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THE RESPONSE OF DAHLIAS TO SOIL-APPLIED HERBICIDES

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Summary In a series of field experiments chloramben, lenacil, linuron prometryne, simazine and trifluralin were applied to four varieties of dahlia growing in sandy loam soil. All except chloramben and trifluralin gave good weed control. Simazine at 1 lb/ac damaged three of the four varieties and was considered to be unsuitable for general use, even as a directed spray. Overall applications of linuron at 1.5 lb/ac caused damage suggesting that it also is unsuitable even as a directed spray. Prometryne at 1.5 lb/ac was more promising although even this caused some foliage damage when applied as an overall spray. The most promising herbicide of those tested was lenacil which appears safe at 4 lb/ac as an overall spray.

INTRODUCTION

Dahlias are a popular crop for cut-flower production and general decorative purposes in both commercial and amenity horticulture. The increasing cost and scarcity of suitable labour for hoeing makes chemical weed control attractive. Directed applications of cresylic acid formulations and overall applications of 2,4-DES are currently recommended (Fryer and Evans, 1968), but neither herbicide gives adequate weed control for a long enough period. Simazine, which does give good weed control has been variable in its effect on the crop. Directed applications of 1 lb/ac 7 to 10 days after planting rooted cuttings has been found to be safe on most varieties tested but the margin of safety was small (Fairfield, 1962, 1963, 1964; Luddington, 1962; Clay and Ivens, 1964). Because of the many varieties grown its general use is risky.

In the present work several herbicides have been compared with simazine with the object of finding a treatment that is safer than simazine while giving comparable weed control.

METHOD AND MATERIALS

Three field experiments were conducted in a sandy loam soil at Begbroke during the period 1965 - 1967. The plants were raised from cuttings and hardened off before planting out. These and other cultural requirements such as land preparation, fertilisation and pesticide applications were in accordance with current commercial practice. In each experiment a split-plot design was used with four plants of one variety forming a sub-plot. Three sub-plots containing different varieties constituted a main plot of 12 plants which received the herbicide treatments. The sub-plots and main plots were randomised and there were three replicates. The varieties grown were chosen because of their differential susceptibility to simazine injury in previous work (Clay and Ivens, 1964). Wettable powder and liquid formulations were applied in 50 or 100 gal/ac at 30 psi using an Oxford Precision Sprayer fitted with Allman No. 00, 0 or 1 ceramic fan jets. Directed applications were achieved either by covering each plant with a plant pot with the drainage hole plugged and then applying an overall spray (directed, overall) or by using a single nozzle and directing the spray to avoid the plant which was not covered (directed, not covered). The granular formulation was applied from a bottle with a perforated cap.

Weeds were allowed to develop on all plots for several weeks but they were never allowed to become large before removal either by shallow hoeing or pulling.

The following treatments were applied:-

year	herbicide	dose (lb/ac)	method of application	formulation
1965	chloramben	3 and 6	overall	10% granules
	"	3 and 6	overall	24% aqueous conc.
	simazine	1	overall	50% wettable powder
1966	simazine	1	overall, directed-not covered	50% wettable powder
	linuron	1.5	directed-covered, directed-not covered	50% " "
	prometryne	1.5	directed-covered, directed-not covered	50% " "
	lenacil	2	overall	80% " "
	trifluralin	1	overall incorporated	48% emulsifiable conc.
1967	simazine	1	overall, directed-not covered	50% wettable powder
	linuron	1.5	" " " "	50% " "
	prometryne	1.5	" " " "	50% " "
	lenacil	2 and 4	overall	80% " "

Dahlia varieties, planting and spraying dates and rainfall data are given in Table 1.

Table 1.

Details of three field experiments on dahlias

Experiment	1965	1966	1967
Varieties	Edinburgh Glorie van Heemstede Marion Lister	Edinburgh Marion Lister Newby	Edinburgh Glorie van Heemstede Newby
Planting date	10/6	7/6	9&12/6
Spraying date	21/6	16/6	23/6
Rainfall (in.)			
week before spraying	0.96	0.28	0.03
day before spraying	0.00	0.00	0.00
day of spraying	0.00	0.08	0.00
day after spraying	0.01	0.09	0.00
week after spraying	0.54	0.50	1.11
month after spraying	1.86	2.25	1.99

RESULTS

Crop response - 1965 Experiment

Chloramben caused no obvious injury symptoms, but for 4 to 6 weeks after application the 6 lb/ac treatment caused hardening of the foliage. Simazine at 1 lb/ac caused severe injury to Marion Lister, many plants being killed. Glorie van Heemstede showed moderate injury (leaf necrosis) and the growth of plants was subsequently checked. No injury symptoms or growth check was observed on Edinburgh. The effect on flower production is shown in Table 2, and it is clear that where damage occurred to the foliage there was also a reduction in the number of flowers.

Table 2.

<u>The effect of chloramben and simazine on flower production of 3 varieties of dahlias in 1965</u>

Treatment	Mean no. flowers picked per plant over season			
	Edinburgh	Glorie van Heemstede	Marion Lister	Mean for 3 varieties
Control (untreated)	28	34	26	29
Chloramben (spray)				
3 lb/ac	21	41	20	27
6 lb/ac	31	48	28	36
" (granules)				
3 lb/ac	22	38	20	27
6 lb/ac	27	37	24	29
Simazine (spray)				
1 lb/ac	36	21	5	21
S.E. of means		± 4.1		± 2.6

- 1966 Experiment

Three weeks after application both linuron treatments and lenacil caused slight veinal chlorosis on the expanded leaves of Newby. Trifluralin caused hardening of the leaves of all three varieties and yellowing of the lower leaves of Newby. Simazine caused moderate damage to Marion Lister and Newby but Edinburgh was unaffected. Eight weeks after treatment damage symptoms were confined to the simazine plots, they were only slight on Edinburgh and Newby but moderate on Marion Lister. On all three varieties damage was slightly less pronounced where directed application was used instead of overall. Simazine at 1 lb/ac as an overall spray caused an appreciable reduction in the flower production of Marion Lister. The directed application caused a smaller reduction which was similar to the reduction by both simazine treatments on Newby. Trifluralin also reduced the yield of Newby. These were the only treatments to have adverse effect on flower production (Table 3). All treatments increased the yield of flowers on Edinburgh compared with the untreated plots.

- 1967 Experiment

Injury to the foliage was assessed on three occasions. The results in Table 4 show that linuron caused most damage, but only from the overall application. Edinburgh was damaged less than Glorie van Heemstede and Newby. The maximum scores at the second assessment indicate the development of symptoms during the two weeks after spraying. Two weeks later scores were lower indicating some recovery from chlorosis but more important that new growth was normal. Simazine and prometryne caused similar amounts of injury and as with linuron it was confined mainly to the overall treatments and was less severe on Edinburgh. Lenacil caused a little damage but this was confined to Edinburgh. The diameter of each plant was measured on August 28th. The overall applications of linuron reduced the diameter of all three varieties by 22 to 36%. Other treatments were without effect. The number of flowers that were picked is shown in Table 5. The overall application of simazine and linuron reduced the yield of Glorie van Heemstede by 44 and 28% respectively. Smaller reductions were caused by other treatments but none of the differences was statistically significant. The treatments that caused most foliage damage did not cause the greater reductions in yield. At the end of the season tuber weight was

Table 3.

The effect of 5 herbicides on flower production of 3 varieties of dahlia in 1966

Treatment	Mean no. flowers picked per plant over season			
	Edinburgh	Marion Lister	Newby	Mean for 3 varieties
Control	9.8	15.5	19.6	15.0
Lenacil 2 lb/ac overall	14.3	22.1	23.3	19.9
Linuron 1.5 lb/ac at				
directed, covered	17.7	21.6	25.2	21.5
directed, not covered	16.2	20.8	19.9	19.0
Prometryne 1.5 lb/ac				
directed, covered	13.1	17.9	20.7	17.2
directed, not covered	13.8	16.0	31.3	20.4
Simazine 1 lb/ac				
overall	15.5	7.3	13.7	12.2
directed, not covered	17.4	12.2	15.9	15.2
Trifluralin 1 lb/ac				
incorporated preplanting	10.6	15.6	16.5	14.2
S.E. of means		± 7.9		± 5.6

Table 4.

The effect of 4 herbicides on the foliage of 3 varieties of dahlia in 1967

Treatment	Damage score (mean of 12 plants)								
	Edinburgh			Marion Lister			Newby		
	30/6	7/7	28/7	30/6	7/7	28/7	30/6	7/7	28/7
Control (untreated)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lenacil 2 lb/ac overall	0.0	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.1
4 lb/ac overall	0.0	0.7	0.0	0.0	0.1	0.0	0.0	0.2	0.0
Linuron 1.5 lb/ac									
overall	1.1	1.7	0.8	1.6	2.9	1.5	1.5	2.4	0.5
directed not covered	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Prometryne 1.5 lb/ac									
overall	0.0	0.2	0.2	0.5	0.8	0.2	1.1	0.8	0.1
directed not covered	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Simazine 1.5 lb/ac									
overall	0.0	0.2	0.1	0.0	0.6	0.2	1.0	0.6	0.1
directed not covered	0.0	0.2	0.1	0.0	0.0,	0.0	0.0	0.0	0.3

Damage scale:- 1, very slight necrosis; 2, 10 - 20% area necrotic; 3, moderate injury, 50% foliage necrotic; 4, severe injury 80 - 90% " "

Table 5.

The effect of 4 herbicides on flower production of 3 varieties of dahlia in 1967

Treatment	Mean no. flowers picked per plant over season			
	Edinburgh	Marion Lister	Newby	Mean for 3 varieties
Control	22	39	34	32
Lenacil 2 lb/ac overall	22	43	29	31
4 lb/ac overall	23	39	35	32
Linuron 1.5 lb/ac				
overall	21	28	23	24
directed, not covered	18	40	38	32
Prometryne 1.5 lb/ac				
overall	24	37	32	31
directed, not covered	22	45	35	34
Simazine 1 lb/ac				
overall	23	22	30	25
directed, not covered	26	35	29	30
S.E. of means		± 4.1		± 2.2

determined. Simazine as an overall spray caused a 56% reduction in the variety Glorie van Heemstede. Overall application of linuron and prometryne also tended to reduce the weight of tubers in this variety, but to a lesser extent. The response of Glorie van Heemstede to the other treatments and the response of the other varieties was less pronounced but there was a trend for overall application to result in lower tuber weight.

Weed control - 1965 Experiment

There was a substantial population of weeds (mainly Senecio vulgaris) at the cotyledon and first true leaf stage when the treatments were applied. These weeds developed into a dense cover on the control plots. Simazine gave almost complete weed control. The control achieved by chloramben was poor; 3 lb/ac giving 20% and 6 lb/ac 70% reduction when assessed 5 weeks after application. There were no consistent differences between the granule and wettable powder formulations.

- 1966 Experiment

Many weeds at the cotyledon stage were present when the treatments were applied. All the treatments gave excellent weed control for 4 weeks. Ten weeks after application there was 3% weed cover on the simazine, linuron and prometryne plots and 17% on the lenacil plots. By this time weed-control had broken down on the trifluralin plots and they had 70% weed cover.

- 1967 Experiment

Five weeks after application, all the plots that were treated with herbicide were virtually weed-free whereas the unsprayed plots had a 30% weed cover. All the treatments gave effective weed control throughout the season.

DISCUSSION

Simazine at 1 lb/ac has continued to give excellent weed control and in three years has not reduced flower production of Edinburgh even when applied as an overall spray, thus confirming the tolerance of this variety to simazine (Fairfield 1963, 1964; Luddington, 1961; Clay and Ivens, 1964). The other varieties, Glorie van Heemstede, Marion Lister and Newby, although more tolerant to directed than to overall sprays have not shown an adequate margin of tolerance.

Of the other herbicides tested, chloramben and trifluralin, although showing some promise in terms of crop tolerance did not give adequate weed control. Lenacil appears the most promising treatment because it can be applied as an overall spray and even at 4 lb/ac did not reduce flower production in a year when heavy rainfall after treatment led to severe injury from other herbicides. Slight leaf injury has occurred on Newby and Edinburgh but this did not appear to be important in these experiments. Its main weakness lies in its recognised ineffectiveness against emerged weeds, although in the present work it did control the weeds which were at the cotyledon stage. Prometryne is also promising although there is less information on its safety as an overall spray and the injury symptoms on Glorie van Heemstede and Newby might indicate an inadequate margin of safety. Linuron, because of the injury symptoms caused by overall applications cannot be regarded as a promising treatment even though directed applications have not caused damage.

Acknowledgements

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THE RESPONSE OF HERBACEOUS PERENNIAL FLOWERS TO OVERALL APPLICATIONS OF PARAQUAT AND DIQUAT

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Summary Established plants of 21 herbaceous perennial flowers were sprayed overall with paraquat at 0.5 and 2.0 lb/ac and diquat at 0.5 lb/ac on five dates between mid-November and early April. On nearly all occasions living shoots were sprayed. Although the treatments caused initial damage complete recovery occurred in most instances. November to early February was the safest period. March and April applications resulted in some permanent damage. Paraquat at 0.5 lb/ac was the safest treatment. Diquat at 0.5 lb/ac caused almost as much damage as paraquat at 2.0 lb/ac.

INTRODUCTION

Paraquat, diquat or mixtures of the two can be used for weed control in any situation provided they are not allowed to come in contact with the crop plant. Herbaceous perennial flowers can be conveniently treated with directed sprays during the period from late autumn to early spring when their foliage usually forms a well-defined clump. However an overall spray would be easier to apply and would give more complete weed control. Low doses of paraquat and diquat are recommended as overall sprays for perennial flowers that die down completely in winter (M.A.F.F., 1966). In Northern Ireland astilbe hybrids were unharmed by paraquat and diquat at 4 lb/ac (Loughgall, 1962b) and in Germany paeony was unharmed by diquat (Leiber, 1964) when all the foliage had died down; these experiments support the M.A.F.F. recommendation. Overall applications are not recommended for subjects which retain green foliage through the winter (M.A.F.F., 1966) although lily-of-the-valley (Convallaria majalis) was not damaged when sprayed with paraquat at the spearing stage. (Biologisched Bundesanstalt, Braunschweig, 1961). It has also been shown that overall applications of paraquat and diquat to strawberries in the winter do not produce permanent damage (Loughgall, 1962a).

The object of the present investigation was to observe the response of a range of perennial flowers to overall applications of paraquat and diquat applied between mid-November and early-April.

METHOD AND MATERIALS

The work was carried out at Begbroke on established plants of a range of lined-out herbaceous perennial flowers which were cut back to their basal growth in autumn 1967. Paraquat* and diquat** were applied at five dates between November 17th 1967 and April 4th 1968. Throughout this period rainfall was below average. Minimum temperatures were also below average except in March when they were almost average, resulting in a delay to growth in the spring. Each plot contained two

* Gramoxone 'W'
** Reglone with 0.1% Agral 90 in the spray solution

plants. The treatments were not replicated. The number of plants available did not allow each subject to be sprayed with each treatment on all five application dates (see Table 1). The treatments were applied in 50 gal/ac at 30 psi using an Oxford Precision Sprayer fitted with Allman No. 0 ceramic fan jets. At each spraying date ground cover of living tissue was expressed as a percentage of the basal area in November. The initial response was assessed one week after application: thereafter assessments were made at monthly intervals during 1968. From May 1968 onwards growth was expressed as a percentage of the height and spread of unsprayed plants of the same species.

RESULTS

One week after application the foliage invariably showed considerable damage in the form of 'water-soaking' (tissues light to dark brown in colour but not desiccated) or necrosis of leaf tissue. In most cases regrowth occurred, the new shoots being normal in colour. Table 1 contains the assessments made on May 14th 1968, by which time the majority of treated plants were not noticeably different from the unsprayed plants. Assessments in June and July showed a similar pattern with most subjects continuing to recover from the initial check. By August and September, when the final assessments were made, recovery was complete from all November and December treatments. The only February treatment to cause permanent damage was diquat at 0.5 lb/ac and this was confined to Lychnis chalcedonica and aster cv. Marie Ballard. This aster was also permanently checked by the two subsequent applications of all treatments and was unique in being the only subject to show an effect at the end of the season which was not apparent at the May assessment. Achillea millefolium was the only other subject to receive a permanent check from all the March and April treatments. In addition to the subjects already mentioned April treatments caused a permanent check to delphinium Belladonna Hybrids, pyrethrum cv. Eileen May Robinson and Marjorie Robinson and Statice limonium latifolium, although in the case of the last two paraquat at 0.5 lb/ac caused no damage.

Figure 1.

Response of 8* herbaceous perennial flowers to applications of paraquat and diquat

*Chrysanthemum - Esther Read
Delphinium - Belladonna Hybrids
Helenium aurantiaca superba
Sidalcea - Rose Queen
Stachys lanata
Statice limonium latifolium
Tradescantia rubra
Veronica longifolium

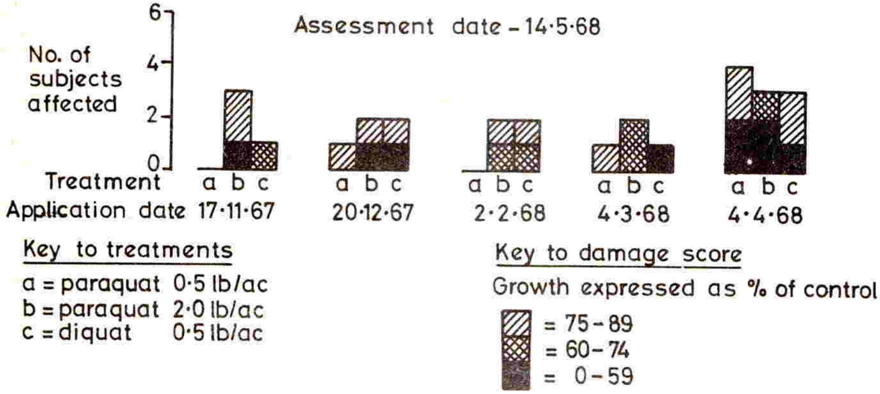

Table 1. Response of 21 herbaceous perennial flowers to applications of paraquat and diquat

Species (and variety)	diam (in.) 17.11.67	assessment date 14.5.68 for application details see note below																				height (in.) on 4.4.68	height x spread (in.) 14.5.68	treatments causing permanent check
		1 17.11.67 %	A	B	C	2 20.12.67 %	A	B	C	3 2.3.68 %	A	B	C	4 4.3.68 %	A	B	C	5 4.4.68 %	A	B	C			
Achillea filipendula	9	70	*	*	*	40	*	X	-		-	-	-		-	-	-		-	-	-		18 x 14	-
" millefolium	15		-	-	-	25	-	-	X	15	X	⊠	⊠	15	X	⊠	X	30	⊠	⊠	⊠		24 x 18	4&5ABC
Aster - Boningale White	9	80	X	*	*	80	*	*	0	80	*	-	-		-	-	-		-	-	-	4	8 x 12	-
" Mabel Reeves	10		-	-	-		-	-	-	85	-	-	*	85	*	*	*		-	-	-		13 x 13	-
" Marie Ballard	9		-	-	-		-	-	-	90	*	*	0	90	0	*	*	90	X	0	*	6	12 x 12	3C, 4&5ABC
" Tudor Rose	7		-	-	-		-	-	-		-	-	-	85	-	-	*	85	*	*	*		5 x 8	-
Chrysanthemum maximum -																								
Beaute Nivelloise	9	60	*	X	⊠	30	*	-	-		-	-	-		-	-	-		-	-	-		8 x 12	-
" Esther Read	18	90	*	0	X	70	*	⊠	⊠	60	*	*	X	50	*	X	*	65	⊠	X	*		9 x 12	-
Delphinium - Belladonna Hybrids	6	2	*	*	*	0	*	*	*	7	*	*	*	30	*	*	*	95	⊠	⊠	⊠	12	22 x 24	5ABC
Helenium aurantiaca superba	8	100	*	⊠	*	30	*	*	*	30	*	*	*	30	*	*	*	50	0	*	*		7 x 9	-
" Moreheim Beauty	5	90	*	*	X	90	*	*	*	70	*	-	-		-	-	-		-	-	-		11 x 12	-
Lychnis chalcedonica	2		-	-	-		-	-	-	50	*	*	X	35	*	-	-		-	-	-		9 x 5	3C
Pyrethrum - Brenda	7		-	-	-	60	*	*	*		-	-	-		-	-	-		-	-	-		14 x 11	-
" Eileen May Robinson	7	60	*	*	*	60	0	0	*	70	0	0	*		-	-	-	95	-	⊠	⊠		18 x 12	5BC
" Kelways Glorious	7	60	*	0	*	60	0	-	-		-	-	-		-	-	-		-	-	-	4	12 x 10	-
" Marjorie Robinson	7		-	-	-		-	-	-	70	*	*	*	70	*	*	*	100	0	⊠	-	4	10 x 10	5B
Sidalcea - Rose Queen	10	70	*	*	*	70	*	*	*	80	*	*	*	80	*	*	⊠	100	*	*	0	9	16 x 18	-
Stachys lanata	24	100	*	*	*	50	*	*	*	40	*	*	*	45	*	*	*	85	*	*	*	3	6 x 24	-
Statice limonium latifolium	15	100	*	0	*	80	0	0	0	70	*	0	0	60	0	X	*	60	*	⊠	0		8 x 9	5C
Tradescantia rubra	6	40	*	*	*	30	*	*	*	20	*	X	*	15	*	*	*	15	0	*	*	3	10 x 7	-
Veronica longifolium	6	5	*	*	*	0	*	*	*	5	*	*	*	5	*	*	*	60	*	*	*	2	11 x 14	-

KEY

Application details

1 - 5 = application dates
% = % ground cover when treated
A = paraquat 0.5 lb/ac
B = " 2.0 lb/ac
C = diquat 0.5 lb/ac

Assessments on 14.5.68 (growth as % of control)

- = no treatment
* = score 90 - 100
0 = " 75 - 89
X = " 60 - 74
⊠ = " 0 - 59

Of the 21 subjects sprayed only 8 were sprayed with each treatment at each application date. The histograms in Figure 1 show that most damage (assessed on May 14th 1968) resulted from the April applications. This is perhaps not surprising since it was the last application. They also show that with the exception of the final application in April paraquat at 0.5 lb/ac was the least damaging treatment. Diquat at 0.5 lb/ac caused almost as much damage as paraquat at 2.0 lb/ac.

DISCUSSION

There is a dearth of data on the response of herbaceous perennial flowers to overall applications of paraquat and diquat. The present work demonstrates the probable safety of such treatments even though it is confined to one season's results on relatively few plants. Subjects not receiving all treatments might have been damaged on the dates when they were not treated although this appears unlikely from the results of those that received all applications (Figure 1), especially if the April application is excluded. The method of assessment adopted does not indicate minor differences in flower number or size but this is not thought to be important. Even when the crops that were tested are grown for cut flower production they are not high value crops and the reduction in the cost of growing the crop which is possible when paraquat and diquat are used for weed control, is probably more important than a small reduction in the quantity or quality of flowers produced.

The safety of applying these herbicides to subjects not showing living tissue has been demonstrated for delphinium - Belladonna Hybrids and Veronica longifolium and supports the earlier work with astilbe (Loughgall, 1962a) and paeony (Biologische Bundesanstalt, Braunschweig, 1961). The results from plants treated when foliage was present appear promising and particularly during the period from mid-November to early February. Even when applied as late as early March, paraquat at 0.5 lb/ac produced effects that did not persist until mid-May.

Acknowledgements

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THE EFFECT OF CHLORTHIAMID ON YOUNG FOREST TREES

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Summary. Experiments in 1964 and 1967 in which chlorthiamid formulated as a 7½% granule was applied in planted crops at rates of from 3-12 lb a.i./ac during March to July were examined for evidence of crop damage.

All species were affected to some degree but differed in their resistance to chlorthiamid damage. Damage was greater at the higher rates and later dates of application. At 4-6 lb a.i./ac in March to May, Sitka spruce, Norway spruce and Corsican pine were quite resistant, Western hemlock and Douglas fir were moderately sensitive, and all *Abies* species were extremely sensitive. The resistance of Scots pine, larches, beech and oak needs clarification since results were erratic or contradicted previous work.

INTRODUCTION

In experiments reported by Aldhous (1964) and Allen (1966) chlorthiamid as a granule containing 7½% a.i. has shown promise for controlling grass and herbaceous weeds in young plantations. Rates of 4-6 lb a.i./ac were shown to provide good control during the year of application when applied February to May, but later applications provided poorer control. Rates of 6-8 lb a.i./ac frequently provided control for more than one season.

Whilst subsequent trials have confirmed that chlorthiamid invariably provides good weed control, the relative resistance of various tree species to damage from chlorthiamid is not so clear. Aldhous (1964) and Allen (1966) presented evidence of damage to crop species, especially at rates above 6 lb a.i./ac. Oldenkamp (1966) specifically warned against the use of chlorthiamid in plantations in Holland.

In the progress report Aldhous (1967) summarised all Forestry Commission trials on chlorthiamid in the years 1962-1966. He concluded that Corsican pine, Sitka spruce, Lodgepole pine, oak, beech and sycamore were not affected by 4 lb a.i./ac applied in March or April, and Norway spruce was damaged very rarely. Of the other species which were widely tested, Scots pine, Douglas fir, larches, *Abies* spp. and Western hemlock were all damaged.

The object of this paper is to present further evidence from three 1964 experiments, and data from two experiments started in 1967 in an attempt to clarify the extent to which chlorthiamid can damage young trees when used for post-planting weed control.

1964 Experiments

Aldhous (1964) reported chlorthiamid damage symptoms from assessments in September 1964, especially at the higher rates. He suggested that some increase in the severity of the damage was possible in the following year.

METHODS AND MATERIALS

Chlorthiamid as a 7½% granule was applied by hand to square yard patches round each tree. Rates of 4,6,8 and 12 lb a.i./ac were applied in April, May, June or July 1964. There were 10 trees per plot, and each treatment was replicated three times. The trees were well established, having been planted at least 12 months before applications..

Three sites which carried the experiment are referred to below. Corsican and Scots pine were tested at Thetford Forest (Norfolk/Suffolk border), Norway and Sitka spruce at Gwydyr Forest (North Wales), and Douglas fir and Western hemlock in the Forest of Dean (Gloucestershire).

RESULTS

The Thetford experiment was last assessed for survival in October 1965, and the Gwydyr and Forest of Dean experiments in August 1968.

Generally, survival decreased with increases in the rate, and with the later application dates, except that for Sitka spruce and Western hemlock survival was rather better in July treated plots than June treated plots.

Table 1 shows the results of these assessments for the 4 and 6 lb a.i./ac rate only.

Table 1.

Percentage survival of crop four years after chlorthiamid applications

Site	Species	Rate	month of application: April	May	June	July	Overall
Gwydyr Forest	Sitka spruce	4	100	97	97	100	97
		6	97	97	93	97	
	Norway spruce	4	100	100	100	83	92
		6	100	97	83	77	
Forest of Dean	Douglas fir	4	87	97	90	90	92
		6	87	90	93	83	
	Western hemlock	4	97	93	63	90	80
		6	93	93	27	83	
Thetford Forest (two years after application only)	Corsican pine	4	100	100	93	93	87
		6	100	90	90	43	
	Scots pine	4	93	77	89	63	76
		6	97	77	70	40	

In general, the effect of increasing the rate or making later applications is to reduce survival.

Overall, Scots pine and Western hemlock are the two most severely affected species, Norway spruce and Douglas fir are moderately affected, and Sitka spruce only very slightly affected. Apart from a very poor survival figure for 6 lb in July, the survival of Corsican pine is also very good.

If the April date only is considered, Sitka spruce, Norway spruce and Corsican pine survivals are excellent.

At Gwydyr Forest, comparisons of the numbers of Norway spruce dead at the end of the first year with the numbers dead in September 1967 (Table 2) show that a true picture of the extent of the damage cannot be obtained at the end of the first growing season. Health scores are similarly misleading.

The same comparisons between assessments in September 1965 and September 1967 showed that most of the Norway spruce which were dead in September 1967 were already dead in September 1965. Aldhous (1964) noted that chlorthiamid damage symptoms took 2-3 months to appear, and this suggests that a true indication of the extent of the damage cannot be gained until the second year.

Table 2.

Number of plants dead in 30 at September 1964 and September 1967: Norway spruce at Gwydyr Forest

Rate a.i./ac	September 1964 April	May	June	July	September 1967 April	May	June	July
4	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	5	7
8	0	0	0	0	1	4	2	16
12	1	2	0	0	4	5	15	24

Height growth of all the species tested in these experiments was rarely affected. The surviving Norway spruce trees at Gwydyr were reduced in height at the 6 and 12 lb rates compared with the 4 lb rate (significant at 1.0% level), and the 12 lb rate at the Forest of Dean reduced the height of Douglas fir compared with the other treatments.

1967 Experiments

(1) At Alice Holt Forest, Hampshire

Nineteen species, including all the common forest species, were included in this experiment, which commenced in the spring of 1967.

MATERIALS AND METHODS

Chlorthiamid as a 7½% granule was applied at 3 and 4 lb a.i./ac either two or four weeks after planting. Each treatment was replicated four times.

Application was by hand to square yard patches with the tree at the centre. The following species were planted late March/early April:-

Scots, Corsican and Lodgepole pines; Norway and Sitka spruce; European, Japanese and hybrid larch; Douglas fir; Red cedar; Western hemlock; Lawson and Leyland cypress; *Abies grandis*, *nobilis* and *lowiana*; beech; Pedunculate and Sessile oak.

The site was on plateau gravel and Gault clay (cretaceous), the soil being a brown-earth. The existing vegetation consisted mainly of bracken with an understorey of *Holcus* spp. and occasional bramble. The site was 300-350 ft a.s.l. with a mean annual rainfall of 30-35 in.

RESULTS

Statistical analysis of assessment data taken in October 1967 shows no significant differences in height growth, and only a few significant differences in health scores and survival (Table 3).

Table 3.

Significant differences in percentage deaths and health scores at October 1967

Species	% deaths: control v treated	% deaths: between dates	% deaths: between rates	health scores: control v treated	health scores: interaction
Lodgepole pine	-	-	-	-	*3 lb @ 2
Douglas fir	-	-	**4 > 3	-	**4 lb @ 4
Western hemlock	*T > C	-	-	*T > C	-
Grand fir	***T > C	*2 > 4	*4 > 3	**T > C	-
Abies lowiana	*T > C	-	-	-	-
Lawson cypress	-	*4 > 2	-	-	-
Leyland cypress	**T > C	-	-	**T > C	-
Beech	-	-	*4 > 3	-	-
Pedunculate oak	-	-	-	-	*4 lb @ 4

*, **, *** = significantly different at 5, 1.0 and 0.1% respectively.
T = treated; C = control; 2 and 4 under dates = weeks after planting; 4 and 3 under rates = lbs a.i./ac.
T > C, 2 > 4 etc. = left-hand result greater than right-hand result.

All the species included in Table 3 have been noted as sensitive to chlorthiamid by either Aldhous (1967) or Allen (1966), excepting Lodgepole pine, Lawson cypress, beech and oak, for which the differences were only at the 5% level of significance.

A further assessment on survival was made in August 1968. Table 4 presents the results for the species which appeared most affected by chlorthiamid applications.

Table 4.

Percentage survival at August 1968 - Alice Holt

Species	0	3 lb @ 2 wks.	4 lb @ 2 wks.	3 lb @ 4 wks.	4 lb @ 4 wks.
Douglas fir	64	52	49	58	51
Grand fir	63	49	25	52	47
Noble fir	61	45	31	39	36
Abies lowiana	41	20	11	17	22
Western hemlock	55	54	46	37	44
European larch	68	56	49	46	44

In all these cases survival of the control was better than any treatment, and survival in the 3 lb rate better than the 4 lb rate although only marginal in some species. There is no consistent difference between application dates. By August 1968 the survival of most species in this experiment was poor. The reason for this is not clear.

(2) At Gwydyr Forest, North Wales

METHODS AND MATERIALS

Chlorthiamid as a $7\frac{1}{2}$% granule was applied at 3 and 4 lb a.i./ac in March or April 1967 to Sitka spruce and Scots pine which had been planted in the winter of 1964/5.

Application was by hand overall to each plot. There were eight trees of each species per plot, and each treatment was replicated four times.

RESULTS

Table 5 shows the health scores at September 1967 and August 1968.

Table 5.

Main health scores of Sitka spruce and Scots pine at Gwydyr

Assessment date	Scots pine 0	3M	3A	4M	4A	S.E.	Sitka spruce 0	3M	3A	4M	4A	S.E.
September 1967	1.0	1.4	1.3	1.6	1.7	0.2*	1.0	1.2	1.1	1.7	1.3	0.2**
August 1968	1.0	1.0	1.1	1.1	1.4	0.1*	1.0	1.0	1.0	1.3	1.3	0.1*

*, ** = differences significant at 5 and 1.0% level respectively.

3 and 4 = lb a.i./ac; M = March and A = April.

Health scores: 1 = healthy, 2 = slightly yellow, 3 = moderately yellow, 4 = severely yellow/brown, 5 = dead.

Both species were clearly affected by chlorthiamid. There was some recovery by August 1968 by which time health score differences were not of an order that would cause grave concern, although they were significant at the 5% level.

Survival was also affected, which is more serious. Table 6 shows the number of trees out of 32 that had died at August 1968.

Table 6.

Number of dead trees out of 32 at Gwydyr - August 1968

Species	0	3M	3A	4M	4A
Scots pine	0	1	0	1	2
Sitka spruce	0	0	0	1	1

All the dead trees showed pronounced swelling round the stem or root collar at ground level, a symptom now well associated with chlorthiamid damage.

The height and shoot growth of the remaining trees was unaffected by chlorthiamid applications.

DISCUSSION

These experiments show that most tree species can be damaged by chlorthiamid as a post-planting application. The higher the rate and the later into the active growing season the application, the greater the risk of damage.

There are, however, definite differences in resistance between species. Corsican pine, Sitka spruce and Norway spruce appear fairly resistant to chlorthiamid at rates of 3 and 4 lb a.i./ac applied in March, April or May, although slight damage can occur.

As most of the experiments reported here have involved applications from April onwards, and generally damage decreased with earlier applications, the degree of damage may be reducible even further by confining applications to February and March.

Abies spp. appear to be the most sensitive of any tested in these experiments, and they are closely followed by Western hemlock and Douglas fir. It would be clearly unwise to recommend the use of chlorthiamid on any of these three species.

At Alice Holt the reduced survival of European larch following chlorthiamid applications compared with the lack of effect on the survival of Japanese and Hybrid larch confirms Allen's (1966) observations. The sensitivity of Scots pine and Lodgepole pine needs clarification, as does that of beech and oak.

Only rarely has the height of remaining trees been affected. This suggests that, unless chlorthiamid kills a tree, it will continue to grow just as quickly in spite of looking rather yellow for a few years.

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FURTHER EXPERIMENTS ON THE CONTROL OF BRACKEN IN FORESTRY WITH DICAMBA

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Summary. Assessments in 1968 of experiments in which dicamba was sprayed at 1 to 8 lb a.e./ac from February to June 1965 showed that control of bracken was still evident $3\frac{1}{2}$ years after application.

The results of experiments in 1967 and 1968, involving pre-planting applications of dicamba at $1\frac{1}{2}$ to 6 lb a.e./ac from December to early June indicate that bracken control is invariably good in the first year provided spraying takes place before full frond development, but varies in subsequent years depending on site factors. Fertility and soil moisture are suggested as being important.

The interval required between application and planting to avoid damage to the crop varies with the season. It is probably about 8 weeks or more in the late spring and summer, but 12 weeks or more during the winter.

The successful use of dicamba for bracken control in forestry depends on exploitation of the first year's control, on vegetational succession and price.

INTRODUCTION

Forestry Commission experiments on bracken control with dicamba during the years 1964-66 have been reported by Aldhous (1964 and 1966). The results showed that dicamba at a rate of 4 lb a.e./ac and greater applied from February to June provided good control of bracken for one or two growing seasons after application. Applications from late June to August, by which time bracken fronds were fully unfurled, gave poor control during the remainder of that growing season, but provided control the following year very similar to that given by applications at the earlier dates.

Trees planted in the winter following applications of dicamba were not damaged by residues. Post-planting applications of 4 lb a.e./ac damaged the crop.

Supporting evidence of the effectiveness of dicamba for bracken control at these rates has been provided by Hodgson (1964) and Hodgson and Donaldson (1966), but Nölle (1966) found applications at similar rates to be a failure in Germany.

This paper presents the most recent data on:-

(i) bracken control with dicamba in the 1965 experiments;
(ii) the results of subsequent experiments with dicamba investigating (a) the reliability of bracken control, (b) the interval required between application and planting, and (c) the effect of winter applications of dicamba on bracken and on the tree crop planted the following spring.

In all experiments 2-year-old trees were planted after dicamba application.

(i) 1965 Experiments

The results of these experiments were first reported at the 8th British Weed Control Conference by Aldhous (1966). Two were re-assessed for bracken control in August 1968.

METHODS AND MATERIALS

The methods, materials and sites were fully described by Aldhous in his paper. Dicamba was applied as an overall spray at 1, 2, 4 and 8 lb a.e. in 25, 50 and 100 gallons of water/ac at monthly intervals from February to June 1965.

RESULTS

Table 1 shows the percentage ground cover at these two sites three to four growing seasonsafter application. It was not entirely certain that the 1 lb/ac rate was having no effect, but for the present purpose this rate can be treated as a control.

Table 1.

Mean percentage ground cover of bracken in August 1968

Site	Date of application	Rate (lb a.e./ac) (mean of 3 dilution rates) 1	2	4	8
Brendon	February 1965	33	30	23	5
	March	43	20	23	5
	April	46	26	20	6
	May	46	18	23	6
	June	33	26	23	5
Forest of Dean	February	90	77	87	33
	March	100	77	83	13
	April	97	83	47	47
	May	90	83	70	53
	June	83	97	87	53

At Brendon the percentage ground cover at the 2,4 and 8 lb rates was still reduced and the 8 lb rate was providing excellent control. Control at the Forest of Dean was not so good, but a similar trend was discernible, and the 8 lb/ac rate was giving a marked reduction in ground cover for all dates of application.

Generally, there was little consistent difference between the results for different application dates, although 8 lb in March and 4 lb in April gave rather better results than applications at other times at the Forest of Dean.

The results of bracken height assessments were similar, the higher the rate, the shorter the bracken, but the effect on height was not so marked as that on ground cover.

(ii) Experiments set up in 1967/8

(a) THE RELIABILITY OF BRACKEN CONTROL

A series of five experiments of simple experimental design using large plots (0.2-0.25 acre) was started in 1967. The experiments were distributed widely in the southern half of the country to test dicamba under a range of conditions.

METHODS AND MATERIALS

Dicamba as an aqueous solution containing 4.8 or 5.0 lb a.e./gallon was applied to ground vegetation at either 3 or 4 lb a.e. in 15 gallons of water/ac by mist-blower or at 4 or 6 lb a.e. in 50 gallons of water/ac by knapsack sprayer. Mistblower applications were overall, and knapsack applications to strips three feet wide along the future planting rows.

Applications were made in late May 1967 (Sherwood, early June). The experimental design was a randomised block with 4 replications.

Sites are listed in Table 2. Generally, soils varied from siliceous sandy types to clay loam types, with drainage being free to slightly impeded. The exception was at the New Forest where the site was on a peaty-podzol derived from Bagshot Sands and Gravels.

Bracken was moderately dense to very dense, and ranged between 3 and 6 feet in height. All sites had an understorey of grass, and some a few scattered herbs. The most common grass species were *Holcus mollis*, *H. lanatus*, *Deschampsia flexuosa*, *Agrostis* spp. and *Molinia caerulea*.

RESULTS

Bracken Control

Table 2 presents the results of assessments on percentage ground cover of bracken for the two growing seasons since application.

There was good control by all treatments in the first growing season except at Sherwood Forest. Here, spraying was carried out later than at the other sites (6-14th June), and probably the bracken frond development was too far advanced for good control in the first year. This was supported by the fact that control in the second year was better than in the first.

Table 2.

Percentage ground cover of bracken - August/September 1967 and 1968

		Treatment				
Site	Year	0(H.W.)	3M	4M	4K	6K
Sherwood Forest, Nottinghamshire	1967	59	36	31	36	33
	1968	84	24	25	33	18
St. Leonards Forest, Sussex	1967	81	14	7	12	5
	1968	77	53	27	49	41
New Forest, Hampshire	1967	61	2	2	1	1
	1968	72	8	5	4	1
Forest of Dean, Gloucestershire	1967	79	27	17	26	23
	1968	98	60	38	72	44
Ebbw Forest, South Wales	1967	69	16	11	15	12
	1968	100	49	38	50	42

H.W. = Hand weeded; 3, 4 and 6 = lb a.e./ac; M = mistblower; K = knapsack.

In the second year, except at the New Forest and at Sherwood (for the reason mentioned above), the bracken recovered quite considerably, although a degree of control was still apparent.

The excellent control at the New Forest was probably due to the bracken not being ecologically well suited to this poor site.

At both the Forest of Dean and Ebbw sites, the heaviest regrowth was observed in the wettest blocks of the experiments. There was not a lot of evidence that recovery had been greatest at the sites receiving the highest rainfall and it may have been that impeded drainage was more important.

Generally, the treatments in order of decreasing effectiveness were 4M, 6K, 3M and 4K, which suggests that a lower rate can be used with a mistblower than with a knapsack.

Assessments on the mean height of bracken for the same two seasons gave a similar but less marked result.

Weeding Times

All plots were hand weeded as required in 1968 to normal field standards. Table 3 shows the times taken, expressed in man hours per acre.

Table 3.

Weeding times in man hours per acre for the season 1968

Site	Control	3M	4M	4K	6K
Sherwood	28.1	-	-	-	-
St. Leonards	12.3	12.0	8.8	11.5	8.0
New Forest	15.5	9.0	7.5	7.9	8.8
Forest of Dean	6.6	6.0	4.0	6.1	4.7

The times taken to hand weed the Sherwood site control plots were very high, but the results presented show that no weeding was required in the treated plots. Normally, hand weeding on such a site should take about 10 man hours per acre.

Compared with the control, savings on the treated plots at the other three sites varied from 0.5 to 8.0 man hours per acre. At St. Leonards treated plots required weeding because of bracken regrowth. At the New Forest, where bracken control was excellent even in the second year, Molinia caerulea re-invaded the site so strongly that it created a weeding problem. At the Forest of Dean the bracken regrew very strongly in 1968, and the understorey of Holcus sp. responded strongly to the reduction in bracken cover; both required weeding.

Hand weeding of bracken will also tend to encourage understorey species of grass to become more vigorous, but dicamba treatments may be more encouraging because they reduce the bracken cover for the whole growing season, and in this case they had reduced the bracken cover during the previous year also.

Effect of Method of Application

Mistblower applications took about one third of the time taken by knapsack applications. Planting was quicker on most mistblower plots because it was unnecessary to mark and follow carefully the sprayed lines.

Although there was some control of the bracken outside the sprayed lines in knapsack treatments due to the effect of dicamba creeping sideways (also noted by Aldhous), untreated bracken tended to fall into treated strips at the end of the growing season and, if tall enough, to smother the trees.

Health of Tree Crop

At no site was there any evidence of trees being damaged by dicamba residues.

(b) THE INTERVAL REQUIRED BETWEEN APPLICATION AND PLANTING

Three experiments were included in this series which commenced in 1967.

METHODS AND MATERIALS

Dicamba was used as either (a) an aqueous solution containing 4.8-5.0 lb a.e./gallon, or as (b) a granular formulation containing 10% a.e. by weight.

Rates of 0, 1½, 3 and 4½ lb a.e./ac of dicamba were applied in March or May 1967 to main plots 45 ft x 9 ft, and then these main plots were split into sub-plots 9 ft x 9 ft for the five subsequent planting dates at 0, 1, 2, 4 and 8 weeks after application.

There were two replications.

All plants were lifted from the nursery in late February/early March and stored at -2° to $+2^{\circ}C$ in polythene bags in cold-stores. The plants required at each planting date were taken from cold-store not earlier than 36 hours before planting, and were transported to the sites in their polythene bags.

Sites: The location of the sites is shown under 'Species' below. Soils were freely drained sandy-loams to loams, carrying moderate to dense bracken 3-6 ft in height with various grass species as an understorey. The mean annual rainfall varied from 30 to 40 in.

Species: Four species were planted at each site:-

Forest of Dean, Glos. - Norway spruce, Douglas fir, Western hemlock, Grand fir.
Ceiriog, N. Wales - Norway spruce, Sitka spruce, Western hemlock, Grand fir.
St. Leonards, Sussex - Norway spruce, Scots pine, Corsican pine, Japanese larch.

RESULTS

Although cold storage is normally a successful technique for keeping plants dormant and thereby extending the planting season, in these experiments all species were damaged so that health and growth assessments were unreliable indications of the effect of the interval between application and planting.

Results of assessments on Sitka spruce at Ceiriog, and Norway spruce at the Forest of Dean, the two species least affected by cold storage, showed that the difference between the health scores of treated plots and control plots was very small when the trees were planted eight weeks after applications. The results of assessments on other species are confusing.

Inspection of the plots provided a rather clearer picture. Damage symptoms clearly attributable to dicamba such as reflexing of needles and twisting of leading shoots became less severe as the interval between application and planting increased. Planted 4 weeks after application, Corsican and Scots pine at St. Leonards and Sitka spruce at Ceiriog showed only small signs of dicamba damage. Planted 8 weeks after application most species showed few signs of dicamba damage.

(c) THE EFFECT OF WINTER APPLICATIONS OF DICAMBA ON BRACKEN AND ON THE TREE CROP PLANTED THE FOLLOWING SPRING

The disadvantage of spring and summer applications is that a whole year of the resultant bracken control is of no benefit to the crop, unless cold storage or other techniques which allow delayed planting can be used.

A series of three experiments was commenced in the winter of 1967/8 to see how effective winter applications were.

METHODS AND MATERIALS

Dicamba as an aqueous solution containing 4.8-5.0 lb a.e./gallon was applied to the ground at 4 and 6 lb a.e. in 50 gallons of water per acre. The spray solution was applied to strips 3 ft wide along the future planting lanes by knapsack sprayer in December 1967, January or February 1968.

Planting took place very early April 1968 with the following species:-

St. Leonards	Rogate	Forest of Dean
Scots pine	Norway spruce	Douglas fir
	Western hemlock	Western hemlock

The plot sizes were 36 to 40 ft square. The experimental design was a factorial combination of 2 rates x 3 dates plus a control to be hand weeded only. There were three replications.

Sites:

(1) St. Leonards Forest, Sussex - as site already described.

(2) Rogate Forest, Sussex - a leached, loamy sand derived from Lower Greensand. Bracken only moderately thick, 2 to 4 ft tall, with patches of *Calluna vulgaris*, and a more or less continuous understorey of *Deschampsia flexuosa*. 200-250 a.s.l. Mean annual rainfall 30-35 in.

(3) Forest of Dean, Glos. - acid brown-earth soil derived from Pennant Sandstone of the Coal Measures (Carboniferous). Bracken dense to moderately dense, 5-6 ft tall, with a strong understorey of *Holcus mollis* and *Deschampsia flexuosa* in large patches. 525-550 a.s.l. Mean annual rainfall 35-40 in.

RESULTS

Bracken Control

The control at all three sites during the first year was excellent, and no hand weeding of treated plots was required. Table 4 shows the effect of treatments on the percentage ground cover of the bracken as at August 1968.

BRACKEN

Table 4.

Percentage ground cover of bracken in August 1968 after winter 1967/8 applications of dicamba

Site	Rate (lb a.e./ac)	month of application: December	January	February	Control (no dicamba)
St. Leonards	4	7	9	10	89
	6	6	7	4	
Rogate	4	0	0	0	93
	6	0	0	5	
Dean	4	5	8	5	46
	6	2	3	5	

Health of Crop

A fairly clear picture of less damage due to dicamba residues with earlier application dates emerged from all sites.

Table 5 illustrates this well for Scots pine at St. Leonards, and Western hemlock at Rogate. The trend is there for Norway spruce at Rogate also, although it is less clear. (July/August health scores were not available from the Forest of Dean site). Except for Norway spruce, the health scores for December applications at 4 lb a.e./ac are not dissimilar from those for the controls, which suggests that there is negligible damage.

Table 5.

Mean health score of trees in July/August 1968 after winter applications of dicamba

Site	Species	Rate	(Health score 1 = healthy to 5 = dead) Dec.	Jan.	Feb.	Control	S.E.	Statistical comparison between
St. Leonards	Scots pine	4 6	1.8 1.8	1.7 2.3	2.1 2.7	1.6	0.23	Control & treats Rates* Dates*
Rogate	Western hemlock	4 6	2.6 3.1	3.2 4.0	3.7 3.9	2.3	0.15	Control & treats *** Rates ** Dates ***
Rogate	Norway spruce	4 6	2.0 2.2	2.2 2.6	2.3 2.5	1.4	0.12	Control & treats*** Rates* Dates

*, **, *** differences significant at 5, 1 and 0.1% levels respectively.

Table 6.

Mean shoot growth of trees in August 1968 after winter applications of dicamba (cm)

Site	Species	Rate	December	January	February	Control	S.E.
St. Leonards	Scots pine (shoot growth)	4 6	8.5 7.6	8.5 7.6	**5.1 **5.1	9.4	0.70

** significantly different from the control at 1.0 level.

Table 6 , showing the mean shoot growth of Scots pine at St. Leonards in August 1968, shows that there has been some loss in height growth from dicamba applications, particularly from those made in February.

Observations during 1968 support the health scores. Symptoms of dicamba on the species used in these experiments was recorded, and at all sites December applications gave only slight dicamba damage symptoms. Occasionally, symptoms from January applications were slight also, as with Scots pine at St. Leonards.

DISCUSSION

The assessments of 1965 experiments show that dicamba can give a degree of bracken control for periods up to four years, by which time the tree crop on such sites would normally be sufficiently tall not to require weeding any longer. The amount of weeding required in these experiments was not recorded, but there would have been very little bracken weeding at the 8 lb rate on both sites.

In the 1967 experiments control in the first year was invariably very good unless applications were late. However, the degree of bracken control varied considerably from site to site after the first year. The factors responsible for this variation have not been fully worked out, although there were some clues. For instance, on infertile and poor bracken sites, such as the New Forest, control was excellent. On better bracken sites, extra or excess moisture in the soil in wet years may cause bracken to regrow strongly in subsequent years. Aldhous (1966) referred to poor bracken control at Gwydyr, North Wales, and suggested that this might have been due to the high rainfall.

Unlike Hodgson and Donaldson (1966) we noted very little effect on most understorey grass species, even though sprays were generally applied before full frond development. Deschampsia flexuosa was the only species for which control was recorded and this species does not normally present a serious weeding problem.

Therefore, where bracken control commences a full growing season before planting, re-invasion by or regrowth of an understorey grass species can provide a weeding problem quite as bad as that provided by the bracken.

Clearly, inability to take advantage of the first year's control of bracken would be a great disadvantage. The interval required for most species following spring applications would appear to be not much in excess of eight weeks, and thus the use of cold storage to enable late planting might be a feasible technique.

The alternative approach of making winter applications seems to require a much longer interval, presumably because lower temperatures reduce the rate of breakdown of the chemical. The initial control of bracken and lack of damage to the crop from December application with 1st April planting is most encouraging. For ease of application it is clearly an advantage to have the bracken flat, and it will be most interesting to see if October and November applications are as good.

With regard to the method of application, because planting is always carried out when the bracken has fallen down or before it has emerged, strip applications have required careful and meticulous marking of sprayed strips. This would certainly be a disadvantage on a large scale. Moreover, the danger of untreated strips fouling treated strips, and acting as a source of re-invasion in later years, suggests that mistblower techniques are a very attractive method of application.

Finally, from the results of the experiments reported here and from previous work, dicamba would appear to be technically well suited for bracken control in forestry as a pre-planting treatment. Depending on the price of dicamba, its use for bracken control in forestry should be a reasonable alternative to hand weeding on dense bracken sites, especially where re-invasion by grasses which cause a weeding problem is unlikely, and particularly if techniques of application and of planting which allow advantage to be taken of the first year's control are satisfactorily worked out.

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VEGETATION CONTROL AND WILDLIFE

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It can confidently be predicted, that, as in the past, man will continue to modify the vegetation cover of this country, on an increasing scale and increasingly towards the establishment of large acreages of relatively few domestic or tree crops. The effects of this on the natural fauna and flora should be of concern to us all.

Now the conservation of wildlife in this country is not concerned to such an extent, as is popularly thought, with rarities. The Royal Charter of the Nature Conservancy says that it is "To provide scientific advice on the conservation and control of the natural fauna and flora of Great Britain; to establish, maintain and manage Nature Reserves in Great Britain .... to organise and develop the research and scientific services related thereto". These are broad terms of reference but they make it clear that the Conservancy is to have a statutory responsibility for the management of all forms of wildlife in all parts of the country. It is often thought, and said, that the Conservancy should concern itself with the more remote, marginal or wilder parts of the country and not with agricultural land, where the paramount importance is the production of food. The fact of the matter is that the Conservancy is concerned with the diversity and richness of wildlife in the country as a whole because this is essential to a balanced and stable environment for man today and in generations to come. Also because "our landscape, which is man's habitat, is a mirror of our minds and values. If the landscape slips back into squalor and confusion, it is only reflecting squalid values and confused ideas amongst those who inhabit and mould it", (Report of the Nature Conservancy, 1961). It is also a fact that, for better or for worse, the bulk of the wildlife, in terms of numbers of species and of populations of individual species, is to be found in the lowland, agricultural parts of the country. As a consequence a high proportion of the wildlife of Great Britain is inevitably affected by lowland agricultural practices. I shall not, therefore, take it as being outside my brief in this paper to consider possible effects of vegetation control on wildlife in agricultural land, as well as in other places.

However, it is as well to recognise that there is nothing sacrosanct about the landscape in 1968. In the lowlands it is very different from that of 150 years ago and would be quite unrecognizable to someone returning from the age of Elizabeth I. It is totally different from that left by the retreating ice, 10,000 years ago. No doubt it will be changed again in the future by shifts in the climate and by earth movements quite outside man's control. We are not concerned with the static preservation of wildlife but rather with a balanced, dynamic, progression based on the conservation of species and communities of both domestic and wild plants and animals. These are the biological elements on which the landscape of the immediate future will be based. In 1968 all we can hope to do is to try to ensure that man's ability to change the environment does not outstrip his understanding of what he is doing.

Although plants and animals are often interdependant in a balanced community, changes of vegetation cover are likely to have a greater effect on animals, than changes in the fauna are likely to have on vegetation. In addition, providing the vegetation cover is suitable, disastrous declines in individual populations of wild animals from pollution or natural causes, can usually be made good in any given area by the natural reproduction of the remnants of the population, or by new recruits from outside. For instance heron populations are now building up again in this country after the disastrous effects of the 1962/63 winter. This is partly due to the fact the nesting sites in their old haunts have remained plentiful. However, if nesting sites had not been available then the recovery in the population would not have taken place. On the other hand, it makes no difference to the trees in which the nests are built whether the herons are there or not. Like all generalisations this argument is open to objection. In the case of the effects of grazing of chalk grassland by rabbits and sheep, the changes in the flora once the grazing pressure was lifted has been dramatic; in this instance a particularly rich flora was dependent on animals for its survival. Nevertheless the point to emphasise is that vegetation provides food and homes for wild animals, and that in order to conserve animals it is fundamentally important to conserve vegetation.

To most field biologists interested in wildlife, rarities are an excitment; something different from the ordinary run-of-the-mill common species. They often need skill to detect and special knowledge to identify. For the professional conservationist they have a much greater importance as particularly sensitive indicator species of subtle changes in the environment, which, if not recognised and if necessary corrected, might lead to much more serious changes and consequent effects on a much wider range of plants and animals including man himself. It is for this reason that the effects of some insecticides on comparatively rare birds of prey has assumed an importance quite out of relation to the possible loss of the few species involved. This is not to say that the loss of individual species should be viewed with complacency. The time span for the evolution of a distinct new species of any given kind of organism clearly depends upon the rate of reproduction and upon evolutionary pressures. During historical times a number of domestic plants and animals, as a result of deliberate breeding programmes and artificial multiplication of chance mutants, have probably by now become so changed from their ancestral forms as to constitute new species. It is doubtful if this has happened to any extent in the wild with the larger plants and animals. The loss of a species is a final thing, taking with it an unique assemblage of genes. There is no replacement by some form of spontaneous generation.

We are concerned therefore about the effects on wildlife of a great variety of man's activities. We are concerned because effects on wildlife may presage effects on man and his environment. We are also concerned with the concept of the conservation of wildlife in its own right. I do not imagine that there are many people here who would not agree with some form of conservation although there may well be differences of opinion about what, where and how much. There are certainly differences of opinion about the relative importance of wildlife conservation compared with the demands of agriculture, recreation, housing, industry and communications.

VEGETATION CONTROL

It is possible to divide methods of vegetation control into chemical, mechanical, natural by grazing and natural by fire. Within these groups there are lesser or greater hazards to wildlife depending upon the detailed method of use or application. Effects on wildlife will increase as the scale of use increases. Effects on wildlife will differ from one kind of land use to another but it must be noted that vegetation control on one kind of land use may affect wildlife in a totally different form of land use adjoining. Finally, hazards from any of these methods of vegetation control can be divided into (a) direct killing or sublethal effects, (b) indirect lethal or sublethal effects, (c) the overall consequences of the removal of the vegetation.

Chemicals

The use of herbicides in cultivated land has undoubtedly had an effect on the wild flora just as changes in agricultural practice and improved seed cleaning techniques has affected other plants. Of course some of the plants that have virtually disappeared from agricultural land as a result of herbicide usage such as poppies (*Papaver* spp.), corn marigold (*Chrysanthemum segetum*) and charlock (*Sinapis arvensis*) were weeds of economic importance. However, it is not really with these plants that we are concerned but with a very wide variety of species of still common plants that have nevertheless been considerably reduced as a result of chemical weed control. Now I am fully aware that to plead for the continued existence of wild plants in cultivated ground will meet with little sympathy from this audience. Any wild plant that establishes itself in cultivated ground will, of necessity, have weedy characteristics. However, this is not quite the same thing as being a weed, which implies an economic status. One is faced, in cultivated land, with the dilemma that weeds of economic status should be efficiently controlled by whatever methods are most suitable, but that as a consequence a large number of plants that have no such importance will be destroyed as well. Ecologically this is of some concern.

Direct toxic and sublethal effects on wild animals from the use of herbicide chemicals in British agriculture have, happily, to date either been non-existent, or at such a low level as to be acceptable. DNOC and dinoseb have in the past caused a certain number of wildlife casualties and the deaths of hares in fields treated with paraquat have been reported from time to time over the last two years. Whilst this is not a matter for alarm, it is not a matter for complacency either. An extensive search through world literature for reports of toxic hazards from the more commonly used auxin herbicides (Way - in press) did not produce any authenticated instances of direct or indirect toxicity hazards to wildlife from the correct agricultural application of these compounds. The urea, diazine and triazine herbicides are of such very low mammalian toxicity that hazards from their use are apparently no greater, and may well be less, than the effects of the application of a similar weight of common salt to the ground. Some other compounds of more restricted use are described (Fryer & Evans 1968) as being moderately toxic to mammals, but there are no indications at the present time that they present any significant hazard.

The use of herbicide chemicals on grassland is very much associated with problems of fertility and stocking rates. One can only say that if selective weed control became very widely practised in British grasslands there would be very serious effects on the native herbaceous flora and the wild animals that depend upon it.

The use of chemical weed control in forestry clearly has implications for wildlife. It is a pleasure to report that an effective liaison exists between the Nature Conservancy and the Forestry Commission; it is to be hoped that an understanding of the economic problems of the one will be met by an equal understanding of the responsibilities for wildlife of the other. A great deal of the use of herbicides in forestry is for very localised or spot treatments of individual trees. However, there is a recent requirement to eliminate broadleaved tree species from a number of mixed forests and some of this work is being done by the use of aerial applications of herbicides. Whilst the chemical or chemicals used are not per se likely to produce a greater hazard to wildlife than the disturbance caused by various methods of mechanical removal, the fact that by their use so many more trees will be affected at any one time must have a greater indirect effect on wildlife. In this respect a new agreement between the Forestry Commission and the Nature Conservancy for an early warning of the intention to use aerial sprays should do much to avoid serious damage to areas of high wildlife interest. In passing it is worth noting the catastrophic effects of the military use of defoliants in Vietnam and realising the potential of these compounds unscrupulously used.

Direct hazards from the use of chemicals for the control of aquatic vegetation, as with their use in agriculture and forestry, have been very carefully considered and the chief danger appears to be a matter of scale of use. Control of aquatic vegetation by the older methods was physically awkward and so time consuming that in any one season only a limited mileage of waterway could be managed. Today, with helicopters and invert emulsions, it would not be impossible to quite accurately treat in one season the vegetation in all the waterways of, for instance, Romney Marsh. This would have the most serious effects on the wildlife of the immediate and surrounding areas. Because of the special hazards of various kinds to man, domestic animals and crops as well as to wildlife, a Code of Practice for the control of aquatic vegetation has been agreed between the various authorities concerned. This excellent document (reproduced in Fryer & Evans, 1968a) has a section on the protection of fish and wildlife from the use of aquatic herbicides.

The use of herbicide chemicals on non-agricultural land is divided between total weed control and partial weed control. Where there is no direct toxicity hazard to wild animals there can be no wildlife objection to the use of total weed killers on industrial sites, railway tracks, around public utility installations or along the kerb edges of roads. Where very short-lived total weedkillers, such as the bipyridyls, are used for this purpose the plant species that replace those that are killed are likely to be the more aggressive rhizomatous perennials, or else the more obvious weedy annuals. The use of paraquat and diquat on farm tracks and inter-field boundaries may have the opposite effect from that which is intended, as the plants that survive or recolonise may well be those that are most objectionable or difficult to control. The use of these chemicals round the edges of cultivated land is to be regretted aesthetically, and from a conservation point of view as these are the places on agricultural land where one hopes that some wildlife may be able to continue to exist. In some preliminary work that I have done this year there was surprisingly little correlation between occurrences of weed seedlings in a range of crops and the distances from the field boundary, or with the occurrence of these species at the boundary itself. Thus couch grass (*Agropyron repens*) and creeping thistle (*Cirsium arvense*) were just as likely to be present 64 yards into a field as they were to be present in the first four yards.

The importance of boundary vegetation as a source of propagules for a subsequent weed infestation is probably much less than is commonly thought. However, one must accept that these two species in particular, as well as a number of other perennial weeds, do invade fields from hedges and headlands on occasions. As the application of paraquat and diquat on boundary vegetation would appear to favour just these species there can be little agricultural justification for their use in this way.

The whole question of the control of road verge vegetation is to be the subject of a British Crop Protection Council symposium in March 1969. Suffice it to say for now that road verges are becoming accepted as being of outstanding importance in the conservation of wildlife in lowland Britain, and especially of the native flora. There is concern therefore that chemical and mechanical management regimes should be evolved to deal with a broad range of vegetation types, site properties and the various requirements of the authorities and organisations involved. Similar wildlife importance can be assigned to railway embankments and cuttings, though the problem here is less urgent. There are also requirements for the control of scrub, notably on Nature Reserves, and the use of 2,4,5-T or 2,4-D/2,4,5-T mixtures for this purpose is recommended practice by the Nature Conservancy. Other individual problems crop up from time to time such as the control of ragwort (*Senecio jacobaea*)at Port meadows, Oxford. In general these problems ought to be judged on their merits and the desire to control certain aspects of the vegetation weighed against the possible effects on other plants and animals.

It is not possible to leave the subject of chemical control without referring briefly to application problems. Spray drift is still with us, although one rarely hears of damage to high value horticultural crops nowadays. There can be little doubt that a great number of quite innocuous herbaceous plants around the edges of arable fields are killed each year by spray drift. Sometimes it is worse than this. One farmer was so tactless this year as to kill a high proportion of the flowering plants on a particularly rich road verge in Cambridge, that was the subject of a special arrangement between the Naturalists' Trust and the County Surveyor for its management. Another even more tactless event was the spray damage to ornamental trees and shrubs in the grounds of the headquarters of the Royal Society for the Protection of Birds. It seems possible that the latter incident was the result of an aerial spraying mishap. The spraying of biologically active materials from the air, and especially from fixed wing aircraft, is so full of potential hazards in Britain that these need to be most carefully and objectively studied before this form of application is allowed to become more generally used.

Mechanical

In most situations there are two essential differences between mechanical and chemical control of vegetation. Mechanical control is less dependent upon timing and effects on plants are more related to their growth form than to any other characteristic. Mechanical control also leads to greater local disturbance of the soil and thus encourages the germination of seeds leading to the establishment of replacement vegetation. This vegetation may be weedier in character than the sort it replaces, for instance where scrub in established grassland has been pulled out. With mechanical cutting, in grassland especially, it is possible by varying the height, timing and frequency of cut to manipulate the composition of the sward. This sort of technique is useful where one has an opportunity, as for instance with road verges, to try to increase the richness and diversity of flowering plants.

Grazing

The grazing animal in grassland has a more or less similar effect to the mechanical cutter, except that there is a much greater amount of selection. In overgrazed grasslands this often leads to the selective development of less desirable species, such as nettles, thistles and ragwort. Effects of dunging and the development of poached areas along tracks and around resting places also lead to a variation in the sward. The influence of rabbits and sheep on the development of the wild flora of the chalk downs, and the results on the chalk grassland flora of the disappearance of this grazing pressure in recent years, is now well known. Sheep and cattle are being used in a number of Nature Reserves to control the growth of coarse grasses that threaten to crowd out the more interesting plant communities.

Fire

Where fire is used as a control agent this is usually done in plant communities that are adapted to periodic burning. The associated wild animal populations appear to be similarly adapted. Only if the fire gets out of control, or is slow burning and gets too hot, is serious damage done. Thus the burning of heather moors generally leads to new growth of the heather with increased cover and food for animals. The vexed problem of the burning of straw stubbles partly done to kill weed propagules, produces a considerable wildlife hazard, especially when the fire is allowed to get out of control and damage or kill the boundary vegetation. This occurs more often than one would expect from mere chance and it is well known that many farmers allow hedges to be damaged in this way in order to provide an excuse to grub them out. The effects on the ground flora are likely to be very similar to those of the bipyridyl herbicides with the encouragement of aggressive weedy, rhizomatous perennials and quickly establishing annuals.

CONCLUSIONS

One can conclude by saying that the hazards to wildlife from vegetation control are more related to the scale of the control rather than the method. In general, hazards from chemical herbicides are not from direct, or as far as one has any evidence, indirect toxicity. It seems likely that the next great steps forward in pest control technology are going to be in the field of prediction. Prediction of degrees of weed infestation and of the most economic and efficient methods of control to deal with them. This will undoubtedly help a large section of the farming community - many of whom now spray prophyllactically with chemicals against weeds whose names they do not know. One hopes that it will also help wildlife by restricting the uninhibited use of chemicals on agricultural land. In non-agricultural land there is undoubtedly a growing market for efficient vegetation control agents. The hazard here is twofold. The widespread destruction of vegetation and the selective destruction of herbaceous plants under the mistaken impression that many of them are weeds wherever they grow. One of the greatest threats to wildlife today is the uncritical demand for suburban standards of tidiness in the countryside and an increasing ability to be able to provide it.

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WEED CONTROL AND THE LOCAL AUTHORITY

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Cause and effect

The social and economic revolution which has followed in the wake of the last war has brought with it a formidable challenge for the Local Authority - one posed, in the main, by the difficulty of competing on unfavourable terms for suitable labour in a highly competitive market. In the many areas of full employment, and this applies particularly to London and the South East, the Local Authority, because of its inability to match wage and salary scales in other spheres of employment, has invariably come off second best. This, in turn, has led to an increased demand for mechanisation and, more particularly, the use of chemicals as an effective aid to the maintenance of hard surfaces and garden features.

These circumstances have also had an important bearing on design considerations in landscaping practice, and this has meant an increasing emphasis on ease of maintenance backed up by mechanisation, chemical control, and the elimination of hand labour to the greatest possible extent.

What are the main problems facing the Local Authority? Briefly, they can be put as follows :-

(a) Highways

The elimination of weeds on footpaths, in kerb channels and gulleys, around items of street furniture, and at the base of boundary fences.

(b) Depots, Stores, Sewage Plants, etc

Here weed control is influenced by special considerations such as the storage of inflammable materials, digestive processes in sewage tanks and sludge beds, and similar problems.

(c) Land temporarily out of use

We are concerned here with the sterilisation of areas set aside for future development. These may be areas acquired for road widening or building development which will become an eyesore and a nuisance if they are neglected.

(d) Parks, Open Spaces and Recreational Areas

The problems here embrace the control of weeds in beds, borders and nurseries, footpaths and fence lines, and on hard surfaces including children's play areas. It will also include the selective treatment of weeds in grass areas,and control of weed growth in ornamental water features.

(e) Inaccessible Areas, Cemeteries, and Areas with a Low Maintenance Requirement

The chemical control of grass growth in areas difficult to control by mechanical means, such as cemeteries (although it is necessary to take care where flowers are grown), and areas of grass generally where a high standard of maintenance is not required.

(f) Special Purposes

Here we are concerned with other measures such as the control of brambles, scrub and small sucker growth, the pre-germination control of weeds on newly sown areas, and the poisoning of tree roots, etc.

It will be apparent from the foregoing that the problems facing the Local Authority are numerous and formidable. An over-riding factor is the need to protect the health of the general public, of animals, and of desirable vegetation by adequate and foolproof safety measures. This is particularly applicable to the highways where the major weed control problems exist. It is equally in the interest of the Local Authority to take adequate precautions if claims for accident or damage are to be avoided.

The past and the present

I now propose to go back in time - about fifteen years in fact - when many of the present day chemicals were still in the laboratory and when sodium chlorate was perhaps the most widely used chemical.

Sodium chlorate did its job very well and still does. It became very popular for Local Authority work because it contained no hazard for man or beast and, with the addition of a fire depressant and efficient application personnel, could be used with confidence for total weed eradication in most situations. Two applications a year - one in the spring and another in the late summer (depending on weather conditions and other factors, this could occasionally be reduced to one application) - gave effective control, and with the advent of sophisticated machinery, hand-operated multi-nipple spray lances and plastic hoods, settled down into routine trouble-free operation. In spite of the many more potent and sophisticated chemicals today, I still have a sneaking regard for sodium chlorate as a total eradicator. In all the years I was concerned with its use on many thousands of miles of highway, only two mishaps occurred and these were minor ones affecting relatively short lengths of ornamental hedging in private gardens. I do, however, recollect hearing of a case concerning an avenue of cherries where the open margin which carried the trees was treated with sodium chlorate by one department, and almost immediately capped with tarmac by another department - a case of the left hand not knowing what the right hand was doing. In this case the trees died but this could not be blamed on the chemical.

In the early 1950's the letters C.M.U. (monuron) began to appear in chemical vernacular and many field trials and experiments were organised to test this new chemical. The early experiments were most promising but great caution was exercised because of reports of mature trees being killed by the chemical getting into drainage water.

The persistent qualities of this chemical were eventually combined with the immediate knock-down effect of sodium chlorate to form a very useful dual-purpose product.

Other chemicals had crowded on the scene in quick succession. The phenoxyacetic acids (including 2,4-D) were the subject of extensive trials and widespread application. Simazine quickly made its mark as an efficient total eradicator and as an aid to weed control in nursery practice.

The growth retarder maleic hydrazide also arrived and captured the public imagination with its great promise of growth control and what this could mean in terms of reduced grass cutting and hedge trimming. Although it made its mark, it has not in practice succeeded in replacing the machine where a high standard of maintenance is required, although it is proving very useful on its own, and in combination, in controlling grass growth where frequent cutting is not called for and where machinery cannot be employed efficiently. Control of hedge growth is still in question and, as far as I know, we have not yet followed the American example of spraying trees to keep them clear of overhead wires. It is my fervent hope that this will never come to pass.

By this time fears were being expressed about the long term accumulative effect of residual chemicals on soils supporting growing crops and it was with renewed interest, and perhaps some relief, that the non-residual materials, such as paraquat and diquat, were welcomed to the scene.

Many other chemicals and combinations of chemicals appeared and mention must be made of the selective materials evolved for specific purposes, such as the use of dalapon for couch and weed grass control generally, the various hormone-type chemicals for weed control in grass, calomel for the eradication of moss, and 2,4,5-T alone or in combination with 2,4-D, for the control of nettles, brambles and brushwood (including cut-stump treatment).

Faced with a bewildering array of chemicals the Local Authorities were glad to turn to the Chemical Companies for help and advice, and I think it appropriate to refer in this connection to the excellent work done by the various chemical concerns in the provision of advice on mechanisation, application and training, which, when one considers the quality and turnover of the average Local Authority labour force, is a very vital consideration.

Before proceeding further I think it is important to emphasise the care and caution that has gone into the experimental and field trial work and in the early days of application this was not done without set-backs and casualties. The severe discolouration of grass in retardation experiments, the pollution of water courses, damage to vegetation and crops on private property, and severe leaching and scorching of ornamental grass areas were all experienced to a minor degree. Early examination of such teething troubles has resulted in the widespread safe application enjoyed today.

To come now to the present position, the build-up of know-how and experience and the compelling need for economy and ease of application (including the use of granule formulations) has resulted in the development of the sophisticated combinations of chemicals in present day use. This is particularly the case with Highway application where a variety of problems are confined within relatively narrow limits, and we now have the non-residual chemicals in the paraquat/diquat family, or a selective weedkiller of the 2,4-D type, in combination with the residual long term persistent herbicide to provide complete weed control at one application. This has had the added advantage in practice of cutting out over-lapping and duplication where more than one department is involved in specific aspects of application.

To summarise, the chemicals mainly used today in the main problem categories are as follows :-

Total Eradication

Residual chemicals - (of a degree of solubility in the following ascending scale) :-

Simazine
Diuron
Atrazine
Monuron
Bromacil

Non-residual chemicals

Paraquat
Diquat

N.B. Sodium chlorate would appear to the layman to come somewhere between these two main categories for total eradication.

Selective Weed Control in Ornamental grass areas

Hormone-type herbicides

2,4-D
MCPA
Mecoprop

A combination of mecoprop and 2,4-D is becoming increasingly popular for this purpose.

Weed Control on Cultivated Land

(Nursery crops including trees and shrubs)

Pre-planting treatments

(1) Selective hormone treatment of grass areas for removal of broad-leaf plants, followed by dalapon before ploughing in.

(2) Aminotriazole applied 4 - 5 weeks before planting.

(3) Combinations of (1) and (2) above with occasionally special additions of 2,4-D or MCPA for special problems such as *Convolvulus arvensis*, etc.

Post planting

Residual - Simazine (still the most widely used chemical for this purpose).

Chlorpropham (alone or with supplements of fenuron or diuron, for winter application).

Lenacil (a promising new herbicide giving a broad spectrum of control, including knotgrass (*Polygonum aviculare*) and mayweeds etc).

Chlorthiamid and Dichlorbenil - Granular formulation selectives. (These are giving good control of some perennial weeds, e.g.docks and sorrel (*Rumex* spp.), thistle (*Cirsium* spp.), and horsetails (*Equisetum* spp.) etc).

Non-residual - Paraquat/diquat (These are replacing the hoe in many situations to gain most substantial advantages over hoeing. Engineering problems are posed and techniques involving row-crop work steerage hoes with various crop protectors as well as special low pressure spray jets to avoid drift are necessary.

If I have overlooked any chemicals or not dealt adequately with others, I apologise. What I have attempted to say is tied up with my own experience or that of others with whom I am closely associated.

Dosage rates are not given as these are already adequately covered by manufacturers' instruction, and some variation may be necessary anyway in the light of prevailing circumstances.

What of the future?

It would be foolish to look for any improvement in the labour situation in the light of prevailing economic, employment, and educational trends. On the other hand, with new road construction and building development proceeding apace, the maintenance responsibilities resting on Local Authorities will continue to expand, and this can only mean an intensification of the quest for the ideal chemicals and methods of application, i.e. chemicals that can be easily stored, are safe and easy to handle, do not leach, and after the initial application can be kept going by annual booster application. This must go hand in hand with the evolution of spraying equipment that will be both efficient for the purpose and foolproof.

With science moving forward at an ever-increasing pace, and new and exciting chemicals in the pipe-line, we can look forward to the future of weed control with confidence. In the meantime, there is considerable scope for research into the many and varied aspects of chemical application, including the accumulative effect of residual weedkillers on various soils and surface vegetation. Additionally, perhaps we should look more closely at the more sophisticated timing of application and choice of chemicals in relation to the biology of weeds and, in particular, the matching time of application and choice of chemical to the period of peak germination for a given specie. Similarly, the relationship between crop activity and weed activity must be exploited, e.g. dalapon applications in mid and late autumn to control couch in growing crops.

It is certain that 'cocktails', i.e. mixtures of herbicides will become increasingly popular and there will certainly be much more interest in the future in 'booster' dose techniques. More consideration might also be given to the incorporation of chemicals in base formation treatments for the construction of footpaths and other hard surfaces.

In conclusion, although the Local Authority's concern is with amenity rather than food production, this environmental aspect is becoming of increasing importance. It is a fact that weeds, litter, neglect and vandalism often go hand in hand, and this is where chemicals have a vital contribution to make, particularly in built-up and partially built-up areas.

Tourism has become a major economic factor and we must make sure that the face we present to visitors from abroad is a good clean one.

Another important factor is nature conservancy. The impact of "The Silent Spring" still lingers in many minds, and it is important that research should go hand in hand with caution and sound application techniques if public anxiety is to be allayed in the future.

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CHLORFLURENOL FOR GROWTH INHIBITION

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Chlorflurenol, 2-chloro-9-hydroxyfluorene-(9)-carboxylic acid and its derivatives are growth inhibiting compounds belonging to a novel group of chemicals called morphactins (1,2,3). These have already been differentiated and characterised as an independant and separate group of plant growth regulators (4). Structures and mode of action have likewise already been described (5).

Mode of action of chlorflurenol

The effect of chlorflurenol and its derivatives on living plants is similar to that of all morphactins in that they inhibit growth and development but as a rule, they do not cause their death. Treated plants exhibit a suppressed and bushy growth pattern.

This dwarfing effect can be attributed to a reduced rate of cell division in the meristem. The duration of this effect will depend on the dosage applied (6). In addition it has been possible to determine an interaction between the naturally occurring plant growth regulating substances and chlorflurenol (7) as well as an inhibition of their transport and distribution auxins (8,9). These effects interfere with the regulatory and correlating mechanisms active during plant development. Contrary to flurenol (fluorene-9-carboxylic acid) and its derivatives which act selectively in cereals (10) the chlorflurenols distinguish themselves in their extraordinarily broad spectrum of activity. This property is superior to that of the phenoxy compounds and their combinations since practically all dicotyledonous weeds, annuals and perennials as well as many grasses, are susceptible.

On the other hand chlorflurenols are superior to the grass inhibitor maleic hydrazide (MH) because they are effective on dicotyledons as well. Besides weeds and grasses, shrubs and trees also exhibit a reduced formation and growth of new shoots, thus giving the chlorflurenol derivatives an outstanding position among the plant growth regulators because of the range of plants inhibited (4,11).

What is true for the wide spectrum effectiveness of chlorflurenol also holds for its mode of action. The morphactins have a relatively mild effect on the plants which as a rule survive and eventually continue to develop normally (4,11).

This non-injurious type of growth inhibition is true primarily for dicotyledonous plants and clearly distinguishes these new inhibitors from the more aggressive phenoxies which almost always prove fatal to the plant at common dosage rates. Many grasses however, will tolerate relatively large quantities of chlorflurenol better than such well known standards as maleic hydrazide. Under unfavourable weather conditions (drought) these can lead to poor tillering and consequently a sparse ground cover, whereas chlorflurenols have been found to favour tillering of grasses (1). Figure I clearly shows that the chlorflurenol derivatives deserve a special interest as growth inhibitors due to their superior activity over a wide dosage range.

FIGURE I

Growth inhibiting dosage ranges / Comparison of chlorflurenol with mecoprop + 2,4-D and with MH

Inhibition or herbicidal effects 3 months after treatment

Plant species	Products, kg or l/ha.														
	CF 125 (12.5 % chlorflurenol)					phenoxy combination (mecoprop + 2,4-D)					MH 30 (30 % maleic acid hydrazide)				
	16	24	32	40	48	3	4.5	6	7.5	9	8	12	16	20	24
	(2 to 6 kg a.i.)					(abt. 2 to 6 kg a.i.)					(abt. 2.5 to 7.5 kg a.i.)				
Dicotyledons															
Achillea millefol.	2	3	3	3	3/(+)	0	1	3/+	(+)	+	0	0	0/1	1	1/(+)
Tanacetum vulgare	2	3	3	3	3	0/1	2	(+)	(+)	+	0	0	0	0/1	2
Artemisia vulgaris	1	2	2	3	3	0	1	2	+	+	0	0	0/1	2	2
Oenothera biennis	1	2	2	3	3	0	0	2	(+)	+	0	0	0	1	1
Grasses															
Arrhenatherum elatius	0	1	2	2	2	0	0	0	0	1	0	0	2	2	3
Bromus inermis	1	2	3	3	3/(+)	0	0	1	1	2	0	0	1	2	2/(+)
Dactylis glomerata	0/1	1	2	2	2	0	0	0	0	0	0	0	2	2	2
Festuca ovina	0	0/1	2	2	2	0	0	0	0	0	0	1	2	3/+	3/+

Rating

0 = no effect

1 = weak) growth
2 = pronounced) inhibiting effect
3 = very pronounced) (decrease in weight of plant material)

(+) = strong phytotoxicity
\+ = herbicidal effect (death of plants)

The chlorflurenol derivatives have, compared with the well-known growth regulators, a superior therapeutic index. This is underlined in Figure II in the form of a model trial with Galium aparine. The favourable therapeutic index of the morphactins, especially that of the chlorflurenol derivatives, makes it possible for the first time to obtain a prolonged growth inhibition by overdosing the plant in one application with one of these chemicals. The amount of excess chlorflurenol will determine the duration of the growth inhibiting effect. Therefore a "storage" application of a growth inhibiting chemical has become possible through chlorflurenol derivatives (4).

FIGURE II

Therapeutic Index

Growth regulating concentration ranges for plant growth regulators

Biotest comparison with Galium aparine seedlings (1), drop application during cotyledonous stage, dosage 2 x 0.02 ml per plant. Evaluation two weeks after application.

Active ingredients	Concentration, ppm							
	0.001	0.01*)	0.1	1	10	100	1000	10,000
MCPA/acid)	0	0	0	0	0	0	---3---	(+)
2,4-D/acid) (Phenoxies)	0	0	0	0	0	0	---2--------	-3--?
mecoprop/acid)	0	0	0	0	0	--3---	+	+
MH (maleic acid hydrazide)	0	0	0	0	0	0	---1---	(+)
IT 3456 (chlorflurenol methyl ester/morphactin)	0	---1--------	-2----	-3----	-3----	-3-----	-3--------	-3--?

*) is equivalent to 4×10^{-1} nanograms of active ingredient per seedling

Rating

0 = no effect

1 = very weak)
2 = moderate) growth inhibiting or
) growth regulating effect
3 = very pronounced)

\+ = plants died

(+) = plants died (very phytotoxic)

\- - = growth inhibiting or growth regulating concentration range.

Non-injurious retardation of mixed plant populations : "Growth Inhibition".

Tests over a period of several years with various chlorflurenol derivatives (esters, salts) for the inhibition of growth in mixed stands (composed of broad leaved weeds and grasses) represented the primary emphasis of our development work up to this time. In this connection the active ingredients were applied in various formulations (emulsion concentrates, dispersible pastes and wettable powders). These tests have proved the particular suitability of the chlorflurenol methyl ester (coded IT 3456) for this application. A 12.5 % (w/w) emulsion concentrate of this active ingredient (coded HZ 3456 EC) has shown itself to be especially reliable. This formulation has been marketed in the Federal Republic of Germany since 1966 under the name of CF 125. Large scale trials are continuing. The advantageous characteristics of the chlorflurenol derivatives for growth inhibition have been confirmed in practice. CF 125 used alone, will give a sufficiently persistent growth inhibition of grasses along highways and other traffic ways only at doses higher than those needed for the inhibition of broad leaved weeds. It is especially difficult to suppress entirely the formation of flower stalks.

Mixtures of chlorflurenol derivatives with maleic hydrazide

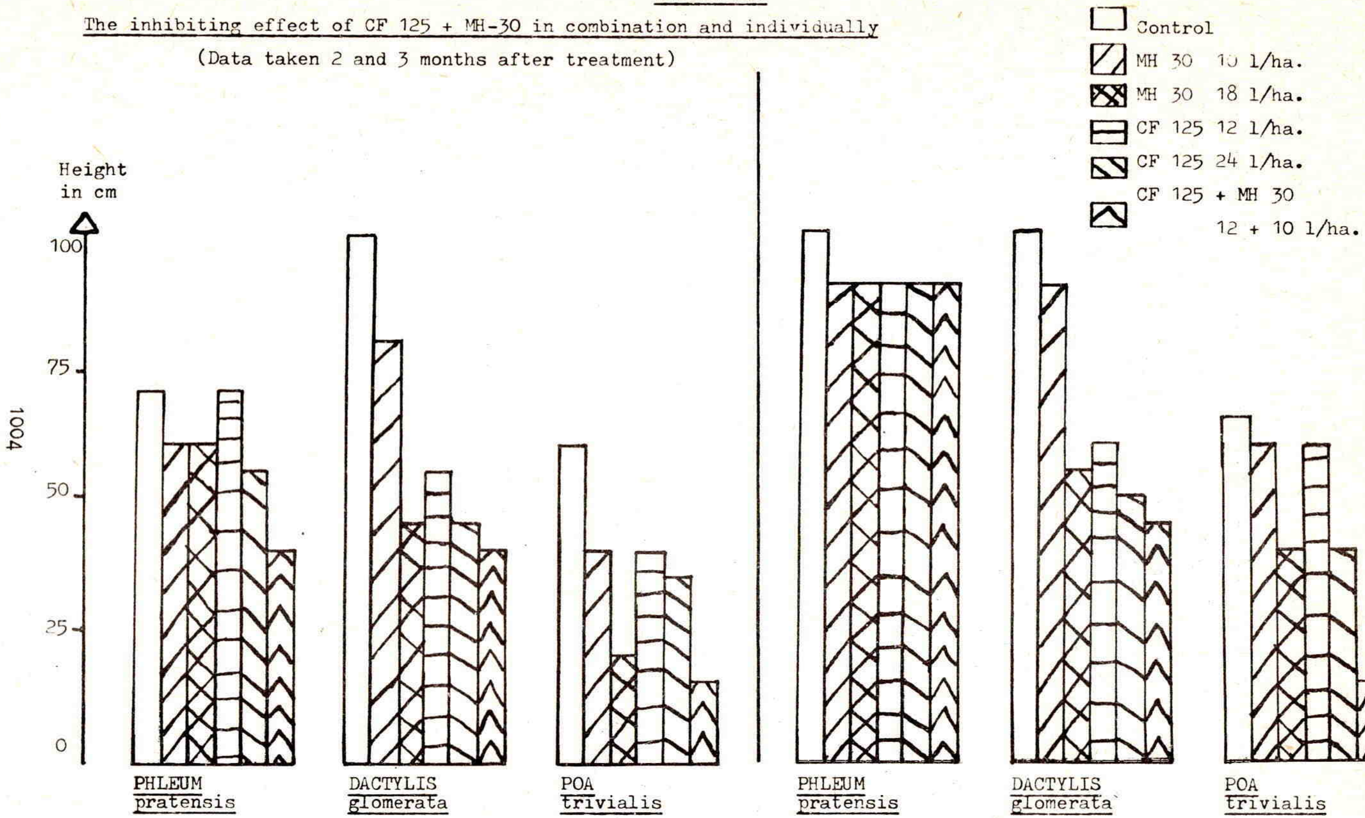
The less distinct and therefore shortlived inhibiting effect of the chlorflurenol derivatives on certain grasses made trials combined with the grass inhibitor maleic hydrazide (MH), appear attractive at an early stage of our work. This would provide broad spectrum effectiveness with sufficient persistence at economical dosage rates. These trials confirmed that chlorflurenol and MH ideally complement each other in their ability to affect the entire grass spectrum. They also demonstrated that such combinations can result in a more than additive effect. This increase in activity on important grass species by means of a combination of chlorflurenol and MH (12) is supported by Figures III - V. These show the inhibiting effect of the chlorflurenol + MH 30 combination as seen on the major grass species.

For the evaluation of Figures III - V it is important to keep in mind that an optimum growth location was chosen in order to obtain distinct differences in growth inhibition. The stated values of inhibition were taken 2 to 3 months after treatment and can be considered equal to values obtained in 4 to 5 months on extensively cultivated areas i.e. highways, road verges etc.

FIGURE III

The inhibiting effect of CF 125 + MH-30 in combination and individually

(Data taken 2 and 3 months after treatment)



(2 months after treatment) (3 months after treatment)

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FIGURE IV

The growth inhibiting effect of CF 125 + MH-30 compared to the tank mixture of MH-30 + phenoxies on easily controlled grasses (Data taken 3 months after treatment)

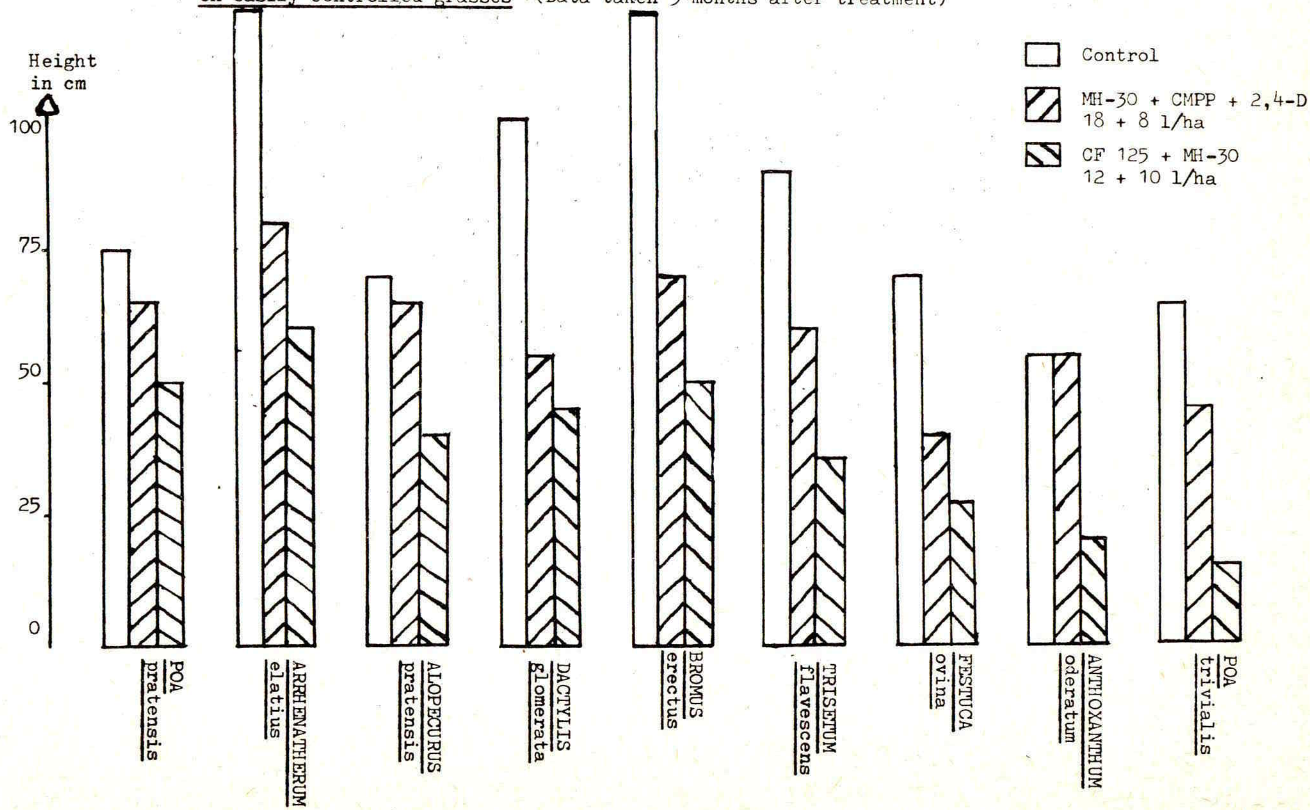
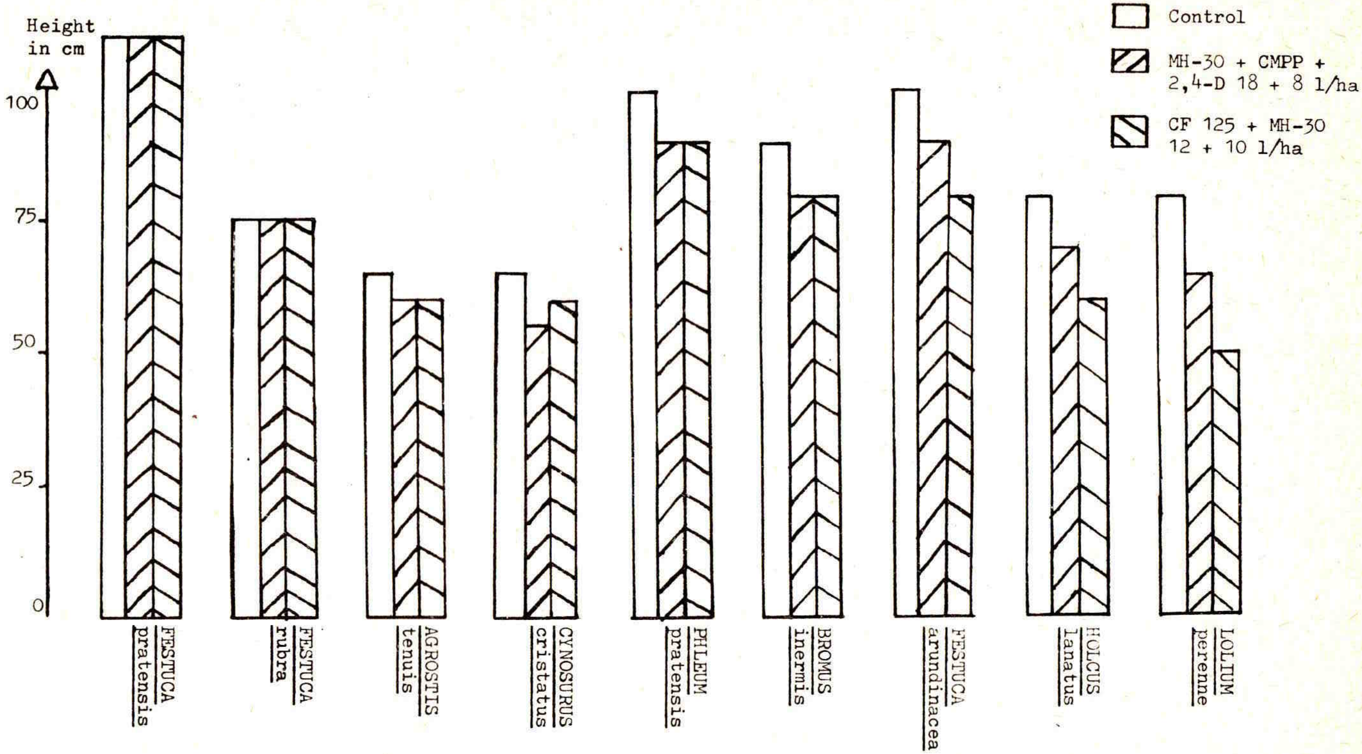


FIGURE V

The growth inhibiting effect of CF 125 + MH-30 compared to the tank mixture of MH-30 + phenoxies on less easily controlled grasses (Data taken 3 months after treatment)



The combined action of chlorflurenol + MH permits a significant decrease in the dosage rate of the 2 components. In numerous trials during recent years, the two components have been found to give optimum results when used at a ratio of 1:2 to 2:1. In the Federal Republic of Germany a tank mixture of 10 - 15 litres CF 125 (12.5 % chlorflurenol methyl ester) and 10 litres MH 30 (30 % MH diethanol amine salt) has already been used successfully for general growth retardation over a period of 3 years. This is equivalent to 1.25 - 1.85 kg chlorflurenol methyl ester and 3.0 kg MH/ha.

The choice of an adequate dosage rate for spring application to last the entire season will depend on location as well as the composition and viability of the vegetative cover (soil, precipitation, temperature, plant species).

The application of a mixture of these two products has also proved effective in lowering maintenance costs of other extensive grass areas as may be found on airports, military terrains and depots as well as ditch-banks. The mixture, however is not suited for application on more demanding grass areas i.e. decorative lawns. Development work is continuing on a marketable combination product for this field of application.

Advantages of the combination chlorflurenol + MH for general growth inhibition

Based on our experience to date with chlorflurenol and MH in growth inhibition, one can expect the following advantages as compared with the usual application of MH + phenoxy combinations.

(a) Non-injurious mode of action; this avoids the danger of thinning out of the vegetative cover. Worth mentioning is that the eradication of desirable dicotyledonous species can be avoided, e.g. *Achillea millefolium* or *Trifolium* spp. Also the danger of thinning out following a dry period is minimised due to the favourable effect of chlorflurenol on tillering.

(b) Increased spectrum effectiveness due to the more pronounced effect of the chlorflurenol components on several tall growing umbellifers such as *Anthriscus silvestris*, *Heracleum sphondylium*.

(c) The time of application, which is often critical, is lengthened by 2 - 3 weeks.

(d) The possibility of a slightly later application can mean better growth inhibition of the later developing dicotyledonous species (i.e. *Artemisia vulgaris*, *Cirsium arvense*) and thereby obviate the need for a second application of phenoxy growth regulators.

This aspect also makes the addition of increased quantities of chlorflurenol interesting (15 to 20 l/ha CF 125).

Other experimental applications of chlorflurenol

A broad spectrum effectiveness, non-injurious action and an advantageous therapeutic index are noteworthy characteristics of the chlorflurenol derivatives as new growth inhibitors. For this reason further areas of application are being investigated on a worldwide basis (4).

Non-injurious inhibition of woody plants

The chlorflurenol derivatives lastingly inhibit or stop new growth of many types of woody plants if treatment takes place at a suitable stage of development (mainly at the beginning, or soon after the appearance of new shoots). This has been shown to be true under various climatic conditions. It should be possible to decrease the frequency of trimming extensive hedges or to control the growth of bushes and trees underneath telegraph and power lines, along traffic ways and many other places.

Controlled vegetative cover - as a guard against soil erosion

Many cultivated areas are exposed to the destructive forces of wind and water. On such endangered surfaces a long term dwarfing effect of natural vegetation, planted ground cover or green manure crops is of considerable interest. Due to the non-injurious effect and its growth inhibiting action on a large array of plants, the chlorflurenol derivatives raise the possibility for the maintenance of a low growing protective cover of green plants. This is true above all for long term protection against erosion in areas of perennial plantings.

Determining plant morphology

Several further aspects on the subject of directing growth and development of plants were previously outlined (4).

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APPLICATION EQUIPMENT FOR INDUSTRIAL WEED CONTROL

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The past 30 years has seen an ever-increasing expansion of the industrial weedkilling market, and at the same time the discovery of many new chemicals. These two factors, combined with the shortage and cost of labour, have inevitably brought about the development of equipments suitable for applying chemicals to such sites as oil refineries, marshalling yards, electrical installations, Local Authority highways, storage yards, in addition to railways.

The basic facts of modern weedkilling techniques are, of course, well known, so this paper traces through the years the development of equipments designed to deal economically and efficiently with all conditions and all chemicals for this rapidly expanding industrial market.

Until shortly after the last war, organized industrial chemical weed control in the U.K., was confined to the railways, when a proprietory solution, containing sodium chlorate mixed with calcium chloride to reduce the fire hazard, was used. This solution was applied to railway tracks twice a year by a spray train at a solution rate of 135 gallons to the acre, and at an approximate speed of 20 m.p.h. The chemical concentrate and water were mixed in bulk at a 1:3 ratio, and applied by means of a large axle driven meter pump through cone nozzles over a maximum 17'6" swath.

The outer portions of the track were treated by hollow cone nozzles fitted to swinging booms, which had to be retracted when passing signal posts, bridges and platforms, resulting in unsprayed portions of track around each of these obstructions.

During the 1950's, residual chemicals in the form of substituted ureas and triazines were developed, and these required a completely different approach to application techniques.

The residual chemicals were very powerful, expensive and generally insoluble, and had to be applied accurately at low dosage rates, being maintained in suspension until the point of application. On railway tracks, trials had indicated that mixtures of chlorate and residuals were necessary on the cesses or walking ways, whilst in relatively clean ballasted track residual chemicals alone provided satisfactory weed control with a single annual treatment.

A number of methods were developed to provide these treatments, the most successful being the equipments now employed on British Railways and, more recently, in other parts of the world. (Fig.1)

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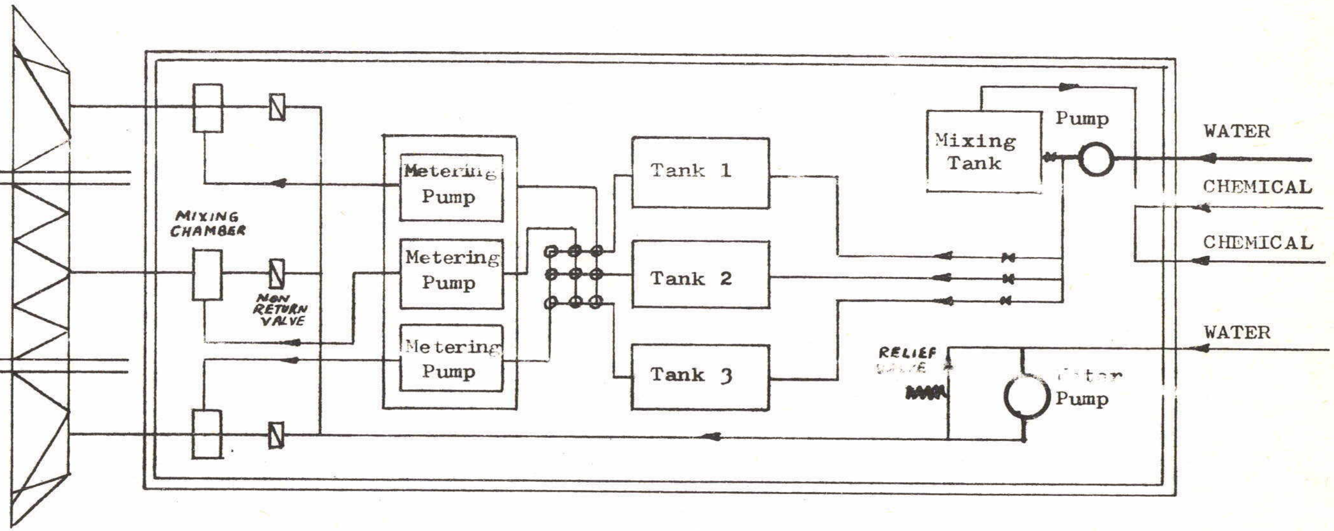


WEEDKILLER TRAIN PIPING DIAGRAM

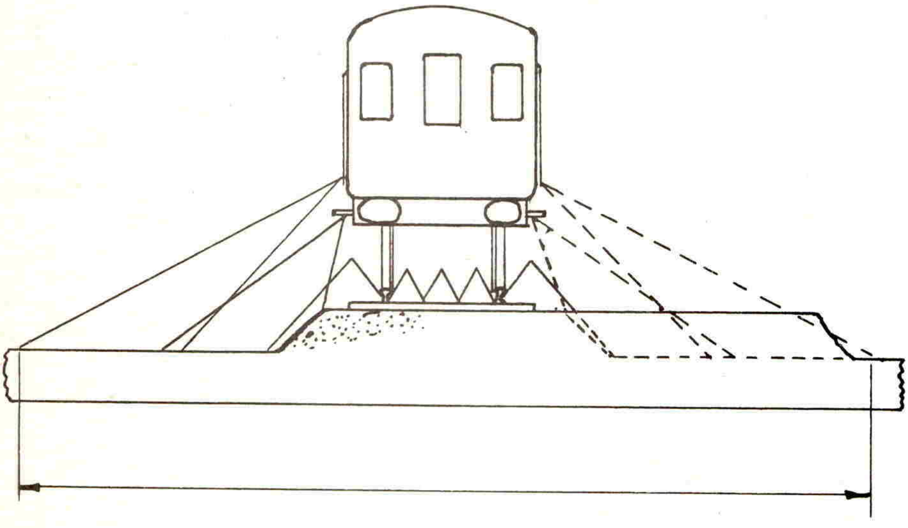
(Fig. 1)

The basic principle of the equipment is water displacement by chemical concentrate, in which the water is used only as a means of obtaining an even cover over the required swath width. Mixtures of chemical concentrate and residual herbicide powders at the required ratio e.g. 12-lb. diuron/120-lb. sodium chlorate, or residual herbicide powders and water, are prepared in a mixing tank and transferred to storage tanks fitted with mechanical agitation. The slurry or concentrate is then drawn by one of a number of adjustable axle driven meter pumps, which inject the chemical into the water flow. As the meter pumps are axle driven, the pump output is always directly proportional to the train speed, and the facility of adjustment to the meter pump output enables the treatment to be changed to suit track weed growth.

The water flow is provided by a separate water pump, which is fitted with a sensitive relief valve. The sole purpose of this pump is to provide a constant spray pressure of 20p.s.i., and a full spray pattern regardless of train speed. The water passes through a non-return valve and control valve to a mixing chamber. At this point the chemical or slurry is joined, and a thoroughly mixed spray solution flows toward the nozzles. As the train speed increases, so does the metered flow of chemical, but the spray pressure and nozzle output remain constant. The displaced water is by-passed to the water pump suction feed. An increase in train speed reduces the solution rate from high volume to between 20 and 60 gal/ac., the strength of the solution changing to provide the correct chemical treatment.

The development of this method coincided with nozzle development. This allowed the replacement of the retractable spray booms by "wing" nozzles, which would withstand the wind pressure and slipstream encountered at speeds of 50 m.p.h.

A full effective width of 40'0" can be treated by 9 nozzles. (Fig. 2).



WEEDKILLER TRAIN SPRAY PATTERN (Fig.2)

The wing nozzle can be rotated to adjust the width to suit the track formation.

With the development of more powerful soluble chemicals for foliar and root absorption, we are now studying the problem of faster speeds and yet lower solution application rates.

In very recent years, attempts have been made to spray the grass areas of cuttings and railway verges with a paraquat/diquat mixture to avoid the expense of hand cutting. Using a similar method of chemical injection but different nozzles, a 6'0" swath of grass is treated.

To maintain the 6'0" swath required, it is necessary to adjust the spray nozzles constantly as the terrain and distance between the rail and verge change, and also to avoid adjacent gardens and allotments.

During the last four years, British Railways have changed their methods of weed control. Whereas they once purchased chemical weedkillers and used their own labour and equipment, or hired equipment to apply the weedkiller, the greater part of on-track work is now placed to contract. Spray trains can easily cope with the present track mileage, but there are many acres of sidings and marshalling yards which also require weed control treatment.

To treat a proportion of these "off-track" areas, a number of mobile teams, each with a specially equipped Land Rover, have been assembled. These equipments also have to be capable of any other weed control work.

Into a long wheel based Land Rover is built a 120 gallon tank fitted with mechanical agitation, a pump capable of providing 20 g.p.m, at 200 p.s.i., which can apply any type of weedkiller either through a front mounted spray boom, or handlance and 200-ft., hose. Power to the pump, and for agitation, is provided by a short power take off shaft. The front boom control is mounted in the tank, but folds forward into the cab to a convenient position beside the driver. The boom is fitted with low-drift fan nozzles, which operate at 10-15 p.s.i., and hormone chemicals have been applied at 10 m.p.h., and 40 gal/ac., in gusty wind conditions without damage to adjacent gardens.

One of the developments which has increased productivity and enabled difficult and congested areas, such as rail sidings, to be economically treated, is the "quick charged" knapsack sprayer. Using a 3 gallon capacity pressure charged sprayer, the equipment is fitted to the operator when empty, and filled with solution in less than 30 seconds by the use of the Land Rover pump and quick release couplings.

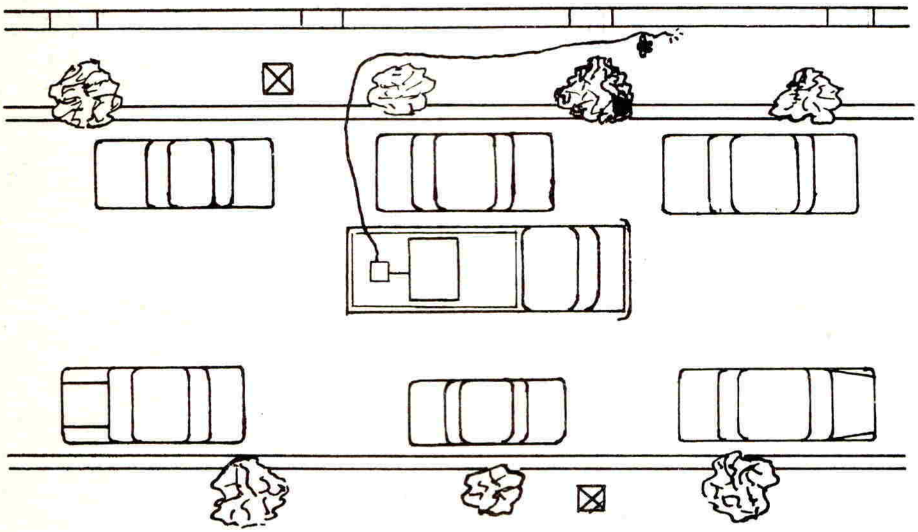
By planning the areas to be treated, "dead" walking is eliminated and the sprayer recharged without the arduous and difficult operation of mounting the loaded sprayer onto the shoulders. Anyone who has used a knapsack sprayer will know what an effort and how tiring this can be.

By fitting a quick release coupling to the end of the 200-ft., long Land Rover hose, chemical under pressure can be supplied to island sites, or places where the vehicle cannot have access. This equipment is also eminently suitable for other industrial work.

No doubt the publicity given to developments in the agricultural field, and the use of selective chemicals in the garden assisted the interest in, and development of, weedkilling in the local authority market. The application of chemical weedkillers again called for specialized equipment to reduce the risk of chemical damage to trees, shrubs and gardens adjacent to footpaths and sites to be treated. To ensure that chemicals may be applied in as safe a manner, and as accurately as possible, a range of equipments has been developed and made available for hire or sale, as part of the service of chemical supply.

Initially, the basic spray equipment took the form of a portable engine/pump unit and chemical solution storage tank mounted on a lorry, refuse truck or barrow, the chemical being applied through a hose and handlance to vegetation on pavement slabs or wall and fence lines. Over larger areas rigid spray booms were used.

Although this method was, and still is, satisfactory, work study of this operation indicated that one of the chief faults of this handlance and long hose method, when used on pavements, was the time lost in operation. (Fig.3).

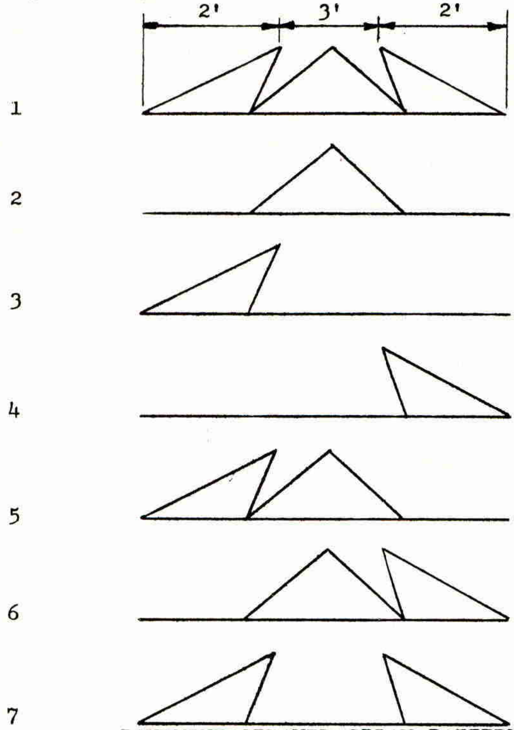


HAND SPRAYING URBAN PAVEMENT

(Fig.3)

Most urban streets have lamp-posts, trees or parked vehicles on the kerb line, and the vehicle carrying the tank of spray solution has to park in the road, often obstructing the traffic flow.

The operator walks the pavement to the extent of his hose, and then has to retrace his steps to the obstructing lamp-post, tree or vehicle, and then again walk down the road, thus reducing his production time to one third of his walking time and effort. This waste of effort reduced the pavement sprayed to approximately only ¼ mile per hour. To overcome this, a self contained 20 gallon, wheeled unit has been developed which is easy to handle, simple to operate, and can effectively spray a 2'0", 3'0", 5'0" or 7'0" swath. (Fig.4).



PAVEMENT SPRAYER SPRAY PATTERN (Fig.4)

Being pedestrian operated, it is independent of the recharge vehicle, and by carrying a chemical supply and drawing water from hydrants, can be operated by one man to treat over 1 mile of pavement per hour. Each of the three nozzles on the front boom is independently controlled, giving the operator an instant choice of seven spray patterns. The side nozzles used on this machine are a direct development of the nozzles used on the spray trains, operating with minimum of drift at 10 p.s.i., pressure.

Great attention has to be paid to details in providing equipment that is simple to operate, light and portable, but sufficiently robust to withstand a great deal of tough treatment. Where possible, plastic materials have been used, but not always with success.

In an attempt to reduce the risk of drift, and ensure thorough cover of foliage or ground, the solution application rates in the industrial world are often far greater than those used in agriculture. The pavement treatments are normally at 90 or 135 gal/acre.

In 1965 an amendment to the Road Traffic Act, permitted the use of a mechanically propelled vehicle on pavements, with a maximum weight of 1 ton and speed of 5 m.p.h. To obtain the maximum advantage of this advance, a new self-propelled machine has been developed. This unit has a hydraulic hydrostatic drive with one pedal to control the vehicle speed, and a hydraulically driven constant speed power take-off shaft, which makes the machine versatile and easy to drive.

The 70 gallon tank capacity and a safe drift free application of 40 gal/ac., further reduces the cost of the weed control operation. This should lead to a greater use of chemicals, and a higher standard of local authority maintenance, together with increased productivity and efficiency.

This same machine can be used for snow clearing, gritting, and is also readily adaptable for other street maintenance duties.

On many sites, water is difficult to obtain; it is also a very heavy commodity to transport, and a large part of industrial total weed control is economically completed with the use of dry granular weedkillers. These first entered the market in the mid-1950's, and a range of equipments have been developed for application. Among the most successful and widely used is the chest mounted "Grani-Spreader". Fitted with an adjustable oscillating shutter, this machine may be used in any place where foot access can be obtained. Spreading granules over an 8'0" swath, treatments of between 175 and 1200-lbs., per acre can be applied.

A special machine for laying a narrow band of granules to kerb edges, fence lines and such bizarre places as grave kerbs is the "Grani-Line". This machine comprises a tubular steel frame and handlebar, mounted on a single pneumatically tyred wheel. An "ON/OFF" adjustable feed control, connected to the bottom outlet of the 20-lb., capacity hopper enables the wheel-driven mechanism to dispense granules via an outlet tube to the desired position. The "Grani-Line" will apply granules at selected rates of application, over both wide and narrow bands, without risk of dust drift.

With regard to cemeteries and churchyards, experience has shown that maintenance funds are rarely adequate for more than periodic grass cutting, and overgrown kerbs present a hazard to the mowers. By removing close-growing grass and weeds, the graves are clearly defined, look tidy and do not require the close attention of the mowers.

The application of bipyridylium herbicides has presented no particular problem with existing application equipment. The only equipment developed specially for this use is the "Edger". This will apply chemical in a 2" band to kerb edges, or municipal flower and grass borders.

The "Edger" consists of a 5 gallon plastic tank mounted on a tubular steel frame. An "ON/OFF" control permits the flow of the solution to a specially constructed single wheel, incorporating an absorbent plastic material on its outer circumference. This transfers the bipyridyl weedkiller in a clear and well defined "band", without drift or lateral movement.

CONCLUSIONS.

We are all aware that the success of a chemical treatment depends mainly on two things - the efficiency of the chemicals used, and the method and accuracy of application. By providing equipment that is simple to operate and maintain and relatively inexpensive to purchase or hire, we are encouraging not only a wider and safer use of herbicides, but promoting even further the expansion of industrial weedkilling.

Proc. 9th Brit. Weed Control Conf. (1968)

WL 19,805 - A NEW TRIAZINE HERBICIDE

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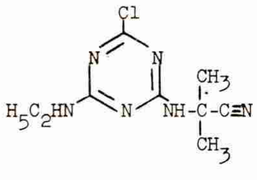
Summary WL 19,805, 2-(4-chloro-6-ethylamino-s-triazine-2-ylamino)-2-methyl-propionitrile, is one of the most active members of a novel group of triazine herbicides. Its physico-chemical characteristics are described and herbicidal properties reported. Particularly interesting is its limited soil persistence and consequent lack of carry-over problems. The metabolism of WL 19,805 in plants and soils, which differs in certain respects from that reported for other triazine herbicides, is briefly described.

Results of field experiments demonstrating selectivity following pre-emergence applications of WL 19,805 to maize, potatoes, peas and wheat, and post-emergence treatments of maize and wheat are presented.

INTRODUCTION

At the Eighth British Weed Control Conference, Barnsley and Gabbott (1966) introduced a novel group of triazine herbicides of which the most active member was WL 9385 (2-azido-4-ethylamino-6-t-butylamino-1,3,5-triazine). It was a highly active herbicide with a short predictable half-life. This short persistence made it potentially useful for extending the range of crops in which triazines could be used. Unfortunately its persistence proved too short in practice, so that under adverse weather conditions poor weed control resulted from pre-emergence applications. Even post-emergence sprays sometimes gave poor results, particularly if weed emergence continued for some time after application.

Recent work in our laboratories has resulted in a further group of novel triazines and one of these, WL 19,805, has been extensively evaluated in the field. An earlier paper has been presented in the United States where the compound has the code number SD 15,418 (Hughes *et al* 1967).



Empirical Formula:
$N_6ClC_9H_{13}$

WL 19,805

2-(4-chloro-6-ethylamino-1,3,5-triazine-2-ylamino)2-methyl-propionitrile

PHYSICO CHEMICAL PROPERTIES

Physical form	:	White crystalline solid		
Melting point	:	166.5 - 167°C (technical material)		
Solubility	:	Water 171 ppm at 25°C		
		Ethanol	4.5%	w/v
		Benzene	1.5%	"
		Chloroform	21.0%	"
		Carbon tetrachloride	<1.0%	"
		Methylcyclohexanone	21.0%	"
		Dichloromethane	15.0%	"
		Hexane	1.5%	"

Vapour pressure :	20°C	:	1.6×10^{-9} mm Hg
	30°C	:	1.0×10^{-8} mm Hg
	40°C	:	5.9×10^{-8} mm Hg

Stability: a) Thermal. Highly stable in accelerated storage tests at high temperatures.

b) Hydrolytic. Hydrolytically stable at neutral pH. At a concentration of 72 ppm the following half lives were obtained at 55°C.

pH	Half life (hours)
1.6	3.0
7.5	6110
11.5	8.4

c) Photochemical. Irradiation of the technical material either as a solid or in aqueous solution resulted in no degradation or loss.

TOXICOLOGY-ACUTE

Species	Route	LD_{50} mg/kg
Mouse	Oral	380
Rat	Oral	182
Rabbit	Oral	141
Fowl	Oral	750
Rat	Intraperitoneal	75-105
Rat	Percutaneous	>1200
Rabbit	Percutaneous	>2000

BIOLOGICAL PROPERTIES

Early glasshouse tests with WL 19,805 showed a high level of pre- and post-emergence activity together with selectivity in maize. Further glasshouse experiments involving pre- or post-emergence applications to maize and mixed weeds confirmed the promise shown by the earlier tests. The results presented in Table 1 show the effects obtained.

Table 1.

Results of glasshouse experiments with maize and mixed weeds

	Dose(kg/ha a.i)required for 90% kill of weeds		Dose(kg/ha a.i)causing 10% depression in maize growth	Selectivity factors	
	a)Broadleaved	b)Grass		a)Broadleaved	b)Grass
Pre-emergence					
WL 19,805	0.07	0.11	4.1	58	39
Atrazine	0.08	0.14	>10	>126	>71
Post-emergence					
WL 19,805	0.14	0.21	<1	-	-
Atrazine	0.24	0.56	<1	-	-

The results in Table 1 were obtained usings sprays of technical material dissolved in 1:1 v/v mixture of acetone and water containing a wetting agent. Formulation as a WP considerably increases the tolerance of maize to post-emérgence applications, as shown in the field results.

Estimates of the leachability of WL 19,805 have been made using both the slotted tube technique (Lambert et al 1965) and thin layer soil plates. In both systems the extent of the movement of the compound was determined by bioassay. The results obtained are presented in Table 2.

Table 2.

Comparative leachability in two systems

	Distance moved (cm)	
	Slotted tube assay	Thin layer soil plate
WL 19,805	12.0	13.7
Atrazine	12.5	13.1

Another bioassay system was used to obtain information on the persistence of the compound in soil. Batches of soil were treated with dosages of compound and stored in loosely stoppered glass jars. The soil was sampled at weekly intervals and the various samples were placed in pots in which young tomato seedlings were planted. After ten days visual estimates of kill were made. By plotting these against time for each dosage it was possible to obtain data on the rate of degradation of the compound in the soil. The half lives obtained for WL 19,805 and a standard in this bioassay are given in Table 3.

Table 3.

Persistence of WL 19,805 in soil half life (days) @ 25°C

WL 19,805	11.7 ± 0.42
Atrazine	24.6 ± 4.21

MODE OF ACTION

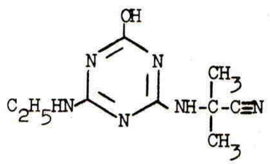
WL 19,805 is a potent inhibitor of the Hill reaction (pI_{50}= 6.6) and there is no reason to believe that its main effect is other than by the inhibition of photosynthesis.

METABOLISM

The metabolism of WL 19,805 has been studied by Wright in plants and by Osgerby in soil (unpublished reports). The tentative scheme of breakdown is shown in Fig 1.

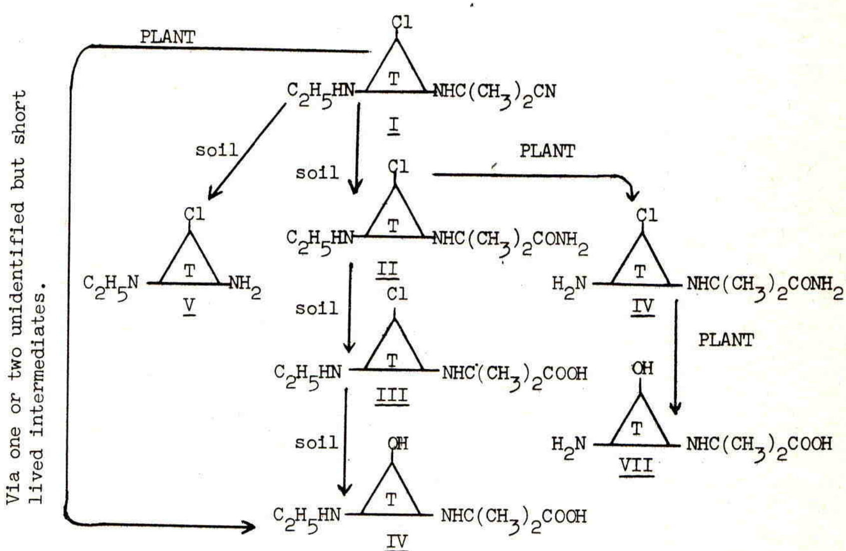
With the exception of compounds I, II and V the herbicidal activity of all the metabolites is extremely low and even that of II is very poor in comparison with that of its parent compound, WL 19,805. Compound V has only been isolated in small amounts from certain soil types.

An interesting feature of this scheme of breakdown is the apparent absence of metabolite VIII which might be expected from work published on other chlorotriazines and their metabolism by maize (Castelfranco et al 1961, Roth and Knüsli 1961, Hamilton and Moreland 1961, Shimabukuro 1967).



Compound VIII

Fig. 1. Metabolism of WL 19,805 in Maize and Soil-after Wright and Osgerby



FIELD PERFORMANCE

During 1967 and 1968 WL 19,805 has been tested in several crops in various countries and the following is a summary of the general results obtained.

Maize: (i) Pre-emergence

Very good weed control is usually obtained for the first 8-10 weeks after application. Weed counts during this period normally showed a 90-95% control. In some areas the weed control continued to be excellent until harvest, but elsewhere re-infestation occurred after this period particularly where perennial weeds were a problem. However, since it is common practice in many areas of the world for a final cultivation to be made at this time this late infestation would usually be unimportant in practice. The degree to which this took place was dependent on several factors, including the predominance of perennial weeds and the rainfall during the second part of the season which would allow weeds to become established. The information gathered from trials on the response of individual weed species has been condensed and is given in Table 4.

It was found that the dosage required to obtain a satisfactory weed control using WL 19,805 was, like that of many other materials, influenced by the organic matter and clay contents of the soil. Field tests have shown that 0.5 kg/ha a.i can be effective on light sandy soils while on heavy soils of medium organic content dosages of 2-3 kg/ha a.i are needed. Soils of high organic matter content often require even higher rates.

It has been shown in the field that maize normally withstands dosages well in excess of those required for weed control. The level of crop tolerance has been remarkably consistent despite the wide range of conditions and countries in which the compound has been evaluated and generally speaking there is no visible crop reaction to doses as high as 8 kg/ha a.i. However, on rare occasions temporary yellowing and growth retardation has been noted following the application of 4 kg/ha a.i but in no instances has yield been affected by this rate. These very slight symptoms have been observed only in one or two percent of all the trials conducted and in the United States were found to be related to adverse weather conditions (i.e. excessive rainfall and cold weather).

(ii) Post-emergence applications

Less work has been done on post-emergence applications. However, the compound has been used in maize both as an overall and as a directed spray, with and without the addition of Korn oil. WL 19,805 gave excellent weed control when used post-emergence, with best results obtained when the compound was sprayed on to the seedling weeds at a time when the maize was about 12 cm high. Applications at a later stage have been less effective. Mixture with Korn oil, used at the rate of 5% of the total spray volume, increases herbicidal efficiency. These mixtures have been used as an overall and as a directed spray with the nozzles placed low between the rows.

Maize has in some trials withstood 8 kg/ha a.i of WL 19,805 applied as post-emergence spray without showing any crop reaction, but in some cases slight and temporary signs of phytotoxicity have been reported following the use of 4 kg/ha a.i. Marked symptoms have appeared following the use of low rates of WL 19,805 with Korn oil, as an overall spray. Applications with Korn oil should be restricted to directed sprays.

Wheat and Barley:

WL 19,805 has been assessed as a pre- and post-emergence herbicide primarily against *Alopecurus myosuroides* (blackgrass) in winter wheat.

Pre-emergence applications resulted in good control (around 90% with 2 kg/ha a.i) of A.myosuroides when assessed at the end of the winter. However because of the short persistence of the compound, pre-emergence applications in the autumn do not control spring germinating seedlings. The use of the compound in this outlet is therefore suggested only for crops sown early in the autumn in areas where a heavy flush of A.myosuroides is likely to appear with the crop and spring germination is not a problem.

Post-emergence applications have been made both early in the autumn, and also in the spring. Early post-emergence applications were hampered by very wet weather and difficult conditions and this, rather than the weed control obtained, is considered to be the limiting factor in the use of the compound at this time. Trials carried out in several European countries showed that the control of A.myosuroides varied from 60-95% following an autumn application of 2 kg/ha a.i. This figure is again based on spring assessments and was equal to or better than the control obtained with the standards used. In addition, the control of the few broadleaf weeds that were present at the time was very good.

Spring applications to winter cereals also gave good results and control of A.myosuroides was normally very good. Again the dose at which this level of control was obtained varied somewhat with soil type. On the light soils rates of between 0.5 and 1 kg/ha a.i were satisfactory. On heavy soils it was necessary to increase the rates to 1.5 kg/ha a.i or slightly more.

Visual crop tolerance assessments indicated that damage did not occur at the rates at which good control of A.myosuroides was achieved. It was felt from these assessments that the safety margin involved with this compound would not however be more than 2 times although this was influenced somewhat by the time of application. Thus applications made early in the spring, February and early March, appeared to achieve a higher safety margin than later applications made in the second half of March and early April.

Potatoes:

The relatively smaller amount of work carried out on potatoes has shown that applications to this crop have given good weed control equivalent to that obtained with many other standard potato herbicides, at rates of between 2 and 3 kg/ha a.i. This is true whether the compound is applied before the emergence of the first shoots, at the time of emergence or after emergence. However, both visual symptoms and yield data have shown that phytotoxicity occurs following post-emergence applications and also high dosages at emergence. No crop damage has resulted from lower doses at emergence or from pre-emergence applications. The situation with regard to crop tolerance appears to be governed to some degree by the soil type and more work is required on this aspect.

Peas:

The limited work that has been done with peas indicates that a dose of between 2 and 3 kg/ha a.i will be sufficient to give good weed control without causing phytotoxicity to the crop.

Residual life in the soil

An outstanding feature of WL 19,805 is its lack of carry over problems due to short persistence in the soil. In the United States following treatment with 2 kg/ha a.i, oats were seeded and established without toxicity within 10 weeks after application.

Field studies in the United Kingdom proved that it was possible to establish sugar beet 8-9 weeks after the application of 2 kg/ha a.i of WL 19,805.

It is considered that this short persistence together with favourable results in a wide range of crops makes WL 19,805 a promising new herbicide.

Table 4.

Weed responses to WL 19,805 (pre- and early post-emergence)

A = usually controlled by 2 kg/ha or less.
B = usually controlled by 1-4 kg/ha (American and Spanish results).
C = usually controlled by 4 kg/ha.
D = not always controlled sufficiently by 4 kg/ha.
* = these species showed a slightly variable response. This was due to different conditions of climate and soil which encouraged these species to extend their period of germination, and thus allowed escapes.

Agropyron repens	D
Alopecurus myosuroides	A
Amaranthus spp	A*B
Ambrosia artemisiifolia	B
Anagallis arvensis	A
Anthemis cotula	A,B
Atriplex patula	A
Avena fatua	B
Bellis perennis	C
Brachiaria cruciformis	C
Brassica sp	A,B
Capsella bursa-pastoris	A
Cerastium arvense	B
Chenopodium album	A,B
C.paniculatum	A
Cirsium arvense	D
Convolvulus spp.	D
Cucurbita spp.	A
Cynodon dactylon	D
Cyperus spp.	B,D
Digitaria sanguinalis	A,B
Diodia teres	B
Diplotaxis erucoides	B
D.muralis	A
Echinochloa crus-galli	B,D
Eleusine indica	B
Erigeron canadensis	B
Euphorbia spp.	A
Equisetum spp.	D
Filago arvensis	A
Fumaria officinalis	A
Galeopsis spp.	A
Galium aparine	A*
G.tricorne	C
Galinsoga parviflora	A,B
Geranium molle	B
Juncus bufonius	A
Lamium spp.	A
Lepidium draba	A
Lolium multiflorum	B
L.temulentum	B
Malvastrum peruvianum	A
Matricaria spp.	A
Medicago lupulina	A
Mentha arvensis	D
Mercurialis annua	A
Mimosa spp.	D
Mollugo verticillata	B
Myosotis arvensis	A

Oxalis acetosella	D
Panicum capillare	B
P.dichotomiflorum	B
Papaver rhoeas	A
Paspalum distichum	D
Phragmites communis	D
Phyllanthus amarus	A
Plantago major	B
P.media	C
Poa annua	A,B
P.trivialis	A
Polygonum aviculare	A*B
P.convolvulus	A*
P.lapathifolium	A
P.pennsylvanicum	B
P.persicaria	A,B
Portulaca oleracea	A,B
Potentilla spp.	C
Ranunculus repens	D
R.trilobus	A,B
Raphanus raphanistrum	A
R.sativus	B
Richardia scabra	B
Rottboellia exaltata	D
Rumex spp.	D
Senecio vulgaris	A,B
Setaria faberii	B
S.glauca	B
S.viridis	A,B
Sinapis arvensis	B
Sida rhombifolia	A
Silene inflata	C
Solanum nigrum	A,C
S.oleracea	B
Sonchus arvensis	A
Spergula arvensis	A
Stellaria media	A
Thlaspi arvense	A
Tussilago farfara	D
Urtica sp.	C
Veronica spp.	A
Vicia sp.	C
Viola spp.	A
Xanthium canadense	B
Xanthium spinosum	C

Note: The response of perennial spp. is not always clear; in general WL 19,805 acts in a similar way to other triazines.

Acknowledgements

Many colleagues have contributed to the data presented in this paper and our thanks are extended to them. In particular the work of Drs. Wright and Osgerby on metabolism in plant and soil is gratefully acknowledged, together with field data from co-workers principally in Canada, France, Germany, Spain and Trinidad.

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C 6989 : A NEW SELECTIVE HERBICIDE

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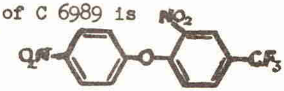
Summary C 6989, 2,4'-dinitro-4-trifluoromethyl-diphenylether, is a new herbicide suitable for use on rice pre- or post-emergence or post transplanting, and pre-emergence in cotton, soybeans, groundnuts, other large-seeded legumes, maize and several other crops in countries with tropical, sub-tropical or Mediterranean-type climates. It is a very versatile herbicide ; in rice at 3 - 4 kg a.i./ha, it will control Echinochloa crus-galli, Cyperus rotundus and other important weeds provided that application is made before the 4 leaf stage, whether or not water is present, and irrespective of how much flood water is placed over the soil. It is compatible with commonly used insecticides, capable of formulation as an emulsifiable concentrate, wettable powder or a granular, and is of extremely low mammalian toxicity. It is persistent and active for up to 8-12 weeks and is active even in dry soil. Its mode of action appears to be largely by contact, as translocation is relatively slow and weak.

INTRODUCTION

a) Physical and Chemical Properties

The structural formula of C 6989 is



giving a molecular weight of 328.2. The melting point of the pure compound is 91.6 - 92.2°C, and the yellow-brown crystals are soluble in water only to the extent of 2 ppm. The crystals are soluble in acetone, ethanol, dimethyl-formamide, xylene and benzene. The formulations developed so far are a 30 % emulsifiable concentrate (subsequently referred to as E.C.), and a 5 % granular.

b) Toxicology

The acute oral LD 50 for rats is above 10 g/kg ; emesis precluded the determination of an LD 50 for dogs, the median emetic dose being 2483 ± 721 mg/kg. No dermal irritation has resulted from application to abraded or intact skin of rabbits, and no toxic symptoms occurred when one dose equivalent to 10 g/kg was applied, or successive application totalling 30 g/kg were made on 15 occasions in a period of 3 weeks. Prolonged feeding tests have further shown the toxicity of C 6989 to be extremely low ; no pathological or histological changes were caused by high dosages in the food consumed by rats, dogs and birds.

EXPERIMENTAL METHODS AND MATERIALS

The activity and selectivity of C 6989 in rice has been the subject of intensive research under both greenhouse and field conditions. Concrete tanks, 60 x 60 x 40 cm, filled almost to the top with soil, provided with a system whereby the water table can be adjusted to give any desired level of water in or over the soil, have been used extensively for greenhouse trials. Simple pot tests on several crops and weeds have also been carried out in addition to the standard randomised block small-plot field screening and yield trials. Persistence trials under field conditions have been done, almost exactly as was done for C 7019 earlier (Green et al 1967).

In assessing crop health and damage to weeds, the E.W.R.C.'s scale of from 1 - 9 has generally been employed, and found to agree accurately with results obtained by taking fresh plant weights. On this scale, 1 represents no observable effect, 4 is an acceptable stand, and 9 indicates total destruction.

RESULTS

Early greenhouse and field results demonstrated that C 6989 was tolerated pre- and post-emergence by rice and wheat, and pre-emergence, especially in tropical and sub-tropical regions, by cotton, soybeans, groundnuts, maize, dwarf beans, peas and sorghum. It has controlled a wide range of broad-leaved and grass weeds, including the important Echinochloa crusgalli, Scirpus spp., Eleusine spp., Setaria spp. and has given an acceptable suppression of Cyperus spp.

Greenhouse and field investigations were then concentrated on elucidating the factors affecting selectivity and activity in rice.

A. Results in Rice

1. Up to 1.5 kg a.i./ha as the E.C. formulation may be used pre-emergent to rice, and this gave consistently adequate control of E. crusgalli. The granular formulation cannot be used at this stage.

2. On direct-sown rice, any rate between 1.5 and 6 kg a.i./ha is selective early in post-emergence ; the granular formulation is somewhat less active than the E.C. at the lower rates.

3. Transplanted rice tolerated all rates between 1.5 and 4 or more kg a.i./ha, and good to complete control of E. crusgalli was consistently obtained, using both the E.C. and the granular formulations, applied pre-emergence to the weed, within 5 days of the transplanting.

4. The E.C. formulation at 2 or 3 kg a.i./ha was tolerated by all of 10 different rice varieties tested, when the herbicide was applied either pre- or post-emergence to both paddy and upland types. Application in this trial was to a moist soil surface, and the paddy rice containers were subsequently re-flooded.

5. In post-emergence applications to direct seeded rice, rates of C 6989 between 2 and 6 kg a.i./ha all gave complete control of E. crusgalli irrespective of whether water was present in the tanks over the soil or whether the tanks were drained. No damage to rice at the 2 leaf stage was observed. On transplanted rice, again C 6989 at 3 kg a.i./ha gave complete, selective control of this weed in the 2 leaf stage applied both to standing water and to drained soil. At 2 kg a.i./ha, C 6989 was slightly more active when applied to standing water than to drained, moist soil for the control of germinating E. crusgalli in transplanted rice.

6. At the 2 leaf stage of both direct-seeded rice and E. crusgalli, C 6989 at 2, 3 or 4 kg a.i./ha gave complete control of the weed when the E.C. formulation was applied. At 2 kg a.i./ha, the granular formulation was slightly less active than the E.C. At the 3 and 4 leaf stages of both plants, the E.C. at all rates again gave perfect selective control ; the granular gave poor weed control at 2 kg a.i./ha and gave only 70 % control at 4 kg a.i./ha. At the 5 leaf stage of E. crusgalli, poor control was obtained with both formulations. The granular formulation must therefore be applied at or preferably before the 2 leaf stage of E. crusgalli, while the E.C. can be used as late as the 4 leaf stage.

7. Both at the 1 - 2 and the full 2 leaf stage of E. crusgalli (10 days and 13 days after sowing under the conditions of the trial), the grass was eliminated from transplanted rice by 3 kg a.i./ha as E.C. or granular, but only completely by the E.C. at 2 kg a.i./ha.

8. Again on direct-sown paddy rice, it was shown that application of C 6989 E.C. at 1, 2 or 4 kg a.i./ha on the day of seeding rice, or 3 days later as the rice shoots emerged, caused the complete kill of the crop. However, 6 days after seeding, excellent tolerance of rice in the 1 - 2 leaf stage was obtained, with complete kill of E. crusgalli, sown at the same time, by 2 and 4 kg a.i./ha. After 9 days, however, the E. crusgalli plants in this trial had begun to show tolerance to C 6989.

9. The depth of water in the tanks (0,2 or 4 cms) made no difference to the excellent performance of C 6989 E.C. 4 kg a.i./ha, applied at the 3 leaf stage of the weed. With 2 kg a.i./ha, however, good control was only obtained in the absence of covering water.

10. Rainfall at different times of application was simulated using a fairly high pressure dispersed jet of water. Echinochloa plants were washed immediately after the application of C 6989 E.C. at 2, 3 and 4 kg a.i./ha under upland conditions, and other batches containing an identical number of young weed plants at different times afterwards. The results are summarised in table 1 below.

Table 1.

Effect of Simulated Rainfall after treatment of E. crusgalli with C 6989

(Plant weights in g : figures in brackets are % of control)

	Time of Washing, minutes after application				
Rate of C 6989	None	Immediately	10	40	90
0	33.0(100%)	-	-	-	-
2	3.2(9.7%)	17.1(51.8)	16.3(49.4)	13.2(40.0)	5.9(17.9)
3	0	16.5(50.0)	6.3(19.1)	1.5(4.5)	3.6(10.9)
4	0	9.9(30.0)	6.2(18.8)	0.5(1.5)	2.0(6.1)

These results show that rain 1 1/2 hours after spraying does not greatly affect the control of E. crusgalli by C 6989 ; the effect of 3 kg a.i./ha, the optimum rate, is not seriously affected by rain even 10 minutes afterwards.

11. Field and greenhouse trials have shown that C 6989 E.C. affords excellent control of Scirpus mucronatus, Sesbania sp., Cyperus microiria, Cyperus globosus, Monochoria vaginalis and Callitriche sp., gives acceptable control of Ipomoea spp. Digitaria spp., Eliocharis spp. and Lyndernia pyxidaria, but that Leptochloa spp., Nymphea stellata and Paspalum distichum are generally resistant to C 6989.

12. Factors which can cause poor results, especially with the E.C. formulation, are flowing water over the treated area, application of the herbicide after the 3 - 4 leaf stage of the weeds, and low temperatures.

13. A field trial in the far East, with a dense infestation of Paspalum, Cyperus rotundus, Scirpus roylei, Sphenochloa zeylanica and Echinochloa crusgalli, sprayed at the 2 leaf stage following the transplantation of rice, gave the following typical results :

Table 2.

Yield trial with C 6989 on transplanted rice

Rate of C 6989	% Weed Control 3 weeks after application	Rice grain yield, kg/ha (mean of 3 reps.)	MRT		
2	90	2125		B	C
3	85	2458	A		
4	96	2458	A		
0	0	2193		B	
0 (weeded)	-	2083			C

Yields followed by a common letter in the column headed MRT are not significantly different at P = 0.05 when analysed using Duncan's Multiple Range Test.

B. Other Crops

While relatively poor weed control and selectivity has been reported from temperate Europe, excellent pre-emergence results have been obtained in soybeans, cotton, maize and groundnuts, other large seeded legumes, small-grain cereals, onions, and pre-transplanting, C 6989 is tolerated by tomatoes, tobacco, paprika and cauliflowers.

A sample of 30 results obtained in soybeans is summarised in table 3 below.

Table 3.

Summary of field results in Soybeans using C 6989 : Means of percentage weed control and yield

Herbicide Applied	Rate of C 6989 lb a.i./ac	Number of trials including this rate	Mean % grass control (8 weeks)	Mean % broad-leaved weed control (8 weeks)	Mean yield, bu/ac
Pre-emergence	2	3	85	no broad-leaved weeds	23.6
Untreated	0 (weeded)			in trials	23.8
Untreated	0 (unweeded)				20.5
Pre-emergence	3	10	88	68 *	34.7
Untreated	0 (weeded)				38.0
Untreated	0 (unweeded)				31.1
Pre-emergence	4	13	86	78 *	37.0
Untreated	0 (weeded)				34.2
Untreated	0 (unweeded)				28.0
Pre-emergence	6	11	90	79 *	32.8
Untreated	0 (weeded)				35.7
Untreated	0 (unweeded)				29.3
At-emergence	1	2	80	100	35.0
At-emergence	2	2	100	100	36.0
Untreated	0 (once weeded)				30.0
Untreated	0 (unweeded)				30.0

* Resistant weed largely *Ipomoea sp.*

Similar results are reported with maize ; initial damage to this crop is often reported, as the rolled shoot in pushing through the treated soil surface can be scorched by the herbicide, giving a broken line of spots across each of the first 3 or 4 leaves. This damage never gives rise to permanent stunting, and is not noticeable after 5 or 6 weeks.

C. Mode of action and persistence studies

Experimental investigation of these aspects is still in progress, and will continue.

Trials on soybeans grown in pots have shown that C 6989 E.C. applied to the cotyledons has a contact burning effect at the point of application, but that there is no visible evidence of translocation. Similarly, C 6989 applied to young or older leaves causes a clearing of the veins locally, but the effects of the herbicide do not manifest themselves elsewhere. Stem application of C 6989 in lanolin paste causes a local browning, but does not affect subsequent development of the plants in any way. Soybeans grown in culture solutions containing C 6989 are more affected ; translocation to the leaves is clearly shown, as the veins become typically lighter in colour and translucent, and exhibit morphological changes as seen in section under the microscope. The roots in the culture solution show reduction in growth and the whole plants are smaller than the controls, the effects increasing with age.

Under field conditions, pre-emergence treatments often result in small necrotic lesions on the tissues which actually contact the herbicide in emerging through the soil, but in the crops mentioned as being tolerant, these effects are outgrown.

The herbicide has demonstrated, both in the greenhouse and in the field, the capacity to reduce the vegetative growth and the tuber formation of *Cyperus rotundus*, often to an interesting degree.

Soil persistence bioassay studies have shown that an initial application of C 6989 at 8 kg a.i./ha, in a temperate climate on a loamy sand soil of low humus content, results in an apparent concentration of 10.8 ppm in the surface 5 cm 10 days after application, which was reduced to 1.9 ppm after 60 days. Further experiments in other soils under tropical conditions are to be initiated.

DISCUSSION

C 6989 is a very versatile herbicide. It can be used selectively in rice pre-emergence or post-transplant, as an E.C., granular, or in the form of a wettable powder, on which work has recently started. It can be used whether or not water is present at any stage of rice development provided that the first leaf has emerged from the coleoptile and is active whatever depth of water is used up to 4 cm. It is not affected greatly by subsequent rainfall if used post-weed emergence. At 3 - 4 kg a.i./ha, provided that the weeds are no larger than the 4 leaf stage, C 6989 controls the majority of annual weed species, and is selective in many other crops than rice.

Recent work has shown that carbaryl, the commonly-used insecticide for rice, can safely be applied to rice after the application of C 6989, and that it is compatible also with the application of the newer CIBA insecticides.

Acknowledgments

The authors wish to acknowledge the work carried out by the staff of the CIBA experimental station at Stein, Switzerland, particularly that of Mr. Beeri, and of the staff of CIBA overseas research stations, for the contribution this work has made to knowledge of the product.

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Proc. 9th Brit. Weed Control Conf. (1968)

2-CHLORO-2',6'-DIETHYL-N (METHOXYMETHYL)-ACETANILIDE A PRE-EMERGENCE HERBICIDE FOR GRASSY AND BROADLEAVED WEED CONTROL

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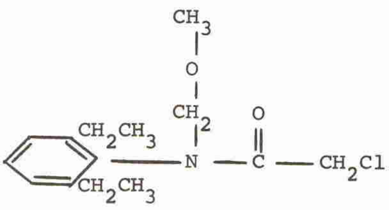
Monsanto Europe S.A. - Brussels

Summary This acetanilide (CP 50144) shows a high degree of activity on annual grassy and broadleaved weeds. Crops which appear highly tolerant to pre-emergence treatment include: maize, peanuts, soybeans, brassica crops and tomato. A lower but acceptable tolerance occurs in cotton. Most of these crops and onions also show post emergence tolerance. CP 50144 is particularly active against annual grasses including *Setaria* spp., *Brachiara* spp., *Digitaria sanguinalis*, *Echinochloa crus-galli*, *Sorghum halepense* and *Poa annua*. It is also active against a wide range of annual broadleaved weeds, the notable exceptions being *Polygonum* spp. and *Raphanus raphanistrum*. The compound is of low mammalian toxicity and non-irritating. It is non-volatile and activity extends over a wide range of soil types and rainfall conditions. Soil persistence for active weed control is in the order of 10-12 weeks.

INTRODUCTION

CP 50144 is identified as 2-chloro-2',6'-diethyl-N (methoxymethyl)-acetanilide, having a structural formula as follows:



The compound has a water solubility of 140 ppm at 23°C. The acute oral LD_{50} to male and female rats is 1,200 mg/kg and the minimum lethal dose by skin absorption is greater than 2,000 mg/kg.

CP 50144 is one of a large number of 2-haloacetanilides that have been synthesised and their biological activity examined. This compound was found to exhibit exceptional properties as a selective pre-emergence herbicide (Husted, R.F. et al, 1966). The locus of absorption appears to be primarily between the seed and the first node of germinating seedlings. Pre-emergence application has generally been the most effective, especially if applied just as the weeds germinate. Early post-emergence application has often given acceptable weed control up to the 2 leaf stage of grasses and cotyledon stage of broadleaved weeds. The compound appears to be active under a wide range of moisture conditions, but does require some moisture to become active. Residual life of the chemical in the soil is relatively short showing a half life of 14-16 days.

The most promising area of use for this compound appeared to be maize and soybeans especially where grassy weeds such as Echinochloa and Setaria were of major importance and development of the compound has been mainly on these crops in the U.S.A. Another promising crop is cotton on which the product is now being commercialised in Latin America. Early greenhouse and field tests indicated a variety of crops showing tolerance including cotton, peanuts, sugar beet, sugar cane, safflower, sunflower, flax, rape, beans, peas and brassica. Consequently, further field tests were undertaken throughout Europe and Africa since 1966.

METHOD AND MATERIALS

CP 50144 was formulated as a 46.2% w/w emulsifiable concentrate and has been tested in 37 countries in Europe and Africa thus covering a very wide range of soil, climatic and cultural conditions. The trials have been carried out by both independent and commercial research workers using a variety of experimental techniques on both small and large scale plots. This report attempts to give an overall summary of results from this work, although by no means complete.

RESULTS

1966

Initially the European trials were confined to sugar beet during the Spring in Northern Europe. However, it soon became obvious that there was insufficient selectivity in this crop. In the Autumn the tests were extended to winter wheat in an attempt to control Alopecurus myosuroides. First results looked promising, but it later became clear that rates sufficient to give adequate weed control caused unacceptable thinning of the wheat. General weed control, however, appeared good down to 1 lb/acre.

1967

Trials were extended to other crops including maize, beans, peas, brassica crops. A summary of the effectiveness on weeds is given in Table 1:

Table 1

Weed susceptibility at 1.5-2 lb/ac: 1967
Assessed on the proposed European Weed Research Council scale

Susceptible 1 - 5	Mod. Suscept. 6 - 7	Resistant 8 - 9
Matricaria chamomilla	Chenopodium album	Sinapis arvensis
Equisetum spp	Mercurialis annua	Polygonum aviculare
Capsella bursa-pastoris	Atriplex patula	Polygonum persicaria
Galinsoga parviflora	Galium aparine	Polygonum convolvulus
Senecio vulgaris	Vicia spp	Raphanus raphanistrum
Stellaria media	Urtica urens	
Echinochloa crus-galli		
Amaranthus retroflexus		
Digitaria spp		
Anagallis arvensis		
Portulaca oleracea		
Fumaria officinalis		
Alopecurus myosuroides		
Lamium purpureum		

The 1967 trials indicated that maize and planted cabbage would tolerate at least 3.5 lb a.i./ac. Peas seemed to tolerate up to 3 lb a.i./ac and rape up to

2

2.5 lb a.i./ac. Beans were more susceptible showing signs of phytotoxicity at 1.5 lb a.i./ac. Soil type appeared to have little effect, but lack of moisture had a significant effect in reducing weed control.

1968

More extensive trials were undertaken on the same crops and extended to include soybeans, cotton, tomatoes and sugar cane. The results on weeds are given in Table 2.

Table 2

Weed susceptibility at 1.5-2 lb/ac: 1968
Assessed on the proposed European Weed Research Council scale

Susceptible 1 - 5	Mod. Suscept. 6 - 7	Resistant 8 - 9
Matricaria chamomilla	Chenopodium album	Polygonum aviculare
Equisetum spp	Sinapis arvensis	Polygonum persicaria
Galinsoga parviflora	Capsella bursa-pastoris	Polygonum convolvulus
Senecio vulgaris	Amaranthus retroflexus	Cardaria spp
Stellaria media	Fumaria officinalis	Raphanus raphanistrum
Echinochloa crus-galli	Cirsium arvense	
Digitaria spp	Anthemis cotula	
Anagallis arvensis	Rumex acetosella	
Spergula arvensis	Galeopsis tetrahit	
Poa annua	Galium aparine	
Lamium purpureum	Solanum nigrum	
Thlaspi arvense	Atriplex patula	
Sonchus asper		
Veronica arvensis		

The trials showed maize, soybeans, peanuts, sugar cane, planted cabbage, planted tomato and turnips all tolerated rates up to 3 lb a.i./ac. Cotton seemed to tolerate up to 2.5 lb, although some phytotoxicity was noted in one trial in Israel, which has been unexplained so far. In the Sudan it would appear the highest rate tolerated was 2 lb a.i./ac. Rape tolerated 1.5 lb but showed phytotoxicity at 2 lb a.i./ac, except in France where the crop appeared to be more tolerant. Beans again showed phytotoxic effects at rates as low as 1 lb a.i./ac, with again the exception of France where higher rates were tolerated. Applications pre-emergence to onions were phytotoxic, but post emergence treatments were safe.

This turned out to be a rather unfavourable year for pre-emergence herbicides due to a very dry Spring; consequently weed control was not quite as good in some areas as in 1967.

DISCUSSION

The spectrum of weeds controlled by CP 50144 is very similar to that of propachlor with some minor differences. Although this compound works well under a wide range of moisture conditions, it is more susceptible to drought than propachlor, needing extra moisture to activate it, as might be expected with its lower solubility. Effectiveness on very high organic soils such as peat and moss soils is also less than with propachlor, but nevertheless giving very good weed control on soils containing up to 15% organic matter. CP 50144 however, is up to twice as active as propachlor on a molar basis and residual activity in the soil is 2 to 4 weeks longer.

The activity of this compound is particularly interesting in maize growing areas where grassy weeds are the major problem as in the south west of France, parts of southern Germany and areas of South Africa. In areas where both grassy and broad-leaved weeds are present, mixtures of CP 50144 with atrazine have given excellent results. (An analysis of 15 trials which included Echinochloa crus-galli showed that the average control at 2 lb a.i./ac was 94% with a range from 92 - 98%. At 1.7 lb the control averaged 88% with a range of 75-98%, compared with 1.2 lb a.i./ac atrazine/acre giving 68% with a range from 30% - 92%). The relatively short residual life of CP 50144 can be utilised in such mixtures to overcome soil residue carry over problems where they occur.

Tests in maize have now arrived at a stage where it is expected to commercialise the product in certain countries of Europe next year (commercial name: Lasso). The trials in cotton are also very encouraging, but a further years work is needed to ensure safe usage on this crop. Trials in brassica crops are also promising especially on transplants. Some further work on rape and swedes is indicated as these seem to be a little more sensitive.

Performance on transplanted tomato looks promising, but this is a crop in which very little herbicide is used.

Rates for good weed control vary between 1.5 lb and 3 lb a.i./ac, and would seem to depend to some extent on soil type and moisture availability.

References

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Proc. 9th Brit. Weed Control Conf. (1968)

ON THE HERBICIDAL ACTIVE SUBSTANCE PROXIMPHAM

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Summary Many aryl carbamoyloximes show a considerable biological activity which depends greatly on the type of substituents in the aryl moiety and on the structure of the oxime moiety in the molecule. The simple O-(N-phenylcarbamoyl)-propanonoxime (proximpham) is particularly interesting because of ease of preparation and favourable chemical, physical and biological properties. Greenhouse and field experiments have shown a remarkable pre-emergence herbicidal activity of proximpham against certain weeds, difficult to control with analogous carbamate herbicides. Several crops such as beet, spinach, onion and carrot proved tolerant to proximpham at herbicidal doses.

The physical, chemical, toxicological and biological properties of proximpham are summarised. Favourable control of weeds is achieved with proximpham plus chlorpropham combinations in some cultivations of vegetable and ornamental plants. In beet the herbicidal control spectrum of propham is complemented by proximpham, but for an efficient control of *Chenopodium album* it is necessary to add further herbicidal components.

INTRODUCTION

The carbanilic acid esters, such as chlorpropham, propham and chlorbufam, used in agricultural practice show serious deficiencies in their herbicidal spectrum. In order to overcome these limitations compounds belonging to the class of aryl carbamoyloximes, which are related in chemical structure and known to affect plant growth, were tested for herbicidal activity and selective properties (Kühle et al, 1958). It was thought that these new compounds might be useful as components of mixtures with the classic carbanilic acid esters.

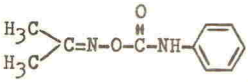
STRUCTURE/ACTIVITY RELATIONSHIPS

For a first rough selection numerous aryl carbamoyloximes were tested for their ability to inhibit seed germination and seedling development of *Lactuca sativa* L. and *Lepidium sativum* L. (Jumar and Grünzel, 1966).

Considering substitution in the basic molecule of the phenylcarbamoyl-propanonoxime $(CH_3)_2C{:}NOCONH{\cdot}C_6H_5$ the introduction of a chlorine atom in the meta position will result in the most effective compound, as was to be expected, without, however, outperforming the non-substituted compound. The p-bromine compound is very effective, too. In the case of the dihalogenated compounds, surprisingly enough, it is not the 3,4-position but the 2,6-position that is more effective. Higher halogen substitution will lead to loss in activity. As for other substituents the methyl, methoxy and methylmercapto group proved favourable and lead to derivatives of good activity - especially when in the meta position. If the oxime function is altered with the aryl group remaining unchanged any enlargement of the simple dimethyloxime portion will result in an evident reduction of activity. Only the compounds monohalogenated in the oxime part still show good activity.

On the basis of these preliminary biological experiments the aryl carbamoyloximes showing best activity were tested in the greenhouse and in field plots against various weed and crop species. The simple phenylcarbamoylpropanonoxime (proximpham) was used for the following extended trials as result of the initial evaluation and because of its ease of preparation.

CHEMICAL AND PHYSICAL PROPERTIES

Structure:	
Chemical name:	phenylcarbamoylpropanonoxime (proposed common name: proximpham)
Empirical formula:	$C_{10}H_{12}N_2O_2$ Molecular weight: 192.2
Solubility:	Water, 500 ppm (20°C); soluble in most of the organic solvents but practically insoluble in n-hexane.
Physical form:	white crystals
Melting point:	109.5°C
Vapour pressure:	5×10^{-6} torr at 20°C Volatility: 0.05 mg/m^3
Thermal stability:	Stable at normal temperatures. At > 90°C dissociation to phenylisocyanate and propanonoxime.
Hydrolytic stability:	In neutral and acid medium hydrolysis to NN'-diphenyl urea and aniline takes place as first order reaction. In alkaline medium proximpham hydrolyses in a second order reaction to N'N'-diphenyl urea and alkali carbanilate. In neutral aqueous solution the half-life of the hydrolysis is 13 days.
Photochemical stability:	No decomposition or deactivation in sun-light.
Stability in soil:	The decomposition of proximpham in soil was studied in model tests and in field trials with a 50% wettable powder using gas chromatography, thin layer chromatography and column chromatography as well as colorimetric methods. The decomposition proceeds partly microbially and partly chemico-hydrolytically. The half-life of decomposition is 7 - 10 days depending on the type of soil and its microflora. Using 2 kg of active substance/ha proximpham is practically completely decomposed after 5 weeks. The microbial decomposition can be retarded by adding low quantities of sterilizing substances.
Sorption in soil:	The sorption reaction resembles that of propham. The content of organic matter rather than of clay minerals in the soil is the decisive factor in determining the degree of sorption from dilute aqueous solutions. Sorption to the soil particles takes place primarily by weak van der Waals linkage forces, so that most of the active substance can be desorbed again by water.

TOXICOLOGY

Proximpham was tested as the active substance for its acute and subacute toxicity. With oral administration to male and female rats the acute toxicity test showed a medium lethal dose LD_{50} = 1540 mg/kg with the limits 1470 mg/kg - 1610 mg/kg. Symptoms include restlessness, reduced motility, paralysis of the hind extremities, apathy and lying prone; there is a decrease of the intoxication symptoms with surviving animals within 24 hours.

In the subchronic test the trial substance was administered to male and female rats in the diet. A depression of growth was to be seen from the 5000 ppm level. After having fed proximpham over 12 weeks lower haemoglobin values and erythrocyte numbers existed from the 500 ppm level upwards. There was no influence on cholinesterase and transaminase activity. At the 100 ppm level no influence on the relative weight of the organs was detectable.

With concentrations from the 500 ppm level upwards the macroscopic investigation proved splenomegaly. Histologic changes were found in the thyroid gland, liver, spleen, kidney and suprarenal gland.

In the subchronic test over 90 days a proximpham concentration in the diet of 100 ppm was found to be a harmless dose.

BIOLOGICAL DATA

Herbicidal control spectrum

The active substance formulated as wettable powder was tested as an aqueous suspension against various weed and crop species in greenhouse and field experiments according to the methods described (Jumar and Grünzel, 1966). Application was to the soil surface pre-emergence. The herbicidal activity on several species of Compositae and the resistance of some crops are remarkable. Table 1 summarises the results.

Proximpham as a component in herbicidal combinations

Proximpham shows a considerable herbicidal activity against certain weeds which cannot or only with difficulty can be controlled with analogous carbamate herbicides (propham, chlorpropham) - such as Galinsoga parviflora, Senecio vulgaris, Sonchus spp. and also Lamium spp. On the other hand several crops such as beet, spinach, onion and carrot proved tolerant to proximpham given in herbicidal doses. According to experiments which were made on the basis of these findings the new active substance can be used successfully as a component in herbicide combinations.

Favourable results were achieved with chlorpropham-proximpham combinations in onion, carrot, spinach and cornsalad as well as in gladiolus corms. In general a proportion of 1:1 with 4 - 5 kg of total active substance/ha proved to be a favourable mixture. Growth impairment or injury to the crops did not occur.

As sugar beets show sensitivity to chlorpropham, combinations of propham and proximpham were tested with this crop. In order to increase the activity of these combinations against Chenopodium album further herbicidal active substances were added in low quantities as third components. In this case fenuron and diuron added in low quantities have proved favourable up to now. They, however, involve the danger that following heavy rainfall leaching into the germination zone of the beets will occur and cause phytotoxic damage. The total dose of active substance for pre-emergence treatments was 3 - 5 kg/ha.

With application in spinach the most favourable results were achieved by adding chlorpropham to proximpham-propham combinations. With a total dose of active substance of 4 kg/ha the chlorpropham portion was 25%. The prevailing weeds Stellaria media, Chenopodium album, Urtica urens, Polygonum spp., Lamium spp. and especially Galinsoga parviflora were killed or heavily affected without damaging the spinach.

Table 1

Herbicidal spectrum of phenylcarbamoylpropanonoxime

0 = no effect   + = low up to moderate effect
++ = good effect   +++ = very good effect up to complete kill

Test plants	Dose of active substance kg/ha						
	3	4	5	7	10	15	20
Urtica urens L.		+	++	++	+++	+++	+++
Urtica dioica L.		0		+			
Polygonum spp.	0	0	+	+			
Chenopodium album L.	(+)	+	++	++	++	++	+++
Melandrium album Garcke	0	0	0	+	++	+++	+++
Stellaria media Vill.	0	+	+	++	++	++	++
Thlaspi arvense L.	0	+	++	++	++	+++	+++
Capsella bursa-pastoris Med.	++	+++	+++	+++	+++	+++	+++
Fumaria officinalis L.	0	0	0				
Euphorbia spp.	0	+	+	++	++	++	++
Viola tricolor L.	0	+	+	+			
Anagallis arvensis L.		0		+			
Lamium spp.		+	+	++	++	++	++
Veronica arvensis L.	0	(+)	+	++	++	++	++
Galinsoga parviflora Cav.	+	++	++	+++	+++	+++	+++
Senecio vulgaris L.		++	++	++	+++	+++	+++
Sonchus spp.		+	+++	+++			
Onion (Allium cepa L.)		0	0	+	+		
Carrot (Daucus carota L.)		0	0	0	0		
Scorzonera (Scorzonera hispanica L.)		0	0	0	+		
Cut Lettuce (Lactuca sativa L.)		(+)	+	+	++		
Sugar Beet (Beta vulgaris L.)	0	0	0	0	+	++	+++

Residue studies

Residue studies have been carried out on treated sugar beets. The methods of analysis used have a lower detection limit of 0.05 ppm. Even with a dose of 6 kg proximpham/ha (about 3 times the normal dose) no residues of aniline containing compounds in the root and the leaves of the beets were found during harvest.

DISCUSSION

Due to its chemico-physical properties, its control spectrum and its selectivity proximpham is suitable for combinations with existing carbamate herbicides, where the range of activity of the latter is not sufficient for efficient weed control. Combining proximpham with propham or chlorpropham gives herbicidal effects which can be achieved by the single active substances only in very high doses which will not be tolerated sufficiently by the crop. Like other soil herbicides Proximpham needs a certain minimum level of soil moisture to be effective. Due to sorption high humus contents in soil will reduce the weed control activity.

Acknowledgements

The toxicological data were supplied by H.J. Lewerenz; for contribution to the physico-chemical, analytical and radiochemical studies the authors thank D. Spengler and K. Sieber.

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NEW CONTACT HERBICIDES PARTICULARLY FOR THE CONTROL OF MAYWEEDS

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Summary 1. In tests covering 400 compounds from three groups of substances (arylcarboxyalkoxyurea, oxadiazinediones and benzothiadiazinones) the best effects, particularly on mayweeds such as *Matricaria chamomilla*, *Matricaria maritima (inodora)* and *Anthemis arvensis*, were shown by

2-methyl-4-(3'-trifluoromethylphenyl)-tetrahydro-1,2,4-oxadiazine-3,5-dione and
3-isopropyl-2,1,3-benzothiadiazinone-(4)-2,2-dioxide

2. Besides mayweeds a number of other dicotyledonous annual weeds were effectively controlled.

3. Grassy weeds and millets, with the exception of Cyperaceae, were unaffected.

4. The compatibility of these new herbicides with all cereals including maize and rice is very good.

5. All of these new compounds do not colour, and act solely on contact, i.e. exclusively through the foliage. They produce practically no effect on germinating seeds in the soil.

INTRODUCTION

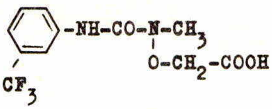
In order to find selective non - colouring contact herbicides in addition to the benzoxazinones discovered earlier (Fischer 1965), arylcarboxyalkoxyureas, oxadiazinediones and benzothiadiazinones were tested. Particular importance was attached to selectivity, especially in monocotyledonous crops.

Of more than 400 compounds from these groups of substances* the following showed particularly good weed control and safety to crops:

* These compounds were synthesized by the main laboratory of BASF.

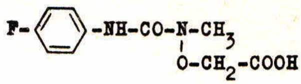
1. **From the group of arylcarboxyalkoxyureas:**

I



N-3-trifluoromethylphenyl-N'-carboxymethoxy-N'-methylurea

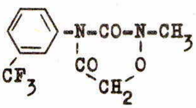
II



N-4-fluorophenyl-N'-carboxymethoxy-N'-methylurea

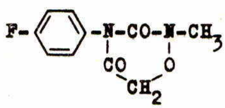
2. **From the group of cyclic urea = oxadiazinediones**

III



2-methyl-4-(3'-trifluoromethylphenyl)-tetrahydro-1,2,4-oxadiazine-3,5-dione

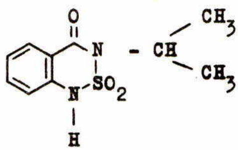
IV



2-methyl-4-(4'-fluorophenyl)-tetrahydro-1,2,4-oxadiazine-3,5-dione

3. **From the group of benzothiadiazinones**

V



3-isopropyl-2,1,3-benzothiadiazinone-(4)-2,2-dioxide

Chemical and physical properties

The chemical compounds specified are solids in the pure state and have defined melting points. They are sparingly soluble in water and comparatively readily soluble in the most common organic solvents. Their vapour pressure is not high.

It can be seen that in addition to Matricaria chamomilla, Matricaria maritima (inodora) and Anthemis arvensis other dicotyledonous weeds common in Europe are effectively controlled. Grasses and millets, with the exception of Cyperaceae, are however extremely resistant to these compounds. Greenhouse tests and field experiments showed a high effectiveness against the foliage of Cyperus spp. Trials discovering the effect of these compounds against the parts of Cyperus spp. below ground level are running.

In field tests the overall effect on dicotyledonous weeds could be intensified and the herbicidal spectrum considerably broadened by adding growth regulants such as 2-(methyl-4-chlorophenoxy)-propionic acid.

Moreover, the compounds II and IV unlike compounds III and V listed in the table, had a strong effect on the millets tested including Echinochloa crus-galli, Setaria viridis, Setaria glauca and Digitaria sanguinalis.

Resistance of crops

Our greenhouse tests and particularly the numerous field tests show that all the new herbicides specified have very good compatibility with wheat, barley, rye, maize and rice when applied post-emergence at the rate of 1 - 3 kg/ha. No lasting damage to crops was observed even in very warm weather with direct sunlight.

Residual action in the soil

Tests carried out in three different soils (loamy soil, humus and light sandy soil) showed practically no herbicidal effect of the above new compounds on mustard and oats sown 6-8 weeks after an application of 6 kg/ha of active ingredient. Thus new crops can be sown after this period without any risk of damage, for example after ploughing.

References

FISCHER, A. (1965) 2-Phenyl-3,1-benzoxazinon-4, ein neues Kontaktherbizid und seine Mischungen. Mededelingen van de Landbouwhogeschool en de opzoekingsstations van de Staat te Gent, 30, 1963-1976.

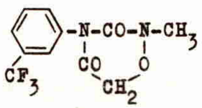
BIOLOGICAL PERFORMANCE

From the above groups of arylcarboxyalkoxyureas, oxadiazinediones and benzothiadiazinones the best effects on mayweeds and other dicotyledonous weeds was shown by compounds III and V, both in the greenhouse and in the field. The compounds act almost wholely on contact. Biological data so far available suggest that there is practically no herbicidal action at application rates of 1 - 3 kg/ha on weed seeds as they germinate. At higher rates (10 - 20 kg/ha) a certain effect on the germination of certain weeds was observed. However, the residual effect is too slight for the compounds to be used pre-emergence. The foliar action of the products was found to be strongly accelerated in the greenhouse and particularly in the field by high temperatures (20 - 30°C). In cool weather the effect was usually somewhat delayed.

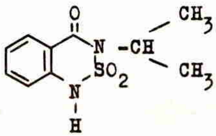
Effect on weeds

According to results available the best control was achieved at an early stage of development, i.e. from the cotyledon to about the 4 true - leaf stage of the weeds. The percentage mortality can be seen from the following table:

III



V



	1,5 kg/ha	1,5 kg/ha
Matricaria chamomilla	100 %	100 %
Matricaria maritima (inodora)	100 %	80 %
Anthemis arvensis	100 %	100 %
Chrysanthemum segetum	100 %	100 %
Sonchus arvensis	100 %	80 %
Polygonum persicaria	90 %	90 %
Lamium amplexicaule	60 %	60 %
Stellaria media	70 %	100 %
Galium aparine	60 %	50 %
Ipomoea spp.	80 %	60 %
Amaranthus retroflexus	60 %	50 %
Solanum nigrum	100 %	50 %
Cyperus esculentus	50 %	50 %
Cyperus rotundus	90 %	80 %
Cyperus difformis	100 %	100 %
Echinochloa crus-galli	20 %	20 %
Digitaria sanguinalis	0 %	0 %
Alopecurus myosuroides	10 %	10 %
Apera spica-venti	10 %	0 %

100 % = total destruction
0 % = no effect