±		1.06	2.15	1.86	0.51	70.9
Expt II						
Untreated		13.6	39.6	30.6	23.2	1237
S.E. mean ±		0.68	1.08	1.01	0.31	51.1
35% emergence						
Paraquat	1.1	13.3	36.1	27.5	22.5	980**
Glufosinate	0.6	13.1	37.3	29.3	23.1	923**
80% emergence						
Paraquat	1.1	11.6	31.9***	25.8*	23.6	1050*
Glufosinate	0.6	12.2	32.9**	26.5*	23.7	785***
S.E. mean ±		0.95	1.52	1.43	0.44	72.2
Sig. of effects						
Expt I						
20% v 80%		NS	NS	NS	NS	+++
Paraquat v Glufosinate		++	+	+	NS	+
Expt II						
35% v 80%		NS	++	NS	NS	NS
Paraquat v Glufosinate		NS	NS	NS	NS	+

*,**,*** - Significantly different from Untreated at the 5%, 1% or 0.1% level
+,++,+++ - Significant at the 5%, 1% or 0.1% level
NS - Not significant

SCRI Expts - Chitting and second-year records

Tubers for chitting and subsequent replanting were chosen at random from the whole-plot samples. There was no indication in either experiment that herbicide treatment had any residual effect on sprout numbers or growth (Table 2). There was also no evidence of residual adverse effects of

TABLE 2

SCRI Expts Chitting and second-year records

Herbicide	kg a.i./ha	Chitting records A	Chitting records B	Haulm height (cm)	F.wt g/plant Haulm	F.wt g/plant Tubers
Expt I		15 March	18 April	20 June	10 Aug.	15 Aug.
Untreated		14.9	20.0	31	425	797
S.E. mean ±		0.78	1.12	0.8	31.2	36.3
20% emergence						
Paraquat	1.1	14.5	17.8	30	451	883
Glufosinate	0.6	15.5	21.8	32	545*	887
80% emergence						
Paraquat	1.1	15.2	18.0	32	476	778
Glufosinate	0.6	14.9	18.4	33	435	804
S.E. mean ±		1.11	1.58	1.2	44.2	51.3
Expt II		15 March	30 April	20 June	15 Aug.	17 Sept
Untreated		14.0	15.2	46	485	1152
S.E. mean ±		0.44	0.66	1.6	20.0	26.7
35% emergence						
Paraquat	1.1	13.8	16.3	45	428	1139
Glufosinate	0.6	13.9	15.3	44	452	1145
80% emergence						
Paraquat	1.1	14.2	14.2	46	468	1164
Glufosinate	0.6	14.4	15.6	48	433	1138
S.E. mean ±		0.62	0.93	2.2	28.3	37.7
Sig. of effects						
Expt I						
20% v 80%		NS	NS	NS	NS	NS
Paraquat v Glufosinate		NS	NS	NS	NS	NS
Expt II						
35% v 80%		NS	NS	NS	NS	NS
Paraquat v Glufosinate		NS	NS	NS	NS	NS

* - Significantly different from Untreated at the 5% level
NS - Not significant
A - Mean length (mm) longest sprout B - Fresh wt sprouts g/10 tubers

initial herbicide treatment on the growth and yield of replanted daughter tubers.

ESCA Expts

Effects of the two herbicides on emerged shoots were as reported in the SCRI experiments. Records of % ground cover by crop foliage taken 14 days

(Penicuik) or 24 days (Coupar Angus) after herbicide application showed relatively little difference between untreated plots and those treated with paraquat. However, glufosinate-ammonium had significantly delayed the development of crop cover in comparison with paraquat and the untreated control at both sites (Table 3). Foliage on untreated plots began to senesce earlier than on treated plots, but there was relatively little difference between those sprayed with paraquat and those given glufosinate-ammonium. Harvest records showed little evidence of adverse effects of herbicide treatment on the final yield of tubers or on the distribution of size grades. Yields at Penicuik were very low generally, following late planting (24 May) and early summer drought, but this had no relationship to experimental treatments.

TABLE 3

ESCA Expts Crop Records

Herbicide	kg a.i./ ha	% crop≠ cover 11 July	% foliage senescence 14 Sept.	F.wt tubers (total) t/ha	No. tubers (1000/ha)	% no. tubers by grade(diameter) >60 mm	30-60 mm
Coupar Angus							
Untreated		40	27	37.3	290	16	72
Paraquat	0.6	37	12	37.7	291	16	75
Glufosinate	0.6	28***	9	36.2	263	22	65*
S.E. mean ±		2.6	-	1.28	21.6	3.5	2.7
Penicuik							
Untreated		21	18	17.3	237	12	85
Paraquat	0.6	21	9	19.5	272	12	87
Glufosinate	0.6	16**	8	17.0	238	12	86
S.E. mean ±		1.4	-	1.62	21.6	2.9	3.3

*,**,*** - Significantly different from Untreated at the 5%, 1%, or 0.1% level

≠ - % ground cover by crop foliage

DISCUSSION

The very detailed assessment of possible residual effects of herbicide treatment on daughter tubers at SCRI was carried out because in a parallel series of experiments at Invergowrie (Lawson & Wiseman, 1984) glufosinate-ammonium was evaluated as a haulm desiccant treatment and caused severe stunting and malformation of sprouts in chitted tubers. This effect was further evident in delayed and erratic field emergence and subsequent growth of daughter tubers and ruled out the use of this chemical as a desiccant for seed crops. Similar effects have subsequently been reported by the North of Scotland College of Agriculture (Addison, 1984) and by ADAS in England (Eagle, 1984). It was particularly important therefore to check if translocation to daughter tubers occurred following the much earlier application of glufosinate-ammonium just after crop emergence. Our results showed no evidence of any problem.

Paraquat should not be applied after emergence of seed crops (Anon. 1983) although many growers take the risk in seasons where adverse weather conditions prevent pre-emergence application. The SCRI treatments were purposely designed to compare the effects of post-emergence treatment with the two herbicides to see which offered the greater risk of crop injury. Since glufosinate-ammonium delayed foliage recovery more than did paraquat in these trials, strictly pre-emergence application would appear even more necessary in seed crops with this herbicide than with paraquat. This should also give added protection against any risk of translocation to tubers.

Paraquat is currently recommended for application at various stages up to 40% emergence in non-seed crops. The ESCA trials showed no adverse effects of either treatment at 55% or 95% emergence at Penicuik or Coupar Angus on the final yields of ware crops. Seasonal factors have a major influence on the ability of injured crops to 'catch up' with comparable untreated crops, however, and in both trials relative yields were probably influenced by the earlier cessation of growth (as indicated by more rapid senescence) on untreated plots in an unusually dry summer. The greater delay to canopy development with glufosinate-ammonium at both ESCA sites and in the SCRI experiments suggests that maximum emergence limits for this herbicide for all categories of ware potato crops should be somewhat lower than for paraquat. This would provide insurance against the greater risk of reduced yields in years when adverse weather, disease, early desiccation, or other factors shorten the effective growing season of treated crops.

With these provisos, the authors feel that glufosinate-ammonium is well worth further development as an alternative to paraquat for weed control at and shortly after crop emergence in potatoes.

ACKNOWLEDGEMENTS

Thanks are due to Hoechst (UK) Ltd for experimental samples and to the farmers who provided the ESCA trial sites.

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TRIALS WITH METRIBUZIN APPLIED AS A LOW DOSE PROGRAMME

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ABSTRACT

Experiments were laid down at 4 different sites in the eastern part of England during 1984. At each site pre-emergence, post-emergence and repeat low does post-emergence treatments with metribuzin were compared. The number of repeat low dose treatments varied from one up to 3 according to site. For repeat low dose treatments 0.24 kg/ha a.i. were applied. At most sites 1.05 kg/ha a.i. were used for single pre and post-emergence treatments. At one site only single treatments of 0.24 kg/ha a.i. were applied at a pressure 200 and 300 kPa and weed control compared. Both metribuzin-sensitive and tolerant maincrop varieties were used, varying with site. Results showed the repeat low dose programme to be as effective as the full single dose post-emergence treatment. The pre-emergence treatments were less effective on organic soils than either post-emergence treatments. Increasing pressure with a single low dose treatment increased weed control marginally. Reduced low dose programme treatments of metribuzin were damaging to metribuzin-sensitive cultivars.

INTRODUCTION

The herbicidal properties of metribuzin were first described by Draber et al (1968) and the material introduced later by Bayer A.G. and E.I. du Pont de Nemours & Co. (Inc) as a herbicide for use in a range of crops.

In the U.K. metribuzin is currently available as a water dispersible granule containing 70% w/w active ingredients as Sencorex WG.* This product is recommended for use at the rates of 0.5 or 1.0 kg/ha a.i. used pre-emergence of early or second early potatoes according to soil type and 0.7 or 1.0 kg/ha a.i. for maincrop potatoes according to soil type pre or post-emergence, with the exception of the cultivars Maris Piper and Pentland Ivory which can be treated pre-emergence of the crop only. Most effective post-emergence weed control is achieved when metribuzin is applied to susceptible weed species at the cotyledon up to the 1-true leaf stage.

In recent years repeat low-dose programmes of weed control for sugar beet using the active ingredients metamitron and phenmedipham have been developed. The principle of such techniques is to use a reduced rate of active ingredient and an equally reduced rate of water: reduction has usually been to 33% of original full rate recommendation. Applications of herbicide are usually made 3 times, at 7-10 day intervals, coinciding with susceptible weeds having developed to the cotyledon up to 1-true leaf stage. Herbicide is usually applied overall. This technique was evaluated by ADAS and British Sugar plc amongst others and found to be as effective, usually cheaper than previous overall applications of herbicides and faster and

* Sencorex is the Registered Trade Mark of Bayer A.G.

requiring less experienced staff than traditional band-spraying (e.g. Madge 1982, Breay 1985). Occasionally crop tolerance to the herbicide has been improved (Breay 1983). Initially, higher pressures than normal were thought to be necessary for repeat low-dose herbicide programmes although this has been shown not to be the case (May 1982).

With the foregoing advantages having been shown for repeat low-dose herbicide programmes in sugar beet it was considered that similar possibilities might exist for the technique in the potato crop. Metribuzin as the major herbicide for post-emergence use in potatoes was chosen for the trials described. Several potato cultivars were selected although the effects of the technique on the cultivar Maris Piper were of particular interest due to its popularity nationally and its susceptibility to previous full dose post-emergence metribuzin treatments. Results of ADAS trials in 1984 harvest year are reported. These have been extracted from comparative herbicide trials.

MATERIALS AND METHODS

Four trial sites in the eastern part of England were chosen. Details are given in Table 1.

Experimental layout varied according to site. Treatments were replicated and control (i.e. nil treatments) included. Agronomic treatment of experiments varied according to location: each site was managed in accordance with good local agricultural practice. Seed source varied between trials but was common within any site.

Observations on weed control and crop tolerance were made at all sites whilst yield assessments and size grade measurements were also made at Terrington and Arthur Rickwood Experimental Husbandry Farms. Weed assessments were made on quadrats although technique varied between sites.

Overall plot size varied according to site: all fell within the range of 3 or 4 rows each of between 8.5 and 10 m in length.

At the Manea, Terrington EHF and Arthur Rickwood EHF sites, normal dose (according to soil type) applications of metribuzin both pre and post-emergence and a 3-spray low dose programme were planned. However, at Manea, Cambridgeshire no further weeds emerged after the second application in the 3-spray programme and the third application was not therefore applied.

RESULTS

Weed counts in treated and untreated plots at each site are given in Table 2. Yield assessments from sites at Arthur Rickwood and Terrington EHF's are shown at Table 3.

DISCUSSION

From results shown in Table 2 all metribuzin treatments reduced weed populations relative to the untreated controls. On the organic soil types at Manea and Arthur Rickwood EHF, pre-emergence weed control was less effective than post-emergence weed control, as may have been expected. Total and ware yields were none the less significantly higher than those of control plots but not significantly different from those of other metribuzin treatments at Arthur Rickwood EHF, the only organic soil from which yield recordings were taken. Differences in weed control between full dose and repeat low dose treatments applied post-emergence were very small at all sites. At Terrington EHF there was no significant difference at the 5% probability level in terms of weed numbers amongst the 3 metribuzin treatments tested. These results are broadly in agreement with those reported in trials by Bayer UK Ltd where weed control from low dose programme treatments was equivalent, and often superior, to standard post-emergence treatments (Forrest 1985)

Crop tolerance to metribuzin applied pre-emergence was good with all varieties tested. However, with the cultivar Maris Piper a noticeable check in growth occured with post-emergence treatments. Subjective assessment suggested this to be less with the repeat low-dose programme than with a single full dose of metribuzin. Significant differences between the post-emergence metribuzin treatments in terms of total or ware yield were not recorded. Again this coincides with data recorded by Bayer UK Ltd (Forrest 1968)

At the Surfleet Marsh site single low-dose treatments of metribuzin were applied at pressures of 200 and 300 kPa. Differences in weed control between the two treatment pressures were small albeit that the latter had fewer uncontrolled weeds than the former.

In conclusion, it appeared that low-dose programmes of metribuzin were at least as effective as single full dose treatments in terms of weed control. Additionally it was occasionally unnecessary to apply 3 reduced dose applications to achieve equivalent weed control to the single full dose. Cultivars showing susceptibility to full post emergence treatments of metribuzin as typified by cv Maris Piper could not be safely treated with repeat low-dose programmes of the material.

ACKNOWLEDGEMENTS

The authors are indebted to cooperating growers, Messrs Hancock and Sears and the Directors of Arthur Rickwood and Terrington EHF's for assistance in supplying sites and to ADAS colleagues in ADAS Eastern Region and at the previously mentioned EHF's for experimentation and preparation of results.

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TABLE 1

Materials and methods for trials carried out in harvest year 1984

Site	Soil type	a.i. kg/ha	Application pressure kPa	Water volume (l/ha)	Application dates (crop growth stage)	Sprayer	Nozzle
Surfleet Marsh	Silty	0.70	200	200	16 May 1984 (pre em))		CT 8002
Lincs.	Loam	0.35	200	200	25 May 1984 (20% emergence))	OPS	CT 8002
cv Rode Pipo		0.24	200	200	12 June 1984(20 cm tall))	(modified)	CT 8002
		0.24	300	100	25 May 1984 (20% emergence))		CT 80015
Manea, Cambs.	Peaty	1.05)		220	16 May 1984 (Pre-em))		CT 8002
cv Maris Piper	loam	1.05)	200	220	15 June 1984(20 cm tall))	OPS	CT 8002
		0.24)	each	100 each	6 June 1984*)	(modified)	CT 80015
		+0.24)	application	application	15 June 1984)		CT 80015
Terrington EHF	Silty	1.05)		200	9 May 1984 (Pre em))		Teejet 8003
Norfolk	loam	1.05)			18 May 1984 (20% emerged))		Teejet 8003
cv Desiree		)			)	MDM	
		0.24)	200 each)	100 each	31 May 1984 (100% emerged))	Oxford)	
		+0.24)	application)	application	+6 June 1984)	Precision)	Teejet 8001
		+0.24)			+11 June 1984)	)	
Arthur Rickwood EHF	Loamy	1.05)		200	23 May 1984 (Pre em))	)	
Cambs.	peat	1.05)	200 each	200	15 June 1984(15 cm tall))	)	
cv Maris Piper		)	application		)	MDM)	Teejet 8002
		0.24)	)	100	4 June 1984*)	Oxford)	
		+0.24)	)	each	+15 June 1984)	Precision)	
		+0.24)	)	application	+26 June 1984)	)	

*Applications timed to coincide with emergence of weeds.

TABLE 2

Weed population according to site and treatments

Site	Metribuzin Treatment kg a.i./ha	Mean numbers of weeds per square m			
		Polygonum persicaria	Veronica spp	Stellaria media	Other species
Surfleet Marsh, Lincs.	0.70 pre-em)		0.0	0.0	0.1
Assessed 29 June 1984	0.35 post-em)	Recorded	0.3	0.0	0.0
	0.24 post-em)	in	0.0	1.0	3.0
	0.24 post-em)	'Other	0.0	0.0	1.0
	Control*)	species'	5.3	10.9	6.9
Manea, Cambs.	1.05 pre-em	6.3	1.0	0.3	0.0
Assessed 6 July 1984	1.05 post-em	0.0	0.0	0.0	0.7
	0.24+0.24 post-em	6.7	0.0	0.0	1.3
	Control*	55.2	35.7	11.9	5.7
Terrington EHF	1.05 pre-em)	Individual species not assessed.			12.8
Norfolk	1.05 post-em)	Total counts of all species given			16.2
Assessed 18 June 1984	0.24+0.24+0.24)	in column 'Other species'			16.4
	post-em)				55.7
	Control*)				
Arthur Rickwood EHF	1.05 pre-em	10.0	(Not assessed	)	24.1
Cambs.	1.05 post-em	0.0	(separately	)	13.3
Assessed 31 July 1984	0.24+0.24+0.24 post-em	0.0	(incl. with	)	10.0
	Control*	20.3	('Other species'	)	34.3

*Control assessments are a mean of all control treatments and replicates.

TABLE 2 (contd)

Weed population according to site and treatments

Site	Metribuzin Treatment kg a.i./ha	Mean numbers of weeds per square m: Bilderdykia convolvulus	Chenopodium album	Matricaria + Chamomilla spp
Surfleet Marsh, Lincs Assessed 29 June 1984	0.70 pre-em)	Recorded in 'Other species'		(0.0
	0.35 post-em)			(0.0
	0.24 post-em)			(4.5
	0.24 post-em)			(1.0
	Control*)			(40.8
Manea, Cambs. Assessed 6 July 1984	1.05 pre-em	5.3	2.7	0.3
	1.05 post-em	1.3	0.3	0.3
	0.24+0.24 post-em	3.0	1.3	2.7
	Control*	13.4	30.2	55.7
Terrington EHF Norfolk Assessed 18 June 1984	1.05 pre-em)	Individual species not assessed. Total counts of all species given in column 'Other species'		
	1.05 post-em)			
	0.24+0.24+0.24) post-em)			
	Control*)			
Arthur Rickwood EHF Cambs. Assessed 31 July 1984	1.05 pre-em	15.0	12.5	Not assessed separately; incl. with 'Other species'
	1.05 post-em	3.3	0.0	
	0.24+0.24+0.24 post-em	13.3	0.0	
	Control*			

*Control assessments are a mean of all control treatments and replicates.

TABLE 3

Comparison of effects of various rates and timings of metribuzin on yield of potatoes

	Timing of metribuzin	Dose kg a.i./ha	Crop Yield (t/ha) Total	Saleable (40-80 mm)
Terrington EHF	Pre-emergence	1.05	52.0	46.0
Norfolk	Post-emergence	1.05	50.9	45.5
cv Desiree	Repeat low dose	0.24+0.24+0.24	47.8	42.0
	Control*	Nil	47.1	42.6
			SED=2.07	SED=1.79
Arthur Rickwood EHF	Pre-emergence	1.05	44.19	38.84
Cambs	Post-emergence	1.05	40.59	35.13
cv Maris Piper	Repeat low dose	0.24+0.24+0.24	42.04	36.76
	Control*	Nil	33.32	28.78
			SED=3.93	SED=3.62

*Mean of all control treatments

RESULTS OF INVESTIGATIONS INTO THE POTENTIAL FOR WEED CONTROL WITH BENAZOLIN/CLOPYRALID MIXTURES IN SWEDES

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ABSTRACT

Following evidence of the safety of the swede crop to benazolin + clopyralid post-emergence herbicide mixtures from trials in the East of Scotland between 1982-4, a summary of the results from 17 weed control trials in the East of Scotland and England examining a range of benazolin + clopyralid treatments at different crop and weed growth stages is presented. Good control of Stellaria media, Matricaria perforata and Chamomilla suaveolens was noted from rates of 0.225 + 0.038 kg ai/ha benazolin + clopyralid and greater, particularly when the weeds were small. Useful suppression of Chenopodium album, Fumaria officinale and Galeopsis tetrahit was also noted, but weed control was otherwise erratic. Sequential repeated treatments may improve control of some weeds. It is concluded that benazolin + clopyralid mixtures offer the possibility of improved broad-leaved weed control post-emergence in swedes, but to ensure control of a wide weed spectrum,it should only be used as a part of a weed control programme. There remains a need to broaden the spectrum of weed control by mixtures based on these herbicides, or to discover alternative herbicides for post-emergence use in swedes.

INTRODUCTION

The turnip and swede crop occupies about 64,000 ha in Scotland, Wales and England (MAFF 1985). A wide range of pre-emergence residual herbicides are available for use in the crop, but these may not prove sufficiently active in dry springs or poor seedbeds. Inter-row cultivations play a part in controlling emerged weeds, but cannot control weeds emerging in the crop rows, and may require considerable operator skill and time (Lawson and Boag, 1984). The need for broad-spectrum post-emergence products has, therefore, been recognised for some time, particularly since the withdrawal of nitrofen from the UK herbicide market in 1981. Currently clopyralid is the only broad-leaved herbicide recommended for use post-emergence in swedes (Davies *et al*, 1984), but is limited to the control of Compositae weed species. Trials at the Scottish Crop Research Institute(Lawson and Wiseman, 1983/4) and the East of Scotland College of Agriculture (ESCA 1983/4/5) indicated that benazolin + clopyralid mixtures may be safe to the crop, and would broaden the spectrum of weed control. These herbicides are available as a 0.3 + 0.05 kg a.i/ha benazolin + clopyralid product (co-formulated mixture containing 30% wt/wt benazolin-ethyl and 5% wt/wt clopyralid) marketed by FBC as "Benazalox",* a winter oilseed rape herbicide.

This paper reviews work undertaken by the East of Scotland College of Agriculture and FBC Limited, to examine the potential of benazolin + clopyralid mixtures as swede herbicides. The aims of the trials were to ascertain whether or not the mixtures had sufficient weed control activity

* 'Benazalox' is a trade-mark of FBC Limited

under spring and summer conditions, and whether they could be usefully included in weed control programmes for swede crops.

MATERIALS AND METHODS

All benazolin + clopyralid treatments were based on 30% wt/wt benazolin as the ethyl ester and 5% wt/wt of clopyralid formulation; further clopyralid was added as 100% g/ℓ clopyralid as the monoethanolamine salt formulation, 'Format'** (Farm Protection Ltd.).

(a) Benazolin + clopyralid mixtures were applied to swede cv Ruta Otofte at three farm sites in Eastern Scotland in 1983 (Table 1) and at four sites in 1984 (Table 2). They were treated pre-sowing with 1.1 kg ai/ha trifluralin (48% a.i. e.c., Treflan, Elanco UK Ltd.) apart from the Stow site in 1983. Treatments were applied by propane-pressurized Azo knapsack-spray delivering 200 ℓ/ha through T-jet 8003 nozzles at 2 bars pressure to 2mx4m plots. Treatments were replicated in 3 fully randomised blocks. The weeds were treated at the 3 crop stages listed in Tables 1 and 2.

TABLE 1.

Weed control trials: treatments, rates, treatment timings and sites: ESCA 1983

Site	Crop growth stage	Weed growth stage
Stow	4-6 leaf	70-400mm
Falkland	3-4 leaf	50-100mm
Meigle	4 leaf stage	50-150mm
Treatment	**kg ai/ha**	
benazolin + clopyralid	0.15 + 0.15	
" "	0.3 + 0.05	

TABLE 2

Weed control trials: treatments, rates,treatment timings and sites:ESCA 1984

Treatment	kg ai/ha	Treatment timing		
		Early	Mid	Late
benazolin + clopyralid	0.15 + 0.05	√	√	-
" " "	0.15 + 0.1	√	√	-
" " "	0.3 + 0.05	√	√	-
" " "	0.3 + 0.1	√	√	-
" " "	0.6 + 0.1	-	-	√
" " "	0.6 + 0.2	-	-	√
" " "	0.15 + 0.5	√ then	√	-

Site	Crop growth stage			Weed growth stages		
	Early	Mid*	Late*	Early	Mid	Late
Forfar	3 leaf	<150mm	200-400mm	10-20mm	50-100mm	150mm
Balbeggie	1-2 leaf	150-250mm	200-450mm	10-20mm	50-100mm	150mm
Penicuik	2-3 leaf	200-300mm	300-500mm	10-20mm	50-100mm	150mm
Gifford	Cots-3 leaf	100-350mm	200-450mm	10-20mm	50-100mm	150mm

* plant diameter

(b) Benazolin + clopyralid mixtures were applied to various swede cultivars at five farm sites in England and Scotland by FBC Limited in 1983 (Table 3) and 1984 (Table 4). Treatments were applied to crops at 6-8 true-leaf stage in 1983, and circa 2 true-leaf stage in 1984, using a Drake and Fletcher knapsack sprayer calibrated to deliver 200 ℓ/ha at 2-3 bars pressure to 2m x 10m plots. Treatments were replicated in 4 randomised blocks. At all 1983 sites weeds were large at spraying (c 120-360mm across)

** 'Format' is a trade-mark of Farm Protection Limited and from cotyledon to 4-6 true-leaf stage in 1984. Trial areas had been treated pre-sowing with 1.1 kg ai/ha trifluralin at Bannockburn, Thornhill and Pontefract sites in 1983 and at Somerset, East Lothian, Fife (1) and Fife (2) sites in 1984.

TABLE 3.

Weed control trials: treatments, rates, treatment timings, and sites: FBC Limited, 1983

Treatment	kg ai/ha	Crop timing
Benazolin + clopyralid	0.15 + 0.025	)
" " "	0.15 + 0.05	)
" " "	0.15 + 0.1	) 6 - 8 leaves
" " "	0.225 + 0.038	)
" " "	0.225 + 0.05	)
" " "	0.3 + 0.05	)
" " "	0.6 + 0.1	)

Site	Cultivar
Bannockburn	Griffel
Thornhill	Ruta Otofte
Pontefract	Ruta Otofte
Leominster	Ruta Otofte
Ottery St. Mary	Marian

TABLE 4.

Weed control trials: treatments, rates, treatment timings and sites FBC Limited 1984.

Treatment	kg ai/ha	Crop timing
Benazolin + clopyralid	0.225 + 0.038	2 true-leaf
" " "	0.3 + 0.05	" " "
" " "	0.6 + 0.1	" " "
" " "	0.225 + 0.038	2 then 4-6 true-leaf stage

Site	Cultivar
Somerset	Acme
Eyton-on-Severn	Ruta Otofte
East Lothian	Ruta Otofte
Fife (1)	Magres
Fife (2)	Ruta Otofte

RESULTS

The main weed species at the 17 weed control trial sites in Scotland and England and the mean percent weed control for each treatment tested are listed in Table 5. Early timing refers to crops being at circa 2 true-leaf stage, mid timing to crop plants at circa 4-6 leaf stage (circa 150-300mm plant diameter) and late timing to 8-10 leaf stage (circa 200-500mm plant diameter). Early then mid timing refers to a sequential repeated treatment of benazolin + clopyralid/

Good control of Stellaria media was noted from all treatment timings, particularly if 0.225 kg ai/ha benazolin or greater was included in the mixture. At one site control was poor at high rates at the late timing, but this was an exception to the general efficacy of the mixtures. The available product rate of 0.3 + 0.05 kg ai/ha benazolin + clopyralid performed well at all timings. Control of Matricaria perforata and Chamomilla suaveolens was more erratic, but particularly good if 0.05 kg ai/ha clopyralid or greater was included in the mixture, and at the early and mid timings (weeds up to about 100-150mm across) or where sequential early/mid treatments were used. Control at later timings was generally much poorer. Moderate control of Chenopodium album was noted from a range of rates, but the response pattern was very erratic. The best response was obtained by use of the 0.3 + 0.05 kg ai/ha benazolin + clopyralid treatment at the mid timing. Similarly Fumaria officinalis showed an erratic response with good suppression obtained early with 0.3 + 0.05 kg ai/ha and late 0.6 + 0.1 kg ai/ha benazolin + clopyralid, but with a wide range of responses at other timings and rates. Control of Capsella bursa-pastoris, Spergula arvensis, Viola arvensis and Galeopsis tetrahit was generally poor, although excellent control of Galeopis tetrahit was obtained with 0.3 + 0.05 kg ai/ha benazolin + clopyralid at the mid timing.

DISCUSSION

The weed control spectrum of the benazolin + clopyralid mixtures appears limited in spring and summer conditions. Good control of Stelleria media, Matricaria and Chamomilla species may be expected, plus some suppression of a few other weeds, by the 0.3 + 0.05 kg ai/ha benazolin + clopyralid mixture currently marketed as an oilseed rape herbicide. Suppression of weeds such as Chenopodium album and Fumaria officinale may be possibly enhanced by using higher rates of this mixture or by adding extra clopyralid to this basic available mixture. Sequential treatments were examined to see whether weed control could be improved by tackling small weeds, then retreating weeds already damaged by the first treatment of the sequence, and also using the second treatment to control later emerging weeds. The limited information available indicated that at the rates used, 0.15 + 0.038 kg ai/ha benazolin + clopyralid in sequences, Stellaria media control was excellent, and the control of Matricaria perforata and Chamomilla suaveolens good so long as the higher rate of clopyralid was used. However, no clear improvement in control of other weeds was noticed. It is possible that control would be improved by higher rates used sequentially, and the 0.3 + 0.05 kg ai/ha product rate could be considered as a basis for such treatments.

The narrow weed control spectrum leads to the suggestion, however, that benazolin + clopyralid mixtures should only be considered as part of a weed control programme for swedes, and should not be relied upon alone as a complete treatment, or to be expected to recompense fully for poor activity of pre-emergence herbicide treatments.

There remains a need to broaden the spectrum of this mixture or to discover an alternative herbicide treatment, in order to provide the swede grower with an effective herbicide product for post-emergence weed control.

However, in the absence of alternative post-emergence treatments, and where inter-row cultivation is not favoured or possible, then benazolin + clopyralid based sprays may prove a useful addition for the swede grower.

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TABLE 5.

Mean percent weed control with benazolin + clopyralid mixtures: FBC Limited and ESCA trials 1983/4.

Timing	Treatment	Rate kg ai/ha	Mean % control: Stellaria media	Chamomilla, Matricaria spp.	Chenopodium album	Capsella bursa-pastoris	Galeopsis tetrahit	Spergula arvensis	Fumaria officinalis	Viola arvensis
Early	Benazolin+clopyralid	0.075 + 0.088	50(1)	97(2)	(66(2)	0(3)	4(1)	69(1)	21(1)	-
	" "	0.150 + 0.050	82(3)	71(4)	40(2)	3(3)	27(1)	0(1)	54(1)	-
	" "	0.225 + 0.038	94(3)	44(3)	28(1)	20(1)	-	40(1)	-	0(1)
	" "	0.300 + 0.050	90(5)	79(6)	64(6)	22(4)	0(1)	33(2)	87(1)	0(1)
	" "	0.600 + 0.100	96 (3)	78(3)	63(1)	27(1)	-	70(1)	-	0(1)
Mid	Benazolin +clopyralid	0.075 + 0.088	88(1)	95(2)	54(2)	21(4)	-	0(1)	45(1)	-
	" "	0.150 + 0.050	82(1)	91(2)	74(2)	19(3)	-	0(1)	81(1)	-
	" "	0.150 + 0.100	79(3)	60(2)	74(1)	70(3)	21(3)	54(4)	33(3)	33(3)
	" "	0.300 + 0.050	95(5)	81(7)	83(4)	44(7)	100(3)	66(5)	38(4)	45(3)
	" "	0.300 + 0.100	90(1)	88(2)	53(2)	31(3)	-	0(1)	76(1)	-
	" "	0.600 + 0.100	100(1)	52(2)	45(1)	30(1)	-	80(1)	-	
Late	Benazolin+clopyralid	0.150 + 0.025	79(2)	29(2)	32(1)	67(2)	8(1)	-	-	-
	" "	0.150 + 0.050	94(2)	56(2)	70(1)	64(2)	42(1)	-	-	-
	" "	0.150 + 0.100	75(2)	60(2)	54(1)	66(2)	28(1)	-	-	-
	" "	0.225 + 0.038	96(2)	40(2)	46(1)	68(2)	22(1)	-	-	-
	" "	0.225 + 0.050	93(2)	44(2)	56(1)	52(2)	10(1)	-	-	-
	" "	0.300 + 0.050	94(3)	62(2)	61(1)	54(2)	28(1)	-	-	-
	" "	0.300 + 0.100	45(1)	34(2)	34(2)	4(3)	-	0(1)	45(1)	-
	" "	0.600 + 0.100	87(4)	55(3)	72(2)	44(5)	35(1)	0(1)	89(1)	-
	" "	0.600 + 0.200	37(1)	83(2)	59(2)	28(3)	-	0(1)	52(1)	-
Early then Mid	Benazolin+clopyralid	0.150 + 0.050 then 0.150 + 0.050	97(1)	91(2)	66(2)	13(3)	0(1)	0(1)	52(1)	-
	" "	0.225 + 0.038 then 0.225 + 0.038	100(1)	59(2)	33(1)	28(1)	-	-	-	0(1)

(No) Number of sites tested

SUMMER CAULIFLOWER: EVALUATION OF NEW PRE-PLANTING AND POST-PLANTING HERBICIDE PROGRAMMES

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ABSTRACT

The popular combination of trifluralin incorporated pre-planting followed by propachlor post-planting can be equalled by a number of alternative programmes.

Pendimethalin performed as well as trifluralin in terms of weed control, crop yield, quality and harvest date, and napropamide was similar; however both herbicides caused a marginal reduction by yield in percentage Class I heads compared to trifluralin.

The trial proved the value of pendimethalin and napropamide as alternatives to trifluralin pre-planting and metazachlor is suggested as an alternative to propachlor post-planting though it did best in these trials when following either pendimethalin or trifluralin.

For efficient weed control both pre and post-planting treatments are required.

Further investigation of the lower rate of oxyfluorfen used in these trials is justified on transplanted summer cauliflower as the crops recover quickly from initial check and weed control is virtually 100%.

INTRODUCTION

Trifluralin incorporated pre-planting followed by propachlor within a few days of planting generally gives good weed control with little or no crop check, and this has been the standard herbicide treatment on horticultural brassicas for many years. However, the need to thoroughly incorporate trifluralin within 30 minutes into the top 75 mm - 100 mm of soil can present problems, particularly early in the season if the land is wet at application time.

Pendimethalin controls a similar range of weed species as trifluralin (Roberts & Bond 1974) but does not require incorporation (Spankle 1974). Napropamide requires only blending into the top 25 mm of soil which can be achieved by a light set of harrows (Anon 1985).

The trials were designed to see whether pendimethalin and napropamide are satisfactory alternatives to trifluralin, and also to evaluate the relatively new herbicides metazachlor and oxyfluorfen for post-planting application in conjunction with the 3 pre-planting herbicides, as alternatives to propachlor. Oxyfluorfen has performed well on wheat, corn, tomatoes, fruit trees and vines (Biroli et al 1980), and as a pre-planting treatment on brassica crops in Japan and South Africa (Yih R. 1983).

MATERIALS AND METHODS

Experimental layout

Fully randomised block with 3 replicates. Plot size was 4 rows 600 mm apart x 17 plants 450 mm apart, with the 2 centre rows x 15 plants recorded for yield.

Herbicides used	Formulation	Rate kg ai/ha
Trifluralin	48% liquid	1.10
Pendimethalin	33% liquid	0.99
Napropamide (1982)	50% w.p.	0.55
Napropamide (1983 & 1984)	45% liquid	1.13
Propachlor	48% flowable	4.32
Metazachlor	50% liquid	1.00
Oxyfluorfen	23.5% liquid	0.235
Oxyfluorfen	23.5% liquid	0.470

Soil type

The experiments were carried out on a fine sandy loam of the Quorndon series (QN1) in 1982 and 1983. This is a typical cambic gley soil with a subsoil layer of sandy clay loam or loamy sand of a low permeability.

In 1984 trials the soil was a sandy gley soil of the Blackwood series (bK), which is a sand to loamy sand texture at least 80 cm deep. It is stoneless and rapidly permeable with a weak blocky or sub-angular blocky top-soil structure.

Culture

The cauliflower seeds, cv Dominant (Da) in 1982 and White Summer (BrS/SeG) in 1983 and 1984, were sown in the soil borders of an unheated glass-house in mid February and hand planted on the plots at a stage commensurate with good commercial practice.

The whole site was prepared conventionally for planting and the plots marked out. The herbicides were applied by pneumatic knapsack sprayer in 1982 and Oxford precision sprayer in 1983 and 1984 at 760 litres/ha. The trifluralin was incorporated by 2 passes of a hand propelled rotavator and then raked level. The napropamide was raked into the top 25 mm with a hay rake. The pendimethalin was sprayed on the initial plant bed without incorporation. All incorporations were completed within 15 minutes of application. The post-planting herbicides were applied 9-11 days after planting.

Summary of operative dates

	1982	1983	1984
Sown	11 February	14 February	17 February
Planted	16 April	17 May*	25 April
Pre-planting treatments applied	16 April	16 May	24 April
Post-planting treatments applied	19 April	27 May	3 May

*Planting delayed by wet weather

Visual weed, crop vigour and phytotoxicity assessments were made 7 weeks after planting.

EXPERIMENT 1

1982, 1983 and 1984 - Pre-planting herbicide evaluation.

Treatments

	Material
Pre-planting	Trifluralin
	Pendimethalin
	Napropamide
	Napropamide

Post-planting — Propachlor, Metazachlor

EXPERIMENT 2

1983 and 1984 - Post-planting herbicide evaluation.

Treatments

	Material
Pre-planting	Trifluralin
	Pendimethalin
	Napropamide
Post-planting	Propachlor
	Metazachlor
	Oxyfluorfen
	Oxyfluorfen
	Nil

RESULTS

The pre-planting treatments over 3 years and the post-planting treatments over 2 years (experiments 1 and 2 respectively).

Experiment 1

The total estimated percentage weed cover 7 weeks after planting is shown in Table 1.

TABLE 1

Pre-planting herbicides 1982, 1983 and 1984 (figures meaned over propachlor and metazachlor post-planting)

Percentage weed cover≠		
Trifluralin	3.1	(0.49)
Pendimethalin	3.4	(0.53)
Napropamide	4.9	(0.69)
SED (30 df)		(0.091)

≠Figures in brackets are mean values after logarithmic transformation.

Weed control was generally good for all combinations of pre and post-planting treatments, Table 1.

The mean percentage weed cover for the 2 years 1983 and 1984 for the pre-emergence treatments alone was trifluralin 25.9%, pendimethalin 20.0% and napropamide 21.7%. This shows the need for a combination of pre and post-planting herbicides for satisfactory weed control.

Trifluralin pre-planting followed by propachlor or metazachlor post-planting gave marginally better weed control than napropamide due to greater control of Stellaria media. Pendimethalin was as effective as trifluralin in the same pre- and post-planting combinations.

The main weeds present on the sites were as follows:-

1982	1983	1984
Polygonum aviculare	*Poa annua*	*Chenopodium album*
Matricaria Spp	*Stellaria media*	*Urtica urens*
Capsella bursa pastoris	*Matricaria Spp*	*Capsella bursa pastoris*
Stellaria media		*Stellaria media*
Chenopodium album		*Senecio vulgaris*

The marketable yield and % Class I heads are given in Table 2.

TABLE 2

Marketable yield and % Class I (mean of all post-planting treatments

Treatment	Marketable yield (crates/ha) Class I	Total	% Class I yield (by crates)
Trifluralin	1613	2065	78.1
Pendimethalin	1550	2127	73.0
Napropamide	1516	2049	72.7
SED (30 df)	86.2	73.9	2.37

There were no significant differences in total marketable yield or Class I yield between the 3 herbicide programmes but plants receiving napropamide or pendimethalin produced a lower percentage Class I heads than those given trifluralin pre-planting.

Time of 10, 50 and 90% cut and length of cut are shown in Table 3.

TABLE 3

Time of 10, 50 and 90% cut and length of cut in days (mean of all post-planting treatments)

Treatment	Time of cut⁄ 10%	50%	90%	Length of cut (10-90%) in days
Trifluralin	189.3	196.8	205.2	15.9
Pendimethalin	187.8	195.9	203.3	15.6
Napropamide	188.2	196.7	204.2	15.9
SED (30 df)	1.22	0.69	0.86	1.24

⁄190 = 9 July

No significant differences in cutting date or length of cut occurred between herbicide treatments.

These 3 trials indicate that pendimethalin and napropamide applied pre-planting performed well but both gave a slightly lower percentage Class I yield than trifluralin when followed with post-planting herbicides.

Experiment 2

Post-planting herbicide evaluation 1983 and 1984.

Total estimated percentage weed cover 7 weeks after planting are shown in Table 4.

TABLE 4

Post-emergence herbicides 1983 and 1984 (all treatments meaned over 3 pre-planting treatments including nil plots)

Treatment	% Weed Cover†	
Propachlor	8.1	(0.91)
Metazachlor	3.8	(0.58)
Oxyfluorfen (0.235)	2.6	(0.42)
Oxyfluorfen (0.470)	1.7	(0.23)
Nil	22.9	(1.36)
SED (56 df)		(0.066)

†Figures in brackets are mean values after logarithmic transformation.

All herbicide combination treatments significantly improved weed control compared to the nil treatments post-planting. Propachlor was less effective than the 3 other herbicides. Oxyfluorfen at 0.470 kg ai/ha gave almost total weed control, significantly better than the lower rate of oxyfluorfen. Both rates were significantly better than metazachlor, though weed control by the latter chemical was very good.

Propachlor failed to control *P. annua*, *S. media*, *U. urens* and *Matricaria Spp.* as well as the alternative materials.

Effect on yield and quality is given in Table 5.

TABLE 5

Marketable yield and % Class I (mean of pre-planting treatments)

Treatment	Marketable yield (crates/ha) Class I	Total	% Class I yield (by crates)
Propachlor	1643	2009	80.7
Metazachlor	1676	2018	81.8
Oxyfluorfen (0.235)	1705	2033	83.5
Oxyfluorfen (0.470)	1486	1871	79.3
Nil	1582	1946	80.0
SED (56 df)	91.4	82.0	2.48

In general the post-planting herbicide treatments did not affect total yield or % Class I but oxyfluorfen at the higher rate gave a lower Class I yield than the lower rate of oxyfluorfen or metazachlor. The initial scorching and growth check produced by the higher rate of oxyfluorfen had minimal effect on yield. In 1983 napropamide followed by metazachlor lowered both marketable and Class I yield. This did not occur in 1984 but was serious enough in 1983 to suggest that in some seasons this programme will delay development of the plants and reduce head size.

The effect on cutting date and length of cut in days is shown in Table 6.

TABLE 6

Time of 10, 50 and 90% cut and length of cut in days (mean over 3 pre-planting treatments)

Treatment	Time of cut[†] 10%	50%	90%	Length of cut (10-90%) in days
Propachlor	194.4	202.6	211.7	17.4
Metazachlor	193.1	201.7	210.9	17.8
Oxyfluorfen (0.235)	193.4	202.0	213.1	19.7
Oxyfluorfen (0.470)	192.5	202.7	214.1	21.6
Nil	191.4	199.2	209.8	18.5
SED (56 df)	1.21	0.99	1.32	1.49

[†] 190 = 9 July

Plots receiving pre-planting herbicides only reached 10% cut earlier than when followed by propachlor. The other post-planting herbicides did not delay cutting. All post-planting treatments delayed the 50% cut by about 3 days. The higher rate of oxyfluorfen resulted in a later date of 90% cut than plants given nil or metazachlor. Even the lower rate oxyfluorfen produced a later 90% cutting date than the nil post-planting treatment. The only effect on length of cut was that the higher rate of oxyfluorfen took longer than the plants receiving propachlor and metazachlor.

The indications are that metazachlor is equal to the standard material, propachlor, but in these trials the results were inconsistant in relation to yield and percentage in Class 1. Oxyfluorfen offers outstanding weed control in conjunction with one of the 3 pre-planting treatments, and the lower rate of 0.235 kg ai/ha is unlikely to affect yield, quality or delay harvesting.

The same treatments have been repeated in 1985, and although cutting is incomplete at the present time, a similar picture to the reported previous trials appears likely.

DISCUSSION

The 2,6 Dinitroanilines and amides first introduced by Eli Lilly in 1960 and represented in this trial by trifluralin and pendimethalin and the amide compound napropamide are safe to use on transplanted cauliflowers. All control the important annual weeds S. media, C. album, P. aviculare, P. persicaria, P. annua and Veronica Spp.

Most important annual weeds are controlled by pendimethalin and napropamide although S. arvensis is resistant to the latter. Trifluralin is relatively weak on 3 important weeds, S. vulgaris, Matricaria Spp. and C. bursa pastoris.

All 3 pre-planting herbicides are persistant in soils and phytotoxic residues may persist from 15-50 weeks being less for pendimethalin than napropamide. Soil incorporation is required for trifluralin and napropamide but not for pendimethalin.

The advantage of pendimethalin and napropamide compared to trifluralin is that the former requires no incorporation and the latter only surface blending which can be accomplished by normal cultivation.

The post-planting herbicides metazachlor and oxyfluorfen also have important advantages over the standard post-planting herbicide propachlor in terms of weed control spectrum. Oxyfluorfen controls nearly all the annual weeds except S. media and metazachlor is only weak against C. album and S. arvensis.

All these pre and post-planting herbicides are relatively low cost and economical to use on transplanted cauliflowers, with the exception of oxyfluorfen which is not priced and unavailable in the UK.

In these trials we found all pre-planting herbicides none phytotoxic having no effect on total marketable yield or yield of Class I cauliflowers.

The pre-planting herbicides on their own were not as efficient in weed control as when followed by any of the post-planting treatments. However, of the 3 chemicals used post-planting only propachlor and metazachlor can be recommended as oxyfluorfen caused phytotoxicity at the high rate of application. There is also no clearance under the Pesticide Safety Precaution Scheme for use of this chemical on commercial crops of Brassicae in the UK.

However, oxyfluorfen even at the low rate of 0.235 kg ai/ha gave long lasting total weed control, when followed by any of the pre-planting herbicides. This is worthy of attention because at the low rate of application effect on yield and quality were not significant even though early growth was checked.

Metazachlor gave better weed control post-planting than propachlor and as this chemical is cheap to apply and relatively safe to use following trifluralin pre-planting it is a good alternative to propachlor.

The pre-planting herbicide pendimethalin is a safe alternative to trifluralin on transplanted cauliflowers but is not cleared for commercial use under the P.S.P.S.

ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance of Mr A. G. Jones ex ADAS for his advice on trial treatments, and Dr A. Sutherland, National Vegetable Research Station, for statistical analysis of the data. Also the representatives of Stauffer Chemicals, Cynamaid, Rohm and Hass, and Sandoz Products Ltd for guidance on the use of the chemicals and the scientific and farm staff of Stockbridge House EHS for the recording and cultural management of the experiments.

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CINMETHYLIN, IMAZAQUIN AND METAZACHLOR PERFORMANCE FOR WEED CONTROL IN TOBACCO

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ABSTRACT

Cinmethylin alone or as tank mix with other herbicide applied pre-plant incorporated or pre-emergence, imazaquin pre-plant incorporated, pre-emergence or post-emergence and metazachlor early post-emergence over the top of the tobacco were evaluated for: 1) weed control efficacy, 2) effect on growth, yield and chemistry of tobacco, 3) field persistence during the year, and 4) bioactivity as affected by organic matter. *Cyperus* spp control was inconsistent and erratic across years with all three herbicides and application method except PPI cinmethylin combinations. Annual broadleaved weed control was satisfactory to excellent, whereas grass control was excellent. Tobacco growth and yield of cured leaf were not affected by cinmethylin and significantly reduced by imazaquin or by metazachlor in three of the five tests. Where a herbicide was used higher nicotine and N values were measured. Cinmethylin and imazaquin showed bioavailable residues in the soil after four months. Organic matter in the soil affected herbicide bioactivity. Weed control, tobacco chemistry, herbicide bioactivity.

INTRODUCTION

Weeds in a tobacco field may affect tobacco growth and development, reduce yield and quality significantly and alter chemical composition of cured leaf . The role and value of herbicides in tobacco weed control and more generally in tobacco production by eliminating early - and late - season weed competition are well established. Among the new herbicides tested for tobacco weed control in Greece are cinmethylin, imazaquin and metazachlor.

Cinmethylin, provided, when soil surface applied, excellent grass control and suppression of some broadleaved weeds (Bozarth et al, 1984). Incorporation of cinmethylin improved weed control performance when dry conditions occured after treatment.

Imazaquin, evaluated on 26 weed species, gave very good control of a broad spectrum of grass and broadleaved weeds among which were some hard to control weeds such as *Xanthium spp*, *Datura spp*, *Abutilon spp*, and *Ipomoea spp* (Risley and Oliver, 1984). Soil applied treatments (incorporated or pre-emergent) of imazaquin gave similar results. For oriental tobacco grown under dry climatic conditions herbicide incorporation may help considerably weed control performance. Metazachlor already studied extensively elsewhere (Walker and Brown, 1982) and registered for tobacco weed control in Zimbabwe was first tested for tobacco weed control in Greece in 1982. The objectives of these studies were to evaluate for each herbicide : 1) weed control efficacy, 2) effect on growth, yield and chemistry of tobacco, 3) persistence in the field during the year, and 4) bioactivity as affected by organic matter.

MATERIALS AND METHODS

General

Field experiments were conducted in 1983 on a silty clay (pH = 5.8, 1.8% organic matter) and a sandy clay soil (pH = 6.5, 0.5% organic matter); in 1984 on a silt loam (pH = 7.5, 1.2% organic matter) and the sandy clay; and in 1985 on the sandy clay soil. The three oriental tobacco cultivars used for the three soil types were S-79, KP-S2 and KS 82, respectively. Plots, arranged in a randomized complete block (RCB) design with three replications, were 3 X 10 m with 6 rows spaced 50 cm apart for cvs. S 79 and KS 82 and 5 rows spaced 60 cm apart for the cv. KP-S2. Spacing on the row was 15 and 20 cm for the 6 and 5 rows, respectively. Cinmethylin alone at 1 kg a.i/ha and at 0.75 kg a.i/ha as a tank mix with pebulate at 2.9 or ethofumesate at 1.5 kg a.i/ha was applied pre-plant incorporated(PPI) or pre-emergent(PRE) one day before transplanting with a pressurised air sprayer at 2 atm. Imazaquin at 0.25 kg a.i/ha was applied, PPI or PRE one day before transplanting and post-emergent(POE), 20 days after transplanting. Metazachlor at 0.75 kg a.i/ha, was applied early post-emergence over the top of tobacco(OT), five days after transplanting. There were two control treatments. Control A, receiving two cultivations (one about three weeks after transplanting and a second at lay-by time), represented the standard recommended to tobacco farmers practice. Control B received only the second (lay-by) cultivation about 30 days after transplanting as did all the herbicide plots. All other cultural practices were consistent with those recommended for oriental tobacco production.

Percent weed control

Weed control ratings were made at 30 days after transplanting, just before the lay-by cultivation of all treatments. Only the combined data over the locations per year are given and discussed.

Tobacco growth

The effect of each herbicide on tobacco growth was evaluated at 30 and 60 days after transplanting as fresh weight per plant from five plants per plot, sampled at random and cut at the ground level. Data per soil type are given and discussed.

Tobacco yield

Tobacco leaves from each plot were kept separate throughout harvesting, curing, storing, and grading for yield in kg/ha to be determined for each treatment plot.

Chemical determinations

Were made on random composite samples of cured leaves from the five primings for each plot. Nicotine, total N, and reducing sugars were measured by standard procedures (Lolas and Galopoulos, 1982).

Herbicide persistence

In each year random soil samples, at three sites per plot, from 0 to 15 cm were taken in the center rows at 30, 60, 90, 120, and 360 days after herbicide application. At each sampling, the three sub-samples from each plot were composited, air-dried under shade for two days, sieved, mixed well and then transferred, except the 360 days samples, to a freezer and kept at -10^{o}C until used in bioassays, about 15 days after the 120 days sampling. The 360 days samples were assayed three days after collection. For all assays 15-cm pots filled with 1500 g of the sieved soil were used. Fifteen oat seeds were planted in each pot and thinned to the 10 most uniform seedlings after 7 days. Pots were watered as needed. Once a week pots were given complete nutrient solution. At 21 days fresh and dry weight per 10 oat plants per pot were recorded.

Organic matter and herbicide bioactivity

Was studied for three soils, a sandy clay (pH = 6.5, 0.5% organic matter), a sandy loam (pH = 5.5, 0.3% organic matter), and a black organic soil (pH = 5, 20% organic matter) with oat bioassays in pots under greenhouse conditions (23±2/16±3 day/night temperature) in October-November in 1983 and 1984. Pots were filled with 700 g soil mixed with 1, 6, 12, 18 or 100% (w/w) of the black organic soil. After the appropriate herbicide rates (0.75 and 1; 0.20 and 0.25; 0.60 and 0.75 kg a.i/ha for the three herbicides, respectively) were added the soil and herbicide in each pot were thouroughly mixed in a plastic bag. Pots were arranged in a RCB design with five replications. The procedure thereafter was the same as in herbicide persistence section above.

Statistical analysis

Data for each year and soil type were first analyzed as a RCB design for each individual experiment. Then the weed control data for each year were combined and averaged over the soil types. Data for the sandy clay soil type were combined and analyzed as a split-plot in time over the years 1983-84 for yield and chemical composition.

RESULTS AND DISCUSSION

Percent weed control

Cyperus spp control, averaged over the soil types in each year, was incosistent and erratic across years with all three new herbicides and method of application except the PPI cinmethylin combinations (Table 1). PRE or POE application of imazaquin and PPI of cinmethylin could not control *Cyperus* spp more than 60 to 65% (Table 1). Suppression of *Cyperus* spp by cinmethylin was reported also by Bozarth et al (1984) and May (1984). Excellent *Cyperus* spp control was obtained with the tank mix of cinmethylin with pebulate or ethofumesate in 1985 and imazaquin applied PRE or metazachlor applied OT only in 1983. Annual broadleaved weed control was very good to excellent with all three herbicides and application method except POE application of imazaquin in 1984 and 1985 (Table 1). All herbicides, independently of application method gave excellent control of grass weeds in all three years. The PPI application of cinmethylin as a tank mix with pebulate or ethofumesate gave the best weed control of all the herbicides and application methods tested. Generally, the three new herbicides were better in grass than in broadleaved weed control. Of the two application methods of cinmethylin and three of imazaquin better results were observed with PPI and PRE application of cinmethylin and imazaquin, respectively. However Risley et al (1984) reported that PPI and PRE application of imazaquin gave similar results. It is suggested that the better weed control observed, generally, in 1983 compared to 1984 and 1985 was because of the higher rainfall in 1983 (85 mm) than in 1984 (52 mm) and in 1985 (46 mm) during the first month after herbicide application.

Tobacco growth

In 1983, tobacco receiving only the lay-by cultivation or imazaquin PRE or POE was significantly lower in plant fresh weight 30 or 60 days after transplanting compared to tobacco receiving two cultivations as recommended (Table 2). Cinmethylin applied PRE in 1983 in two soil types reduced significantly tobacco growth only at 60 days in the sandy clay soil. Tobacco growth was not affected by OT application of metazachlor only at 30 days in the sandy clay soil.

TABLE 1

Percent weed control in tobacco with cinmethylin, imazaquin and metazachlor

Herbicide	Application		Cyperus spp			Annual broad/s[1]			Annual grasses[2]		
	Method	Rate kg a.i/ ha	1983	1984	1985	1983	1984	1985	1983	1984	1985
Control A	Two cultivations		88	85	95	96	93	90	90	93	90
Cinmethylin	PPI	1	-	65	30	-	90	95	-	95	90
Cinmethylin	PRE	1	85	70	20	85	87	70	92	93	85
Imazaquin	PPI	0.25	-	80	20	-	93	98	-	95	95
Imazaquin	PRE	0.25	95	75	40	95	90	98	95	95	95
Imazaquin	POE	0.25	90	60	40	95	75	60	95	95	85
Metazachlor	OT	0.75	90	80	10	90	85	75	95	95	80
Pebulate + ethofumesate	PPI	2.9 + 1.5	95	95	95	96	95	95	98	93	95
Cinmethylin + pebulate	PPI	0.75 + 2.9	-	-	100	-	-	100	-	-	100
Cinmethylin + ethofumesate	PPI	0.75 + 1.5	-	-	98	-	-	100	-	-	100

[1]Amaranthus spp, Portulaca spp, Tribulus spp [2]Echinochloa spp, Setaria spp, Digitaria spp, Sorghum spp

Similarly, in 1984 and 1985 no weed control either with a herbicide or cultivation for 30 days after transplanting, as with control B, reduced significantly tobacco growth (Table 2). Use of one of the three new herbicides also affected and reduced significantly tobacco growth, except PPI application of cinmethylin alone or as a tank mix with pebulate or ethofumesate, and imazaquin or metazachlor at 60 days, in the silt loam soil. Generally, of the two application methods for cinmethylin and three for imazaquin tobacco growth was less affected where cinmethylin was applied as PPI and imazaquin as PRE. Also for all three herbicides tobacco growth was reduced more in the sandy clay as compared to the silty clay or silt loam soil type.

Tobacco yield

Where one of the new herbicides was used with a cultivation at lay-by time tobacco yield was significantly higher compared to control B receiving only the lay-by cultivation but significantly lower compared to control A receiving two cultivations except PPI or PRE application of cinmethylin in all three soil types and metazachlor in the silt loam and sandy clay soils (Table 3). In the sandy clay soil tobacco yield was higher for PPI than for PRE application of cinmethylin. Generally, tobacco yield with any of the three new herbicides except imazaquin PPI and POE in the sandy clay and PRE in the silt loam soil was not significantly different compared to commercial standards.

TABLE 2

Oriental tobacco growth following weed control with cinmethylin, imazaquin or metazachlor

Herbicide	1983				1984				1985	
	Silty clay		Sandy clay		Silt loam		Sandy clay		Sandy clay	
	30	days 60	30	days 60	30	days 60	30	days 60	30	days 60
	Fresh weight, g/plant									
Control A	91	257	45	252	82	259	40	171	33	91
Control B	65	225	32	72	47	185	20	70	21	41
Cinmethylin(PPI)	-	-	-	-	-	-	42	171	48	99
Cinmethylin(PRE)	76	247	41	167	54	208	36	110	41	92
Imazaquin(PPI)	-	-	-	-	-	-	12	90	8	76
Imazaquin(PRE)	60	222	28	149	40	241	20	112	6	87
Imazaquin(POE)	-	-	33	151	57	262	28	86	24	52
Metazachlor(OT)	45	211	47	190	57	215	26	110	34	61
Pebulate + ethofumesate (PPI)	85	242	54	201	77	283	56	166	42	106
Cinmethylin + pebulate (PPI)	-	-	-	-	-	-	-	-	55	115
Cinmethylin + ethofumesate (PPI)	-	-	-	-	-	-	-	-	50	119
L.S.D.	15	26	11	48	23	47	16	38	8	21
CV %	16	9	18	19	24	23	23	18	11	18

Chemical determinations

Significant herbicide effects on chemical composition of cured tobacco leaf were measured for nicotine and N, but not for reducing sugars (Table 3). Tobacco receiving a PRE application of imazaquin was significantly higher in nicotine (1.71) and N (2.41) compared to controls A and B. All three new herbicides independently of application method, except PRE application of cinmethylin, probably through a better weed control therefore more efficient nutrient utilization, increased significantly nicotine and N compared to control B where weeds were left to grow for the first 5 weeks after transplanting.

Herbicide persistence

The potential limitations in crop rotation due to herbicide persistence in soils suggest a better understanding of the actual or potential long term effect of herbicide residues in soils from the continued and repeated use of herbicides. In 1983 oat bioassays with soil samples taken at 30 day intervals up to 120 days after herbicide application and at 360 days showed bioavailable residues at 30 days for metazachlor and up to 60 days for cinmethylin and imazaquin applied PRE and POE, respectively (Table 4). In 1984 bioavailable residues were found up to 60 days for metazachlor and up to 90 days after herbicide application for cinmethylin and imazaquin, independently of application method. Cinmethylin and imazaquin applied as PPI persisted up to 120 days and reduced oat growth to about 50 to 60% (from 3.89 for control A

TABLE 3

Yield and chemical composition of oriental tobacco following weed control with cinmethylin, imazaquin or metazachlor

Herbicide	Application method	Yield, kg/ha			Chem. composition		
		Silt loam[1]	Silty clay[1]	Sandy clay[2]	Nic.	N	Reducing sugars
					....	%	....
Control A	Two cv	734	3597	1560	1.27	1.95	15.2
Control B	Lay-by only	428	2741	900	1.06	1.82	16.9
Cinmethylin	PPI	-	-	1600	1.42	2.27	16.9
Cinmethylin	PRE	645	3515	1350	1.17	1.97	13.8
Imazaquin	PPI	-	-	1280	1.71	2.41	12.9
Imazaquin	PRE	661	2953	1300	1.46	2.31	15.4
Imazaquin	POE	900	-	1250	1.41	2.16	14.1
Metazachlor	OT	670	3177	1390	1.34	2.09	15.6
Pebulate + ethofumesate	PPI	954	3174	1500	1.40	2.21	13.7
L.S.D. 0.05		227	300	208	0.28	0.32	NS
CV 3		12	7	9	16	11	13

[1]One year data; [2]Two year data (sxcept PPI cinmethylin or imazaquin, not included in the st. analysis)

to 2.03 and 2.22 for cinmethylin and imazaquin, respectively) compared to control A. In both years no herbicide residues were bioassayed at 360 days after herbicide application. It is interesting to note that the rainfall during the growing season in 1983 was twice as much as in 1984. This may explain why herbicides persisted about 30 days more in 1984 than in 1983. Note also the longer persistence of cinmethylin and imazaquin when applied as PPI than as PRE. May (1984) reported soil herbicide activity for eight to nine weeks from PRE applications of cinmethylin under most conditions. The results presented indicate that crop rotation limitations are probable for four months after PPI application of cinmethylin or imazaquin if low rainfall conditions privail. Bozarth et al (1984) reported that cinmethylin did not persist in the soil for more than one season.

Organic matter and herbicide bioactivity

Figure 1 shows, for two rates of each herbicide, oat growth as affected by different amounts of organic matter in three soils. In the black organic soil bioactivity of all three herbicides was less than 20% for the low rate (oat growth 80% or more than that of control) and less than 20 to 30% for the high rate (oat growth 70 to 80% of that of the control). In the sandy loam soil for all three herbicides bioactivity decreased (oat growth as percent of control increased from about 45% to about 75%) as organic matter incorporated in the soil increased from 1 to 18%. Inversely, in the sandy clay soil imazaquin bioactivity decreased as organic matter increased up to 18%, whereas bioactivity of cinmethylin and metazachlor increased with organic matter up to 12 or 18%, respectively. It seems that due to less herbicide adsorption bioactivity of cinmethylin and metazachlor in some soils increases as organic matter increases within certain limits. Similar observation that less herbi-

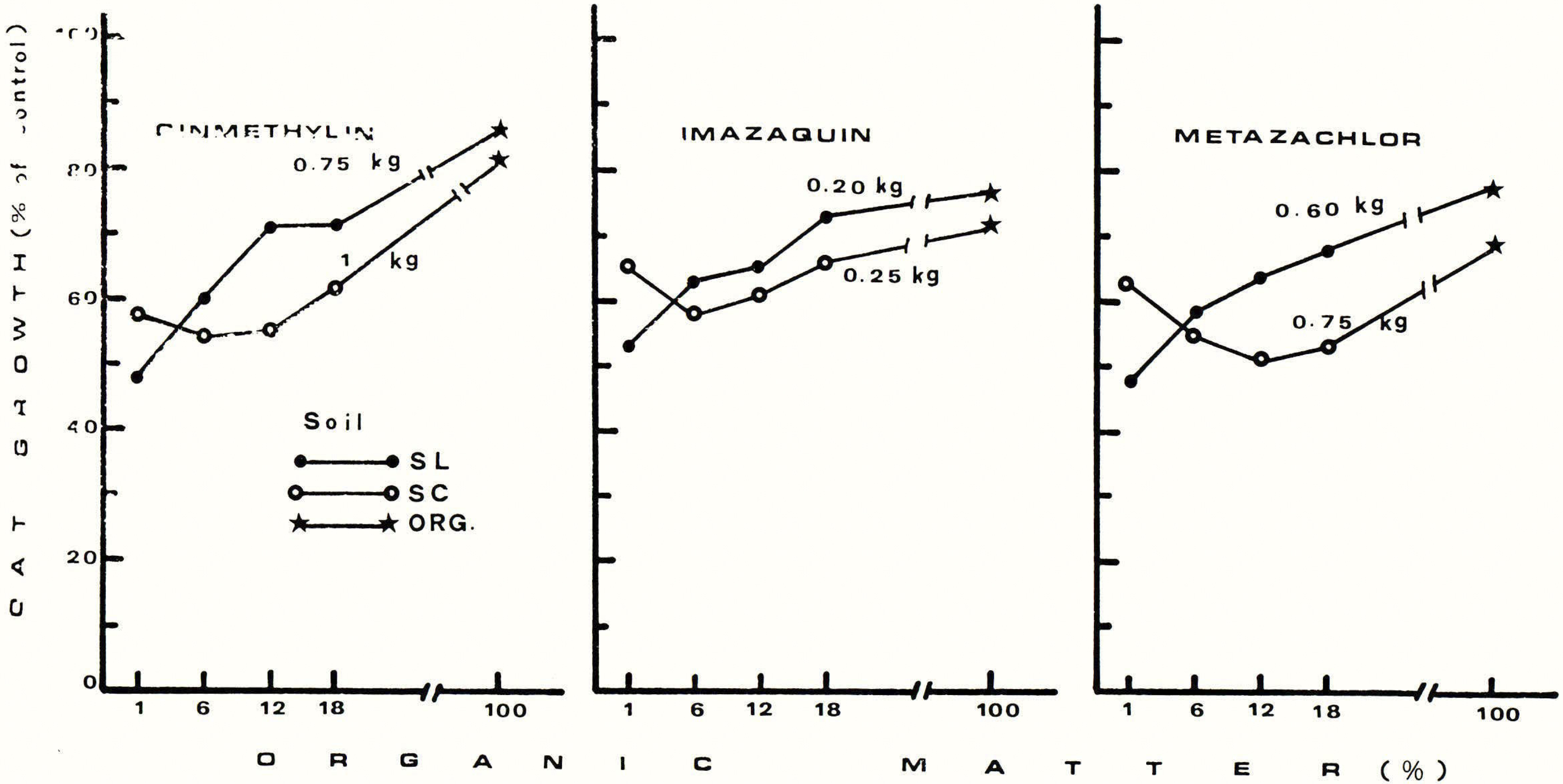

Fig. 1. Effect of organic matter on cinmethylin, imazaquin, and metazachlor soil bioactivity

TABLE 4

Soil bioactivity of cinmethylin, imazaquin and metazachlor during the year

Herbicide	Soil bioactivity									
	1983					1984				
	30	60	90	120	360[1]	30	60	90	120	360[1]
	Oat fresh weight, g/10 plants									
Control A	2.80	2.78	2.52	2.57	3.72	3.87	3.84	3.89	3.89	2.57
Cinmethylin(PPI)	-	-	-	-	-	0.94	1.26	1.96	2.03	2.53
Cinmethylin(PRE)	1.20	1.73	2.39	2.53	4.30	0.80	2.02	2.20	3.56	2.63
Imazaquin(PPI)	-	-	-	-	-	0.60	1.02	1.23	2.22	2.10
Imazaquin(PRE)	1.25	2.43	2.59	2.48	3.41	0.71	0.87	1.33	2.87	2.22
Imazaquin(POE)	1.15	1.60	2.51	2.49	2.89	0.67	1.10	1.16	2.95	2.17
Metazachlor(OT)	1.92	2.88	2.56	2.42	3.50	1.10	2.67	3.79	3.56	2.71
Pebulate + (PPI) ethofumesate	1.94	2.88	2.58	2.54	3.16	0.30	1.08	1.45	1.75	2.28
L.S.D. 0.05	0.33	0.46	NS	NS	NS	0.46	0.61	0.72	0.65	NS
CV %	16	14	10	12	16	19	21	23	13	15

[1]Days after herbicide application

cide was adsorbed than expected when incorporated organic matter increased was reported also by Embling et al (1983). The results presented indicate that cinmethylin and metazachlor may give satisfactory weed control even in medium organic soils. May (1984) reported that cinmethylin was relatively insensitive to variations in organic matter content.

ACKNOWLEDGEMENTS

A. Galopoulos helped in conducting the experiments. Typing was by Sotiria Petropoulou.

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ENHANCING CONTROL OF SUGAR BEET BROAD-LEAVED WEEDS USING ACL 3031 WITH PHENMEDIPHAM AND METAMITRON

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ABSTRACT

ACL 3031 is an enhancer based on 170 grams of surfactants in a paraffinic mineral oil. ACL 3031 was tested in a series of trials in tank mixtures using metamitron and phenmedipham applied at repeat low dose application rates.

The results show that not only was weed control improved but that the application window has also been widened. This would improve the efficacy of farmer applications of herbicides and levels of weed control.

The crop safety was not adversely affected when ACL 3031 was used, either with phenmedipham and/or metamitron.

INTRODUCTION

The majority of herbicide applications on sugar beet are applied in repeat low dose programmes. There are three main reasons for farmers following this regime:-

- Cost effective weed control.
- Preventing weed competition especially during the early growth stages.
- Safety to the sugar beet crop during the early vulnerable crop growth stages.

These repeat low dose treatments do, however, have some limitations. The herbicides are applied at low concentrations of active ingredient, making timing very critical, to ensure good weed control. Good timing is not always easy to achieve on farms with weather and time constraints. It is as a result of the timing factor that various options have been evaluated; the use of tank mixes and the use of adjuvants and enhancers to improve the efficacy of standard sugar beet herbicides.

The adjuvant oils available until recently have all been based on high levels of oil with low concentrations of surfactants and emulsifiers, between 10 and 50 grams per litre. Adherbe* (Code number ACL 3031) was introduced in 1985 as a novel oil based enhancer containing higher levels of surfactants than previously available. ACL 3031 contains 170 grams per litre of surfactants, that is a ratio of circa 6 parts oil to 1 part surfactant compared with the 19 to 1 with the most concentrated formulations available previously.

*Adherbe is a Trademark of Allied Colloids Ltd.

Trials have shown that ACL 3031 could be used at considerably lower rates than other additives to enhance broad leaved weed control properties of phenmedipham and/or metamitron and other herbicides. The improvement in weed control using ACL 3031 means that weeds that had grown beyond the recommended cotyledon stage for the herbicide alone were well controlled.

MATERIALS AND METHODS

A programme of eighteen trials with ACL 3031 was conducted over two years, 1984 and 1985, in the major UK sugar beet growing areas and on a range of soil types.

The replicated trial plots were sprayed using Van der Weij plot sprayers operating at 3 pa pressure and applying the equivalent of 80 to 100 litres of spray solution per hectare. Water used for spraying was local mains water.

The number of repeat low dose applications was governed by the rate of growth of the sugar beet and the crops were sprayed up until the rows met. Two to three repeat low dose herbicide applications were made. This represents farm practice in the UK. Weed assessments were carried out pre and post treatment, vigour assessments were made within seven days of treatment.

ACL 3031 was evaluated with repeat low dose applications of two formulations of Protrum* (both containing 114 grams per litre phenmedipham) and metamitron as water dispersible granules containing 70% w/w metamitron, three way tank mixes of ACL 3031/phenmedipham/metamitron and ACL 3031/ phenmedipham/Atlas Adjuvant Oil (50 grams per litre surfactant in an oil base) was used as the standard adjuvant oil.

ACL 3031 was also evaluated by British Sugar PLC when the product was applied by a tractor mounted sprayer as a three way tank mix of ACL 3031/ phenmedipham/metamitron. These trials were conducted at five sites: Peterborough, Bury St. Edmunds, Allscott, Stretham and York. The weed spectrum was representative on the sites of the major problem weeds affecting sugar beet. The first set of control plots was sprayed when the largest weeds were at least at first true leaf stage. The second set of control plots and adjuvant treatments were sprayed at five to seven days after the normal recommended spray date when metamitron/phenmedipham is used as a two way tank mix. Up to three post emergence applications were made at each site.

Weather Conditions

In 1984 the weather was hot and ground conditions dry. Temperatures were often up to 21°C during the early growing stages of the sugar beet crop. By contrast, in 1985 conditions were very wet and cold with temperatures around 10 to 15°C during the young crop stage. In 1985, due to late planting and cold weather conditions, the majority of sugar beet crops were backward and about three weeks behind average in development, with the consequence that most spraying was carried out during late May and June.

*Protrum is a Trademark of Allied Colloids Ltd.

RESULTS

In the 1984 trial series the addition of ACL 3031 to phenmedipham enhanced the weed control, particularly on the Polygonum spp and Bilderdykia convolvulus. Weed control with ACL 3031 was better than with the standard adjuvant oil. In the trials with metamitron, weed control was especially improved on B. convolvulus which was a particular problem in crops in 1984.

In the 1985 trial series the best regime for weed control when the weeds had grown beyond the recommended growth stage was a three way tank mix of metamitron, phenmedipham and ACL 3031.

Both the 1984 and 1985 trials showed that where large populations of well-developed Polygonum spp and B. convolvulus are present a higher rate of 1 litre per hectare of ACL 3031 needs to be used in order to achieve optimum weed control.

In the British Sugar trials ACL 3031 in a three way mixture with phenmedipham and metamitron gave very economical and effective weed control.

Crop vigour data from the 1984 trials is included and vigour data from British Sugar trials. No adverse effects on crop vigour were recorded in these trials at either the mid or late season assessments.

CONCLUSION

The use of ACL 3031 with phenmedipham and/or metamitron improved their weed control. Weeds normally controlled only at the cotyledon stage were controlled at the two to four true leaf stage with the addition of ACL 3031. Crop safety was not adversely affected.

The results from these trials will enable farmers greater flexibility in spraying sugar beet crops, especially important in inclement weather when spraying is difficult.

ACKNOWLEDGEMENTS

The author is grateful to British Sugar PLC for allowing their results to be published. We also thank Bayer UK Limited for the supply of trial material and the farmers and the trials teams for helping us to carry out the evaluations.

TABLE 1

1984 Trial Series: % Weed Control, % Crop Vigour

4 Sites

Product	Rate/kg ai/ha	Viola arvensis (2 sites)	Chenopodium album (2 sites)	Bilderdykia convolvulus (2 sites)	Geranium Spp (1 site)	Veronica herderifolia (1 site)	Anagallis arvensis (1 site)	Total % Weed Control	% Vigour Reduction
Metamitron	1.19 kg	90	96	49	90	100	76	84	0
Metamitron + ACL 3031	1.19 kg + 0.5 l	95	98	74	94	100	99	93	0
Metamitron + ACL 3031	1.19 kg 1.0 l	95	98	82	95	100	98	95	0
Metamitron + Adjuvant Oil	+ 1.19 kg + 1.7 l	74	100	78	93	100	95	90	0

Sugar beet size: 2 to 4 leaves at first application

Weed size: 2 to 4 true leaves

TABLE 2

1984 Trial Series: % Weed Control, % Crop Vigour

3 sites

Product	Rate/kg ai/ha	Chenopodium album (3 sites)	Viola arvensis (2 sites)	Galium aparine (1 site)	Bilderdykia convolvulus (3 sites)	Polygonum persicaria (1 site)	Polygonum aviculare (2 sites)	Total % Weed Control	% Vigour reduction
Phenmedipham	0.4 1	92	90	83	84	75	77	84	3.3
Phenmedipham + ACL 3031	0.4 1 + 0.5 1	97	99	96	94	78	89	92	5
Phenmedipham + Adjuvant Oil	0.4 1 + 1.7 1	96	98	100	91	75	87	91	8

Sugar beet size: 2 to 4 leaves at first application

Weed size: 2 to 4 true leaves

TABLE 3

1985 Trial Series: % Weed Control

3 sites

Product	Rate/kg ai/ha	Stellaria media (3 sites)	Bilderdykia convolvulus (2 sites)	Polygonum aviculare (2 sites)	Veronica persica (1 site)	Veronica hederifolia (2 sites)	Chenopodium album (2 sites)	Viola arvensis (2 sites)	Total % Weed control
Phenmedipham + ACL 3031	0.4 kg + 0.5 l	93	99	87	93	80	99	98	93
Metamitron + Phenmedipham + ACL 3031	0.88 kg + 0.19 kg + 0.5 l	96	98	98	100	90	100	99	97
Metamitron + Phenmedipham + Adjuvant Oil	0.88 kg + 0.19 + 1.7 l	93	91	95	100	91	100	99	96
Metamitron + Adjuvant Oil	1.19 kg + 1.7 l	80	74	93	93	57	100	85	83

Sugar beet size: 2 to 4 leaves at first application

Weed size: 2 to 4 true leaves

TABLE 4

1985 Trial Series: % Weed Control

3 sites

Product	Rate/kg ai/ha	Stellaria media (3 sites)	Bilderdykia convolvulus (2 sites)	Polygonum aviculare (2 sites)	Veronica persica (1 site)	Veronica hederifolia (2 sites)	Chenopodium album (2 sites)	Viola arvensis (2 sites)	Total % Weed Control
Metamitron + ACL 3031	1.19 kg + 0.5 l	86	80	85	89	48	100	80	81
Metamitron + ACL 3031	1.19 kg + 0.7 l	89	85	90	91	54	100	80	84
Metamitron + ACL 3031	1.19 kg + 1.0 l	85	90	94	89	66	100	84	87
Metamitron + Adjuvant Oil	1.19 kg + 1.7 l	80	74	93	93	57	100	85	83

Sugar beet size: 2 to 4 leaves at first application

Weed size: 2 to 4 true leaves

TABLE 5

1985 British Sugar Trials

5 sites

Metamitron + Phenmedipham kg/ai/ha	Timing	Additive	Rate/ha	Weed control score at mid season	Crop Vigour Score
0.88 + 0.19	A	-	-	6.1	8.0
1.05 + 0.29	A	-	-	6.8	8.0
0.88 + 0.19	B	-	-	6.4	7.7
0.88 + 0.19	B	ACL 3031	0.5 l	7.4	7.9
0.88 + 0.19	B	Mineral Oil	1.7 l	7.3	7.4
0.88 + 0.19	B	Vegetable Oil	1.7 l	5.6	7.8

Timing: A - early normal first date of application
B - delayed timing of first application

Weed control score: 0 - no weed effect. 6 to 8 - strong herbicide effect. 9 - total weed control

Crop vigour score: 0 - total kill. 9 - greatest vigour

THE USE OF DICAMBA TO CONTROL PROBLEM BROADLEAVED WEEDS IN MAIZE

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ABSTRACT

Dicamba was evaluated for the control of perennial and 'triazine-resistant' broadleaved weeds in maize in several European countries, in particular France and the Federal Republic of Germany.

0.2-0.36kg dicamba/ha applied as an overall treatment early post-emergence in maize (coleoptile up to 5 leaves) in programmes with atrazine applied either pre-emergence or tank-mixed together, gave good control of 'triazine-resistant' *Amaranthus* spp., *Polygonum* spp., and *Solanum nigrum*. Applying dicamba with a contact herbicide such as bromofenoxim, bromoxynil or pyridate, at reduced rates of both partners, improved weed control and crop tolerance.

Calystegia sepium, *Convolvulus arvensis* were controlled at rates of 0.24-0.36kg dicamba/ha applied late post-emergence as a directed or overall treatment. *Cirsium arvense* was also susceptible at these rates.

Crop tolerance was good with some varietal variation. The phytotoxic symptoms observed - 'transient onion leaf', and 'ducks feet' (prop root deformation) - were infrequent and did not impair crop yields.

INTRODUCTION

Maize grows slowly during establishment and, as it does not tiller and is planted in wide rows, competition from weeds must be suppressed.

A pre-emergence application of atrazine or simazine used to provide effective control of both annual grass and broadleaved weeds. However, the continuous use of these herbicides at high rates (2.5-4kg a.i./ha) in monocultured maize during the last two decades has led to the well-documented emergence of triazine-resistant weeds such as *Amaranthus retroflexus* and *Solanum nigrum*. This problem of chloroplastic-inherited triazine-resistant weed populations in maize has become progressively more severe and widespread in Europe, especially in France, and in North America (e.g.Bandeen and MacClaren 1976, Barralis and Gasquez 1979, Ducruet and Gasquez 1978).

A further consideration is that using triazines at these high rates in maize prevents the cultivation of subsequent crops such as winter cereals, soya beans and sugar beet because of herbicide residues carryover at phytotoxic levels.

The herbicide strategy in maize now used in Europe still depends on atrazine or simazine, but at lower rates. Any annual broadleaved weeds which emerge after the pre-emergence (surface or pre-plant incorporated) treatment are treated early post-emergence when maize has upto 5 leaves with a contact-action herbicide, sometimes in association with atrazine.

Broadleaved perennials such as Calystegia sepium and Cirsium arvense emerge later. Generally a systemic herbicide is applied, mostly as a directed spray in between the crop rows to ensure good weed coverage.

Dicamba is a systemic growth regulator herbicide with short term residual activity. Susceptible weeds include both annual and perennial broadleaved species. In the USA dicamba, as BANVEL Herbicide (480g dicamba/l, as the dimethylamine salt), is established as a major product for broadleaved weed control in maize.
Dicamba can be applied pre-emergence or post-emergence in maize up to 90cms high. Dicamba is chiefly applied early post-emergence when maize is at the coleoptile to 3-5 leaf stage, as a sequential treatment to control annual broadleaved weeds like Abutilon theophrasti which are resistant to a pre-emergence treatment of a graminicide such as alachlor or metolachlor.

The development of triazine-resistant annual broadleaved weeds and the need to control these and perennial broadleaved weeds demands a polyvalent product like dicamba for optimum weed control throughout the crop's development.(e.g. Gyorffy 1982). This paper describes some of the weed control trial programmes carried out with dicamba in Europe.

MATERIALS AND METHODS

During 1982 through 1985 dicamba was tested in maize against annual and perennial broadleaved weeds in France (109 trials), the Federal Republic of Germany (46 trials), and eleven other countries. The results included in this report were obtained from weed control and crop tolerance programmes carried out in France and the Federal Republic of Germany.

The trial protocols used followed the official guidelines for each country. The most frequent design was a randomized block or latin square with 3 to 4 replicates and plots of 16-40m. Weed control and crop tolerance were assessed using the National or the European Weed Research Council (EWRS) scales.

Dicamba was applied in most trials as the dimethylamine salt but aqueous solutions of the potassium and sodium salts of dicamba were also tested.

BANVEL[R] - Registered trade mark of Velsicol Chemical Corporation,USA

Treatments were applied through a precision sprayer such as the van der Weij AZO sprayer with a 4m boom; directed inter-row applications were made through a drop-leg boom, treating two inter-rows simultaneously. Spray volumes were from 250 l to 400 l/ha, at 250-300 kPa.

Control of triazine-resistant annual broadleaved weeds

The dicamba treatments were made early post-emergence (maize coleoptile up to 5 full leaves) as an overall application.

In France 0.24-0.6kg dicamba/ha was applied as a sequential treatment to a pre-emergence application of 1.0-1.5kg atrazine/ha.

In the Federal Republic of Germany (FRG) 0.24-0.6kg dicamba/ha was applied as a tank mix treatment with 0.6-0.8kg atrazine/ha.

In both France and FRG tank mixes of 0.2-0.3kg dicamba/ha were tested with contact herbicides such as bentazone, bromofenoxim, bromoxynil, dinoterb and pyridate applied at rates down to half the normal recommended rate. The standard used was 0.9kg pyridate/ha.

Control of perennial broadleaved weeds

Dicamba was applied late post-emergence (maize 30-90cms high) as a directed inter-row application, sequential to treatments made to control annual grass and broadleaved weeds, at rates of 0.24-0.6kg dicamba/ha. The standards used for the control of *Calystegia sepium* and *Convolvulus arvensis* were 0.75kg 2,4-D (as amine salt)/ha in France and 1.5kg bromofenoxim/ha in Germany (FRG).

Crop tolerance

Crop tolerance observations were made in the weed control programmes in each country. In France information was obtained from trials made in weed free sites treated pre-emergence with 1.5kg atrazine/ha and taken to yield. Crop tolerance was assessed by visual scores (Commission Des Essais Biologique (CEB)0-10 Scale, with 10 = 100% kill) and crop yields.

RESULTS

Crop Tolerance

In France, crop tolerance trials in weed-free sites (1.5kg atrazine/ha applied pre-emergence) were made during 1983 (5 trials), 1984 (6 trials) and 1985 (12 trials).

The maize cultivars used in the trials were Adige, Blizzard, Dea and LG7. The soil types included black organic sands and calcareous clays. Temperatures at the time of treatment ranged from 15-29 C (air) and 22-30 C (soil).

TABLE 5

France 1985 Control of triazine resistant S. nigrum (2 trials) and Polygonum lapathifolium (2 trials) (CEB 0-10); 1.5kg atrazine/ha applied pre-emergence

		S.nigrum				P.lapathifolium		
Treatment kg a.i./ha	DAT	7	18	22	28	10	17	34
(Weeds/m^2)		(500)				(20-60)		
dicamba	0.29	3	3	3	5	5	7	8
	0.36	4	4	6	7	5	8	9
	0.58	5	8	9	9	7	10	10
pyridate	0.9	9	9	9	10	5	6	7

TABLE 6

West Germany 1984 % control of annual broadleaved species, 30 DAT.

Treatment kg a.i./ha	Matricaria sp.	Polygonum persicaria	Stellaria media	Viola arvensis
(weeds/m^2)	(10-20)	(5-10)	(15-30)	(25-40)
dicamba + atrazine 0.29+0.75	70	90	98	50
dicamba + atrazine + bromofenoxim 0.25+0.75+0.6	98	95	98	55
dicamba + atrazine + bromofenoxim 0.19+0.75+0.75	100	98	100	60
bromofenoxim + atrazine 1.0+0.75	95	95	95	50
pyridate + atrazine 0.75+0.75	98	98	98	55

Maize <20cm. 4 trials. 4 cv (Felix; Mutin; Tau + ETA)

Perennial broadleaved weeds

Since 1981 dicamba has been evaluated as a post-emergence treatment for the control of C. sepium and C. arvensis. Trials were made in France, Germany(FRG), Austria and Eastern Europe, with dicamba being applied at from 0.24 to 0.6kg dicamba/ha. Both overall and directed inter-row treatments were tested. Representative data for France and Germany(FRG) are given in Tables 7 and 8.

TABLE 7

France 1984 Control of C. sepium (4 trials) and C. arvensis (4 trials) (CEB 0-10); directed, inter-row application. Yield as % of untreated

Maize 40-90cms Treatment kg a.i./ha		C. sepium DAT 40	Yield %	C.arvensis DAT 40	Yield %
dicamba	0.24	6	100	8	114
	0.29	7	109	8	100
	0.36	9	109	9	104
	0.42	9	116	8	105
2,4-D	0.75	9	104	9	114
LSD p			NS		NS

TABLE 8

Germany(FRG) 1984, % Control of C.sepium, (2 trials) C.arvensis (3 trials) and Cirsium arvense (1 trial); overall application.

Maize 30-60cms Treatment kg a.i./ha		C.sepium DAT 14	C.sepium 46	C.arvensis 14	C.arvensis 46	C.arvense 14	C.arvense 46
dicamba	0.24	95	100	90	95	-	-
	0.29	98	100	95	98	95	90
	0.36	100	100	95	98	95	90
bromofenoxim	1.5	-	-	90	70	95	90

DISCUSSION

The exploratory trials made during 1980-1982 in several countries in Europe showed that 0.29-0.36kg dicamba/ha controlled many important broadleaved weeds, notably A.retroflexus., C.album, Polygonum spp., volunteer sunflower (Helianthus annuus), also C.arvense and C.arvensis.

Often, because dicamba acts as a growth regulator herbicide, weed control took longer, about 10-20 days compared with 5-10 days for a contact acting herbicide. However, under conditions favouring rapid plant growth dicamba acted as quickly as a contact herbicide.

Extensive trial programmes were made over the four years 1982-1985 in Western Europe, in very varied climatic and soil conditions. These showed that 0.24-0.36kg dicamba/ha applied either sequentially to a pre-emergence treatment of 1.0kg-1.5kg atrazine/ha, or tank mixed with 0.6-0.8kg atrazine early post-emergence in maize at the coleoptile to five leaf stage, controlled triazine-resistant annual broadleaved weeds. Early post-emergence applications with 0.2 to 0.3kg dicamba/ha with reduced rates of a contact herbicide, such as bromofenoxim or pyridate, after 1.0-1.5kg atrazine/ha applied pre-emergence gave improved efficiency and crop selectivity.

Effective control of C.sepium was obtained using 0.29-0.36kg dicamba/ha as a directed spray treatment in France or overall in West Germany. The results were superior to the standards - 2,4-D amine (France) and bromofenoxim (FR. Germany) - both in terms of efficiency and crop tolerance. Crop tolerance was recorded for the weed control trials, in addition to the selectivity programme made in France (Tables 1,2).

Negligible to slight transient crop effects were seen in some years at a few sites in Austria and France. These effects consisted of either a slight leaning effect or an "onion leaf" appearance when the main leaf was slow to unfurl; very occasionally fusion of the secondary (prop) roots, "ducks feet", was seen but at a level too low to score. Crop yields were not affected where these symptoms were observed.

The use of dicamba post-emergence to control triazine-resistant annual broadleaved and perennial broadleaved weeds, particularly bindweeds, provides maize growers in Europe with a valuable and versatile addition to the range of herbicides currently available.

ACKNOWLEDGEMENTS

We are indebted to the farmers who provided the sites, and to members of the official and consultant organisations and colleagues for their guidance and encouragement.

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WEED CONTROL STRATEGIES FOR NO-TILLAGE CORN AND SOYBEAN PRODUCTION

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ABSTRACT

Field trials were conducted in Michigan during 1984 and 1985 to examine early pre-plant herbicide application in no-till corn and soybeans. Potential benefits of early pre-plant applications are 1) greater probability of rainfall for incorporation, and 2) no green vegetation at application time, therefore no need for non-selective post-emergence herbicides. Early pre-plant and sequential applications of commonly used herbicides provided equal weed control and equal or greater crop safety than conventional pre-emergence applications. Full season control of both grasses and broadleaved weeds was obtained from early pre-plant application made 2-4 weeks before planting. Early pre-plant application of cyanazine to no-till soybeans increased weed control but severely injured soybeans in 1984.

INTRODUCTION

Crop production without tillage (no-till) is becoming an increasingly common practice in the United States. Two primary reasons exist for the growing interest in no-till. Reduced tillage systems, such as no-till, which leave residue from the previous crop on the soil surface can significantly reduce soil erosion, especially on highly erosive soils. In addition, no-till reduces the cost associated with land preparation compared to a conventional tillage system. However, no-till places much more dependence on herbicides for weed control (Fawcett 1983).

The standard method of chemical weed control in no-till is a pre-emergence application of residual herbicides, often with a non-selective post-emergence herbicide included if weeds are present at application time (Fawcett 1983, Stougaard et al. 1984). Since the residual herbicides are applied to the surface, the effectiveness of the treatment is dependent on rainfall relatively soon after application to properly position the herbicide (Fawcett 1984).

Application of herbicides early in the spring prior to planting no-till (early pre-plant) has been examined over the past few years. Potential benefits of this approach are: 1) greater probability of rainfall following an early pre-plant application, and (2) elimination of the need for a non-selective post-emergence herbicide since the treatments are applied before any weeds emerge. The potential risk from this approach is loss of season-long weed control with early applications. This risk can be reduced by: 1) increasing the application rates, or 2) making sequential applications where a portion of the total herbicide rate is applied pre-emergence. In studies conducted at Iowa State University, early pre-plant treatments applied 2-4 weeks before planting provided equal or greater weed control than at-planting treatments (Fawcett et al. 1983, Fawcett 1984).

Early application may offer opportunities for the use of herbicides that would otherwise injure the crop. For example, Stougaard et al. (1984) reported that cyanazine applied 1 month before planting was safe on soybeans and provided excellent control of broadleaved weeds.

The objectives of this research were to examine herbicide efficacy and crop tolerance from early pre-plant (EPP), pre-emergence (PRE), and sequential (EPP + PRE) applications in no-till corn and soybeans. In addition, the safety of early pre-plant applications of cyanazine in no-till soybeans was examined.

MATERIALS AND METHODS

General experimental procedure

Field studies were conducted in 1984 and 1985 at or near East Lansing, Michigan, USA. Corn and soybeans were planted with no prior tillage in 76 cm wide rows. Planting population for corn and soybeans were 49,000 and 431,000 plants/ha, respectively. Fertilizer was applied at planting at the appropriate rate as indicated by a soil test. All herbicide applications were made using a compressed air tractor mounted sprayer delivering a spray volume of 215 l/ha at a pressure of 207 kPa. Relevant details about each study are included in Table 1.

Each study was designed as a randomized complete block with three or four replications. Crop tolerance and control of the most prominent weed species were evaluated visually by two people at selected times throughout the growing season. Data was subjected to analysis of variance and treatment means were separated using Duncan's multiple range test.

All herbicide treatments were applied either early pre-plant (EPP) 2-4 weeks before planting, pre-emergence (PRE), or sequentially (EPP + PRE) with approximately 2/3 of the herbicide rate applied early pre-plant and the remaining 1/3 applied pre-emergence. For early pre-plant and sequential applications, the rates of application were approximately 25% higher than for pre-emergence applications with each herbicide except atrazine. All pre-emergence applications included paraquat at 0.28 kg/ha and X-77[1] surfactant at 1/8% (v/v). These were added to the spray mixture to achieve complete kill of all green vegetation present at the time of treatment.

Weed control in corn

Field trials for no-till corn were located in Hickory Corners, Michigan, USA (southwest Michigan) in 1984 and in East Lansing (central Michigan) in 1985. Four herbicide combinations, representing typical herbicide programs in Michigan, were included in the study. Treatments included were: alachlor + atrazine, alachlor + cyanazine, metolachlor + atrazine, and metolachlor + cyanazine. Weeds evaluated in 1984 were *Digitaria sanguinalis* and *Abutilon theophrasti* and in 1985 were *D. sanguinalis* and *Amaranthus retroflexus*.

Weed control in soybeans

Field trials for no-till soybeans were located in East Lansing, Michigan in both 1984 and 1985. Four herbicide combinations, representing typical herbicide programs in Michigan, were included in the study. Treatments included were: metolachlor + metribuzin, metolachlor + linuron, alachlor + metribuzin, and alachlor + linuron. Weeds evaluated in 1984 were *Setaria lutescens* and *Ambrosia artemisiifolia* and in 1985 were *D. sanguinalis* and *A. retroflexus*.

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[1] X-77 is a non-ionic surfactant produced by Chevron Chem. Co., San Francisco, California, USA.

RESULTS

Weed control in corn

In 1984, each herbicide combination provided adequate control of D. sanguinalis and A. theophrasti 16 weeks after planting (Table 2). No differences were observed between early pre-plant, pre-emergence, or sequential application. In 1985, excellent control of D. sanguinalis and A. retroflexus 13 weeks after planting was achieved from each herbicide combination and method of application. Data indicate that early pre-plant or sequential application can provide equal weed control to conventional pre-emergence application in no-till corn.

Weed control in soybeans

Soybean injury was generally greater in 1984, however there were no differences between herbicides or methods of application (Table 3). In 1985, very little injury 3 weeks after planting occurred with early pre-plant or sequential applications. However, pre-emergence application of metribuzin resulted in significantly greater injury. This suggests that the 3.8 cm of rainfall on the early pre-plant treatments (Table 1) may have incorporated the herbicide into the soil to the extent that injury from metribuzin was reduced.

In 1984, control of S. lutescens 8 weeks after planting was variable but in most cases adequate (Table 3). No consistent differences or trends were apparent between early pre-plant, pre-emergence, or sequential applications. Data suggest that control of S. lutescens was greater with treatments including metolachlor than those including alachlor, however the differences were not statistically significant. This observation is consistent with findings of Ritter et al. (1983). A artemisiifolia control 8 weeks after planting was unacceptable for each herbicide combination and application method (Table 3).

In 1985, excellent control of both D. sanguinalis and A. retroflexus was observed 11 weeks after planting (Table 3). Each herbicide combination and application method provided greater than 90% control. Early pre-plant applications were applied 28 days before planting and received 3.8 cm of rainfall prior to planting. Under these conditions, season long weed control was obtained with early pre-plant applications.

In 1984, A. artemisiifolia control 11 weeks after planting was significantly greater where cyanazine was applied as an early pre-plant treatment when compared to a pre-emergence treatment of alachlor + metribuzin (Table 4). However, soybean injury from cyanazine application was significantly greater than with alachlor + metribuzin. Greatest injury was observed where cyanazine was applied early pre-plant at 2.24 kg/ha and metribuzin was applied pre-emergence at 0.28 kg/ha. This treatment resulted in visual injury 3 weeks after planting of 78% which reflected approximately a 30% reduction in soybean population. This type of interaction between triazine herbicides on soybean injury has been reported by Ladlie et al. (1977). In 1985, however, no significant difference in soybean injury was observed between early pre-plant application of cyanazine and pre-emergence application of alachlor and metribuzin (Table 4). Early pre-plant applications were made 18 days before planting in 1984 compared to a 28 day interval in 1985 (Table 1). Rainfall occurring between early pre-plant and pre-emergence applications was 2.5 cm in 1984 compared to 3.8 cm in 1985. These differences in the two studies may partially explain the variable results between years.

TABLE 1

Specific information regarding field studies on weed control under no-tillage in 1984 and 1985

	1984		1985	
	Corn	Soybean	Corn	Soybean
Variety	Great Lakes 592	Corsoy 79	Pioneer 3744	Corsoy 79
Planting Date	5/11	5/17	5/8	5/22
Early Pre-plant (EPP) Application	4/20	5/3	4/24	4/24
Pre-emergence (PRE) Application	5/11	5/21	5/9	5/22
Rainfall between EPP and PRE (cm)	2.5	2.4	2.5	3.8
Rainfall in May-July (cm)	19	17	15	15
Soil Texture	sandy clay loam	sandy clay loam	loam	loam
Soil Surface pH (0-4 cm)	6.3	6.4	6.9	6.9
Previous Crop	corn	soybean	soybean	soybean

TABLE 2

Weed control in no-till corn from four common herbicide combinations as influenced by timing of herbicide application

	Weed Control (%)[a]					
	1984			1985		
Herbicide Treatment[b]	EPP[c]	EPP + PRE[d]	PRE	EPP	EPP + PRE	PRE
	Digitaria sanguinalis[e]			*Digitaria sanguinalis*[f]		
Metolachlor + Atrazine	83 a	88 a	81 a	97 a	100 a	100 a
Metolachlor + Cyanazine	83 a	92 a	82 a	100 a	100 a	97 a
Alachlor + Atrazine	88 a	87 a	80 a	95 a	100 a	100 a
Alachlor + Cyanazine	82 a	82 a	80 a	100 a	100 a	97 a
Untreated		0 b			0 b	
	Abutilon theophrasti[e]			*Amaranthus retroflexus*[f]		
Metolachlor + Atrazine	98 a	97 a	100 a	100 a	100 a	100 a
Metolachlor + Cyanazine	93 a	80 a	93 a	97 a	98 a	98 a
Alachlor + Atrazine	100 a	93 a	93 a	100 a	100 a	100 a
Alachlor + Cyanazine	90 a	90 a	83 a	97 a	100 a	97 a
Untreated		0 b			0 b	

[a]Means within a variable and year followed by a common letter are not significantly different at the 5% level of probability.

[b]The rates of application EPP and EPP + PRE were: metolachlor, alachlor - 2.8 kg/ha; cyanazine - 3.36 kg/ha; atrazine - 2.24 kg/ha. The rates of application PRE were: metolachlor, alachlor - 2.24 kg/ha; cyanazine, atrazine - 2.24 kg/ha.

[c]Herbicide application made 2-3 weeks before planting.

[d]Two applications were made with 2/3 of the rate applied EPP and the remaining applied pre-emergence.

[e]Visually evaluated 16 weeks after planting.

[f]Visually evaluated 13 weeks after planting.

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TABLE 3

Weed control and crop tolerance in no-till soybeans from four common herbicide combinations as influenced by timing of herbicide application

	Weed Control and Soybean Injury (%)[a]					
	1984			1985		
Herbicide Treatment[b]	EPP[c]	EPP + PRE[d]	PRE	EPP	EPP + PRE	PRE
	Soybean Injury[e]			Soybean Injury[e]		
Alachlor + Metribuzin	13 a	16 a	18 a	0 b	8 b	28 a
Alachlor + Linuron	11 a	11 a	14 a	0 b	0 b	0 b
Metolachlor + Metribuzin	14 a	13 a	14 a	0 b	3 b	25 a
Metolachlor + Linuron	10 a	15 a	11 a	0 b	0 b	0 b
Untreated		0 a			0 b	
	Setaria lutescens[f]			*Digitaria sanguinalis*[g]		
Alachlor + Metribuzin	68 b	80 ab	85 ab	95 a	93 a	88 a
Alachlor + Linuron	90 ab	73 b	75 b	97 a	93 a	85 a
Metolachlor + Metribuzin	79 ab	95 ab	89 ab	93 a	92 a	99 a
Metolachlor + Linuron	99 a	98 ab	95 ab	100 a	97 a	95 a
Untreated		0 c			0 b	
	Ambrosia artemisiifolia[f]			*Amaranthus retroflexus*[g]		
Alachlor + Metribuzin	58 a	44 a	64 a	95 a	100 a	90 a
Alachlor + Linuron	68 a	75 a	64 a	92 a	100 a	100 a
Metolachlor + Metribuzin	63 a	55 a	64 a	97 a	100 a	100 a
Metolachlor + Linuron	59 a	65 a	58 a	97 a	100 a	95 a
Untreated		0 b			0 b	

[a]Means within a variable and year followed by a common letter are not significantly different at the 5% level of probability.

[b]The rates of application EPP and EPP + PRE were: alachlor, metolachlor - 2.8 kg/ha; metribuzin - 0.56 kg/ha; linuron - 1.12 kg/ha. The rates of application PRE were: alachlor, metolachlor - 2.24 kg/ha; metribuzin - 0.42 kg/ha; linuron - 0.84 kg/ha.

[c]Herbicide application was made 2-4 weeks before planting.

[d]Two applications were made with 2/3 of the rate applied EPP and the remaining applied pre-emergence.

[e]Visually evaluated 3 weeks after planting.

[f]Visually evaluated 8 weeks after planting.

[g]Visually evaluated 11 weeks after planting.

TABLE 4

Weed control and soybean tolerance from cyanazine application as influenced by application rate and other herbicides[a]

Herbicide Treatment	Application Rate EPP[d]	Application Rate PRE[e]	*A. artemisiifolia*[b] Control 1984	Soybean[c] Injury 1984	Soybean[c] Injury 1985
	---------(kg/ha)----------		--------(%)---------		
Alachlor + Metribuzin	-	2.24 + 0.42	38 b	18 c	28 a
Alachlor + Cyanazine	2.8 + 2.24	-	95 a	39 b	-
Alachlor + Cyanazine + Alachlor + Metribuzin	1.68 + 1.12 -	- 1.12 + 0.28	89 a	40 b	31 a
Cyanazine + Alachlor + Metribuzin	2.24 -	- 2.24 + 0.28	91 a	78 a	33 a
Untreated			0 c	0 c	0 b

[a]Means within a column followed by a common letter are not significantly different at the 5% level of probability.

[b]Visually evaluated 11 weeks after planting.

[c]Visually evaluated 3 weeks after planting.

[d]Herbicide application was made 2-4 weeks before planting.

[e]Pre-emergence.

DISCUSSION

Weed control in corn

Early pre-plant and sequential applications of commonly used herbicides in corn provided equal weed control compared to the conventional pre-emergence application in both 1984 and 1985. The higher rates of herbicide application used with early pre-plant and sequential application may have contributed to their performance.

Weed control in soybeans

In 1984, the lack of acceptable season long *A. artemisiifolia* control may be due in part to the intense pressure of this species in the experimental location. However, even in a situation of marginal control, such as this, early pre-plant and sequential applications provided weed control equal to pre-emergence application. In 1985, early pre-plant herbicide applications provided excellent season long weed control, even with 3.8 cm of rainfall occurring between herbicide application and planting. This suggests that lack of season long weed control with early pre-plant application may not be a great concern if higher herbicide rates are used to compensate for the early application.

Early pre-plant application of cyanazine caused unacceptable soybean injury in 1984 but resulted in less injury in 1985. Data indicate that acceptable crop safety with cyanazine in soybeans will be dependent on the time interval between application and planting, rainfall, application rate, and several other factors. Additional research is required to more accurately predict soybean response to cyanazine application.

In conclusion, early pre-plant and sequential application of commonly used herbicides in corn and soybeans provided equal weed control and equal or greater crop tolerance than pre-emergence application. The concern about lack of full season control from early pre-plant application was not supported by these results in either 1984 or 1985. However, if longevity of herbicidal performance is a concern, sequential applications offer an alternative which may extend herbicidal activity.

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PERFORMANCE OF AC 252 925 FOR THE CONTROL OF A WIDE RANGE OF WEEDS ON RAILWAYS AND INDUSTRIAL SITES IN THE UK

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ABSTRACT

Twelve trials were conducted over two years, where AC 252 925 and mixtures of AC 252 925 with atrazine were tested at different doses for the control of a wide range of monocotyledonous and dicotyledonous weeds on railways and other industrial sites. These treatments were compared with currently used standards. On railways AC 252 925 at 0.375 kg a.e./ha and AC 252 925 + atrazine at 0.25 kg a.e./ha + 2.0 kg a.i./ha respectively were more effective up to 21 weeks after treatment than the standard combination of 2,4-D + atrazine at 2.5 + 12.0 kg a.i./ha respectively.

Control of established weeds on industrial sites by AC 252 925 with or without atrazine was initially less than the standard atrazine + aminotriazole treatments (10.5 + 8.4 kg a.i./ha respectively), but from 8 to 12 weeks after treatment AC 252 925 either alone or in combination with atrazine was clearly more active than the standard. This activity persisted up to the last assessment at 22 weeks after treatment.

INTRODUCTION

AC 252 925 - isopropylammonium 2-(4-isopropyl-4-methyl-5-oxo -2-imidazolin-2-yl) nicotinate, is a non-selective herbicide discovered by American Cyanamid Company, and is sold in the UK and many other countries as 'ARSENAL*' herbicide. Ciarlante, Fine and Peoples (1983) described trials in the USA and Japan where the compound gave long term control of many important weeds on railways and industrial sites.

AC 252 925 belongs to a new class of herbicides, the imidazolinones, and has a wide margin of safety to mammals and other non-target species. The compound is absorbed by the roots and foliage of plants and is translocated to the meristematic regions. In weeds, AC 252 925 acts by reducing the levels of three essential branched-chain aliphatic amino acids through the inhibition of acetohydroxyacid synthese, an enzyme common to the biosynthetic pathway of these amino acids. This inhibition disrupts protein synthesis, leading to an interference in DNA synthesis and cell growth.

*Trademark of American Cyanamid Company

The biosynthesis of these three amino acids and the site of inhibiton occur only in plants, which partially explains the low mammalian, avian, and fish toxicity of AC 252 925.

Depending on the weed species and the method of application, signs of herbicidal activity and death of the weed may not occur for several days to several weeks after application. AC 252 925 has prolonged persistence. Lateral and vertical movement in soils is limited.

The purpose of this paper is to describe trials conducted on railways and industrial sites in the UK with AC 252 925 applied either alone or in combination with atrazine, where complete and prolonged control of all vegetation is required.

METHODS AND MATERIALS

A soluble concentrate formulation of AC 252 925 containing 250g a.e./ litre with a wetting agent incorporated was used in all trials. Where AC 252 925 was applied in mixture with atrazine, the latter was formulated as 80% a.i. wettable powder for railway trials, or as 50% a.i. suspension concentrate for trials on industrial sites.

Trials were conducted on three uses a) railway lines b) control of established vegetation on industrial land and c) maintenance of weed control on industrial land previously treated with non-persistent herbicides.

a) On railways, trials were conducted on track lengths at various locations in southern England. Treatments were applied in early May to tracks and the "cess" (a strip of approximately 1.0-1.5 m wide composed of soil between the stone ballast beneath the track and the embankment, where control of vegetation is usually limited to elimination of woody species). The treatments were applied from a train equipped for herbicide applications at a spray volume of 400-500 l/ha using fan nozzles at a spray pressure of 140 kPa. Comparisons with both the untreated track lengths and standard treatments were made at 7, 11, and 21 weeks after applications.

b) Trials for control of established vegetation were located at five industrial sites in Lancashire, Oxfordshire and Sussex. Plots measured approximately $40m^2$. Treatments were applied to actively growing vegetation in April or May using a knapsack sprayer equipped with fan nozzles at a spray volume of 450 l/ha and a pressure of 70kPa. Although soils at these sites were covered with gravel, ash, or inorganic industrial wastes, they were sufficiently fertile to support substantial weed infestations. AC 252 925 was applied alone in five trials, and in mixture with atrazine in three trials. Comparisons were made with a standard mixture of atrazine and aminotriazole.

c) The one trial for maintenance of a weed-free area was located at a site where contact herbicides had previously been used to control a mixture of annual and established perennial herbaceous weeds. Application techniques and timing were similar to those in (b) above.

RESULTS

a) The results of trials on railways are summarised in Table 1. The main weed species present in the these trials were various grasses, *Potentilla* spp., *Rubus fruticosus*, *Convolvulus arvensis* and *Heracleum sphondylium*. AC 252 925 used alone at 0.25 or 0.375 kg a.e./ha demonstrated greater efficacy than the combination of 2, 4-D + atrazine on dicotyledonous weeds. The higher of these doses was also as effective as this standard on monocotyledonous species. The combination of AC 252 925 with atrazine was clearly more effective than AC 252 925 alone, particularly when assessed 21 weeks after treatment.

TABLE 1

Weed control on railways at three sites with AC 252 925 applied alone or in combination with atrazine

			Mean control (%) of monocot (M) and dicot (D) weeds					
Interval to assess't. (weeks)			7		11		21	
Dose (kg a.e. or a.i./ha)			M	D	M	D	M	D
AC 252 925	+	atrazine						
0.25		0	95	62	25	74	0	30
0.375		0	98	71	100	94	35	40
0.25	+	2.0	100	80	100	93	55	56
2,4-D	+	atrazine						
2.5	+	12.0	100	50	100	11	35	26

b) The results of trials on established vegetation at industrial sites are summarised in Table 2 and Table 3.

The weeds present in these trials were annual and perennial grasses, including *Poa annua*, *Dactylis glomerata*, *Lolium perenne*, *Elymus repens* and the broad-leaved species approximately in order of frequency; *Epilobium angustifolium*, *Hypericum perforatum*, *Artemisia vulgaris*, *Potentilla reptans*, *Ranunculus repens*, *Rumex obtusifolius*, *Leucanthemum vulgare*, *Urtica dioica*, *Cirsium arvense*, *Senecio jacobaea*, *Sonchus spp*, *Equisetum arvense*, *Achillea millefolium*, *Taraxacum officinale*, *Tussilago farfara*, *Trifolium repens*, *Vicia sativa*, *Capsella bursa-pastoris*, *Senecio vulgaris*, *Viola arvensis*, *Plantago lanceolata* and *Euphorbia exigua*.

TABLE 2

Control of established vegetation with AC 252 925

	Mean control (%) of monocot (M) and dicot (D) weeds*							
Interval to assess't. (weeks):	3-6		8-12		16-18		21-22	
(no. trials sites)*	(5)		(5)		(4)		(3)	
Dose (kg a.e. or a.i./ha)	M	D	M	D	M	D	M	D
AC 252 925								
0.5	62	71	98	96	94	85	80	72
0.75	75	78	99	97	97	96	95	88
atrazine + aminotriazole								
10.5 + 8.4	99	95	96	83	88	63	80	62
S.E.M. = 5.6								

*at the total 5 sites, assessments were up to 16-18 weeks at four and to 21-22 weeks at 3 sites

TABLE 3

Control of established vegetation with AC 252 925 in combination with atrazine in 3 trials

	Mean control (%) of monocot (M) and dicot (D) weeds					
Interval to assess't. (weeks):	5-6		9-11		18-19	
Dose (kg a.e. or a.i./ha)	M	D	M	D	M	D
AC 252 925 + atrazine						
0.5 0	72	75	99	98	89	87
0.75 0	80	83	100	97	93	95
0.5 + 2.0	82	80	100	96	95	87
0.75 + 2.0	87	83	100	98	99	87
atrazine + aminotriazole						
10.5 + 8.4	98	95	99	78	96	60
S.E.M. = 4.6						

Whilst AC 252 925 applied alone at 0.5 to 0.75 kg.a.e./ha was not as effective as the combination of atrazine + aminotriazole at the 3-6 weeks assessment, it was more effective thereafter up to 22 weeks after treatment, especially on dicotyledonous species. Mixtures of AC 252 925 with atrazine were more effective than AC 252 925 alone on monocotyledonous species at the 5-6 weeks assessment and were approximately equal from 9 to 19 weeks after treatment.

c) Control of weed re-growth and re-infestation in the one trial conducted in a weed-free area (Table 4), was clearly greater after treatments of AC 252 925 alone than after standard atrazine + aminotriazole treatments.

TABLE 4

Control of weed re-growth and re-infestation with AC 252 925 in one trial

			Control (%) of monocot (M) and dicot (D) weeds			
Interval after treatment (weeks):			12		18	
Dose (kg a.e. or a.i./ha)			M	D	M	D
AC 252 925						
0.25			100	76	96	68
0.5			100	96	100	93
atrazine	+	aminotriazole				
2.4	+	2.0	68	63	56	38
3.4	+	2.7	87	55	90	76

DISCUSSION

The trials described demonstrated that AC 252 925 is a very effective herbicide for use on railways and industrial sites. The prolonged persistence of AC 252 925 applied alone allows effective weed control to be maintained for 6 months or more at the higher doses tested (0.75 kg.a.e./ha). A single annual treatment is therefore adequate in many circumstances even under heavy weed re-infestation.

The lower dose of AC 252 925 (0.25 kg.a.e./ha), in combination with atrazine at 2.0 kg.a.i./ha, provided greater weed control during the first few weeks after treatment and also greater herbicidal persistence compared to the low doses (0.25 or 0.37 kg.a.e./ha) of AC 252 925 applied alone.

Because of its high degree of activity, AC 252 925 is being tested for other uses, such as 'conifer release' (selective control of weed competition after trans-planting), site preparation in forest management and control of aquatic and semi-aquatic weeds along ditchbanks. Control of *Pteridium aquilinum* has been outstanding with applications of AC 252 925 at 0.25 kg.a.e./ha or higher.

ACKNOWLEDGEMENTS

The authors are indebted to British Rail and all the companies that allowed trials to be conducted on their premises.

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WEED-CROP INTERACTIONS AND THE OPTIMAL TIMING OF WEED CONTROL

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ABSTRACT

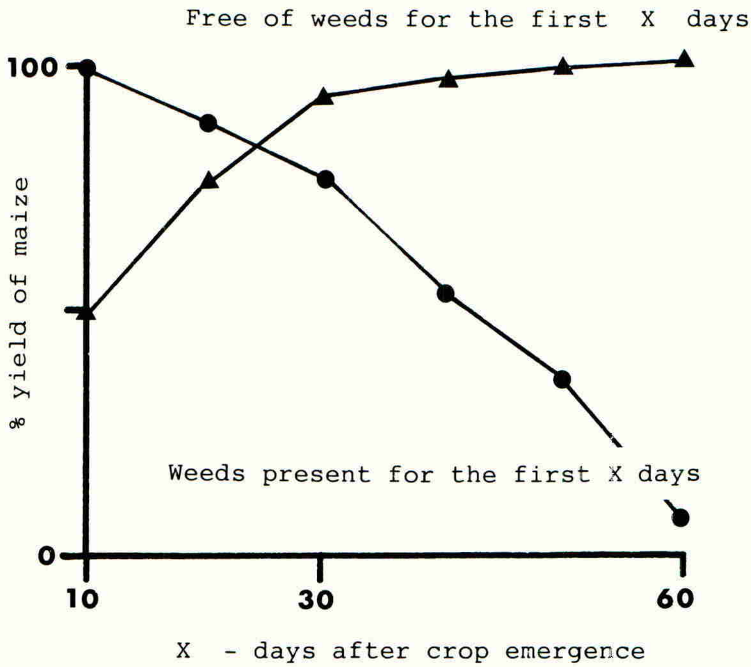
Effective weed control within established weed-crop communities demands precise timing of control practices. This requires knowledge of yield loss resulting from the duration and timing of the weed infestation. A new method of analysis is introduced which identifies the optimum period of weed control, using as an example an investigation into wheat yield losses resulting from an infestation of Elymus repens. The approach is discussed in relation to the concept of the critical period of competition. A hypothetical example is used to show that the optimum timing of control may vary with weed density and age-structure.

INTRODUCTION

It is a tenet of weed management that the timing of control practices is crucial to overall success. This is particularly the case where control is practised during the growth period of the crop. Nieto,Bondo and Gonzales (1968) investigated the timing of control by an experimental design in which the crop was kept weed-free for varying periods after sowing and also weed infested for varying periods after sowing and weed free thereafter. For both maize and beans, there were two periods during which weeds caused minimal yield losses; up to 10 or 12 days after sowing and then after 30 days from sowing. Therefore the optimal timing of weed control is between 10 and 30 days after sowing (Fig. 1) - a period termed 'the critical period of competition'.

This experimental design has been repeated for many crops and not surprisingly the results vary substantially between weed-crop systems (Roberts, 1976; Weaver, 1984). Sometimes no critical period is found ; whilst in other studies it is influenced by sowing rate and fertiliser level. After reviewing the available literature, Zimdahl (1980) concluded that attention should be paid to specific weed-crop systems rather than to generalisations.

Fig. 1. An illustration of the critical period of competition (after Nieto et al., 1968) for maize.



If taken to its limit, it is implied that the study of the critical period of competition is of little benefit to the farmer, since it is affected by too many factors. In this paper we present a more quantitative approach to this subject which we believe allows an improved understanding of the critical period of competition, both in a general sense and also of specific cases.

The biological basis of the critical period of competition

The yield of an individual plant depends upon the availability of resources - light, water, and nutrients and as the plant grows the area from which it takes up resources increases (Ross and Harper, 1972). At the start of the cropping season, weed and crop plants may well be so small that the individual plants have acccess to sufficient resources for maximum growth - i.e. competition is not taking place. Weeds may be left in the crop during this period as they are not affecting crop yield. Eventually the plants begin to compete and yield hierarchies are established ; individual plants grow to shade out their neighbours and to establish root systems by virtue of faster growth rates or earlier emergence. Once established, such hierarchies tend to be self-perpetuating over the generation time in plant populations (Ford,1975), the larger plants obtaining resources to a disproportionate extent compared with their suppressed neighbours. However if these larger plants are removed their neighbours may be able to grow faster to compensate for the effects of earlier competition. The possible extent of such compensation depends upon the age of the plant - for a cereal, for example the components of yield are established at different periods during the life of the crop and so the capacity for compensation is reduced.

In Fig. 1 therefore, the early emerging weeds are capabable of causing the greatest yield loss, and the longer they are left amongst the crop, the smaller the crop plants are and the less able to compensate. Therefore the longer the crop is weedy the less the eventual yield. On the other hand the later emerging weeds are unable to effectively establish and compete with the crop as they are low in the yield hierarchy.Therefore weeds allowed to emerge after 30 days have a negligible effect upon crop yield.

The optimum period of control thus represents a window in the cropping season during which the early emerging weed cohorts can be destroyed before they cause appreciable yield loss and the subsequently emerging weeds are unable to compete effectively within the crop. It is not a 'critical period of competition' as the processes of weed-crop competition are no different during this period than in any other.

It is clear that the extent and duration of the optimum period of weed control will be affected by all the factors that can influence weed-crop competition. The 'period' is bound to be sensitive to environmental factors and management and may not exist at all.

A model for weed-crop competition

In any weed-crop system, the yield of the crop is some function of weed density. In one-weed one-crop systems, crop yield Y can be described by the model

$$Y = c\,(1 + \alpha N_w / N_c)^{-1} \qquad (1)$$

where c is the weed-free yield, N_c is the density of the crop, N_w is the density of the weed and α describes the average competitive impact of each weed on the yield of the average crop plant (Firbank *et al.*,1984). The term αN_w represents the net competitive pressure on the crop and α depends on the relative growth rates of the two species, their age-structures, upon the environment and upon the time during which competition is allowed. The parameter α therefore can be used to describe weed-crop competition in a more exact way than by using crop yield alone as the affects of density, of weed and crop and of weed-free yield do not confound the estimate of competitive impact. Meaningful comparisons can therefore be made between experiments using this parameter as described below.

MATERIALS AND METHODS

Ninety pots, each 30 cm square and 30 cm deep were filled with a loam-peat-sand compost without additional fertiliser and a further ninety with the same compost augmented with NPK (see Table 1 for the composition of these soils)and arranged in a polythene tunnel house. 25 wheat seeds (cv Broom) were

TABLE 1.

Nutrient analysis of the two soil types used in the experiment.

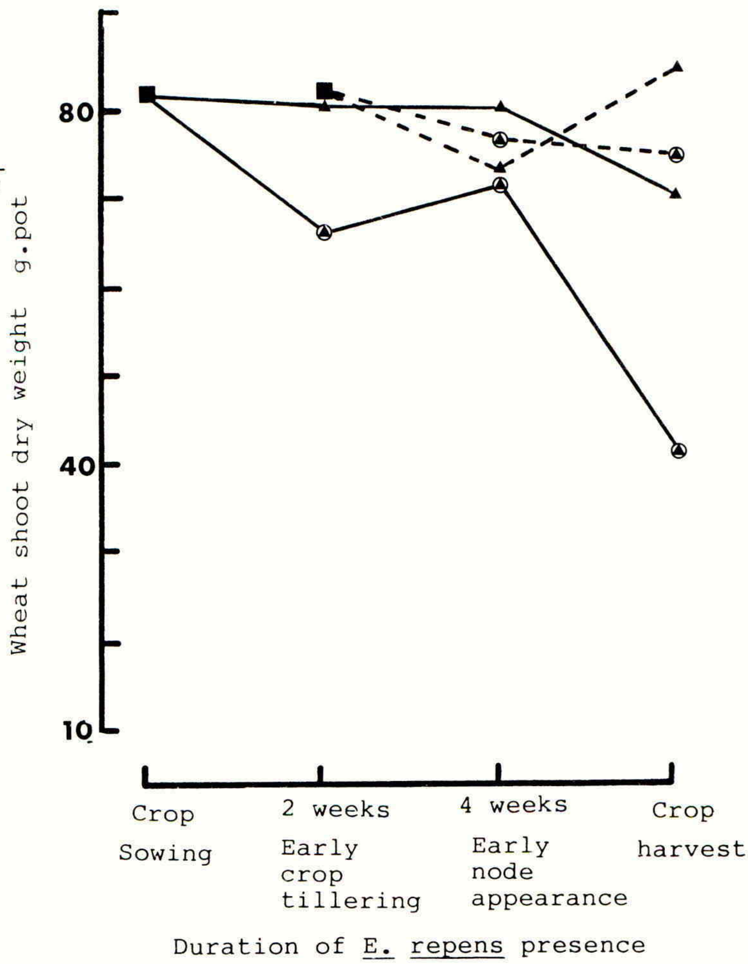
	Low fertility	High fertility
pH	6.4	5.9
K index	2	5
P index	3	8
Mg index	3	3
NH_4 ug/g soil	28.5	89.5
NO_3 ug/g soil	12.3	10.4

sown into each pot on 25 May 1984. 10 pots of each soil type were left as controls. Into the other pots rhizome fragments of E. repens were introduced in a factorial design, either at high (16 buds per pot) or low (4 buds per pot) density and as large (4 buds per fragment) and small (1 bud per fragment) rhizome fragments. For each treatment combination, the rhizomes were introduced either simultaneously with the crop (cohort 1) or two weeks after (cohort 2) by which time the wheat was just beginning to tiller. The E. repens shoots were harvested at soil level, leaving the rhizomes intact, either after two weeks (cohort 1 only); after four weeks (for both cohorts), by which time the wheat was beginning to show visible nodes; or at final harvest. The crop was harvested during mid-August 1984 and the shoot dry weight per pot of wheat was measured. The experiment was conducted as a randomised block design and each pot contained only one cohort of E. repens harvested at the most once before crop harvest.

RESULTS

No significant differences were recorded in wheat yields between equivalent treatments of pots with large or small rhizome fragments and these data have been pooled for analysis giving 8 replicates per treatment.

Fig.2 The effects of density, cohort and time of removal on wheat biomass. Couch was either introduced with the crop (Cohort 1 ——) or after two weeks (Cohort 2 - - -) at four nodes per pot or 16 nodes per pot (symbols in circles) and removed before or at crop harvest. Control yield ■ .



The greatest depression in crop yield occurred with the high density infestation of E. repens present throughout the growth of the crop (Fig. 2). Plants of this first cohort caused greater yield loss if cut after two weeks than after four weeks, as the early 'control' allowed substantial regrowth of the E. repens shoots which competed with the crop. The optimum period of removal of these E. repens shoots was approximately 4 weeks. Plants of the second cohort had little effect upon crop yield even if left until harvest.

Equation 1 may be fitted (by least squares estimation of logarithmically transformed data) to subsets of the data to estimate the value associated with E. repens plants of each cohort and each time of harvest. The α values of the plants of cohort 2 are all very low reflecting their very small effect upon crop yield. For cohort 1 the values vary greatly however. If removal occurs after 4 weeks, the values reveal again a small effect on crop yield per E. repens bud, but if the shoots were harvested only at the time of the crop α values exceed one - i.e. each E. repens shoot has a greater competitive effect on a wheat plant than another wheat plant (Table 2.)

TABLE 2

Estimates of the competition coefficient α describing the competitiveness of E. repens shoots towards wheat plants under two fertility regimes. See text for details.Data are mean and s.e (lower figure) based on 24 degrees of freedom.

	Cohort			
Time of removal after sowing (weeks)	1		2	
	Fertiliser		Fertiliser	
	Low	High	Low	High
2	0.36	0.23	-	-
	0.22	0.04		
4	0.17	0.11	0.12	- 0.04
	0.17	0.16	0.14	0.18
Harvest	1.05	1.25	0.06	0.17
	0.29	0.37	0.14	0.21

No significant differences were recorded between equivalent α values for the two fertility levels.

DISCUSSION

The optimum period of weed control is that period when control results in the minimum net competitive pressure exerted by the weed population on the crop. The net competitive pressure is defined by the term αN_w and so from the results of this pot experiment, this term is minimised for E. repens plants introduced with the crop if the shoots are removed after four weeks. This treatment would cause a yield loss equivalent to a fifth as many plants surviving until harvest. Since E. repens plants introduced after the crop have so little effect upon crop yield, the optimum period for weed control is at around four weeks, a finding unaffected by the two fertiliser levels used here.

It is easy to envisage more complex situations arising and in particular the critical period could vary according to the age-structure of the weed. For example, suppose the competitive pressure of weed cohorts on a crop are as given in Table 3 and that the total competitive pressure of all cohorts present is the sum of the competitive pressures of all cohorts present, then the critical period of weed removal depends upon the age structure. A population of largely early emerging plants should be weeded earlier than one predominantly of later emerging plants. The critical period of weed removal should not be regarded as a fixed period except under highly predictable circumstances.

The value of the analysis of competitive pressure is twofold. First it allows the quantitative description of competition in such a way as to permit valid comparisons between experiments by excluding the effects of density and weed free crop yield. It may prove possible to use this approach to define optimum periods of control in the field rather in the manner of the example above, but more work is needed before this is possible.

The second major advantage is that by consideration of equation 1, a range of strategies for successful weed management become obvious. Yield Y can be increased by

a) increasing the weed-free yield - improved management and variety (α may be expected to change);

b) increasing crop density;

c) decreasing absolute weed densities;

TABLE 3

The competitive pressure resulting from differing times of control on a hypothetical weed population, as affected by weed age-structure. It is assumed that the weed emerges in 3 cohorts and can be removed after each cohort has emerged or left until harvest.

a) Hypothetical values for weeds of each cohort.

Time of Weeding	Cohort c1	c2	c3
1	0.1		
2	0.5	0.05	
3	0.9	0.10	
Harvest	1.0	0.50	0.10

b) Net competitive pressure (Σ (αN_w)) associated with each time of removal for a range of age structures.

Age structure (c1:c2:c3)	Time of removal 1	2	3	Harvest
12:4:2	3.4	6.4	11.3	14.2
6:6:6	4.2	3.9	6.3	9.6
2:4:12	3.4	2.4	2.8	5.2

c) Percentage yield loss associated with each time of removal for a range of age structures using the model,

$$l = \frac{\Sigma(\alpha N_w)}{N_c + \Sigma(\alpha N_w)}$$

where l = yield loss, N_c = crop density (25 plants), and N_w = weed density in each cohort.

Age structure (c1:c2:c3)	Time of removal 1	2	3	Harvest
12:4:2	0.12	0.20	0.31	0.36
6:6:6	0.14	0.13	0.20	0.28
2:4:12	0.12	0.09	0.10	0.17

d) decreasing average values of the weed population; which can be achieved by

i) manipulating age structure in the weed crop association to favour the crop in yield hierarchy development;
ii) manipulating weed and crop growth rates differentially;
iii) timing weed control for the optimum period;
iv) manipulating weed species composition.

None of these ideas are new but until now they have not been integrated into an analytical system which allows quantitative estimation of these strategies, showing clearly that the optimum period of weed control is only one aspect of successful weed management.

ACKNOWLEDGEMENTS

The work reported here was funded by the Agricultural and Food Research Council. We thank Dr. P.D.Putwain for discussion, Jo Woodhouse, Zara Taylor for technical assistance and the Director of Ness Botanic Gardens for facilities.

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